

# Incidence, Characteristics, and Outcomes of Emergent Isolated Coronary Artery Bypass Grafting

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**Data on emergency coronary artery bypass surgery (CABG) are limited. We studied patients who underwent isolated CABG at Mayo Clinic between 1993 and 2019. Baseline characteristics and in-hospital outcomes of emergent CABG were described in consecutive eras (1993 to 2000, 2001 to 2010, and 2011 to 2019). Cumulative survival was estimated by the Kaplan Meier method for the overall group, and stratified by the indication of surgery. In the 14,455 isolated CABG included, 427 (2.95%) were emergent. The number of emergent CABG decreased from 222 to 150 and 55 in the consecutive study eras. There was a temporal increase in the prevalence of heart failure, but no change in mean age, and prevalence of hypertension, diabetes, renal failure, or atrial fibrillation. The proportion of patients with failed/complicated percutaneous coronary intervention decreased from 38.2% in 1993 to 2000 to 22.7% in 2001 to 2010 and 25.5% in 2011 to 2019 ( $p = 0.003$ ). In 2011 to 2019, 100% of patient received an internal mammary graft compared with 75.6% in 1993 to 2000 ( $p < 0.001$ ). Operative mortality was 8.7% overall (8.6% in 1993 to 2000, 10.0% in 2001 to 2010, and 5.5% in 2011 to 2019,  $p = 0.56$ ). There were no differences in postoperative complications except for the incidence of renal failure and new dialysis which increased over time. Predicted 10-year survival was 57.0% and was not different according to CABG indication ( $p = 0.12$ ). In conclusion, we documented a temporal decrease in the incidence of emergent CABG between 1993 and 2019, especially those performed due to complications of coronary interventions. Despite the higher prevalence of left ventricular dysfunction and the more complete revascularization in more recent years, in-hospital mortality did not increase. © 2020 Published by Elsevier Inc. (Am J Cardiol 2020;00:1–5)**

Coronary artery bypass grafting (CABG) remains the most common cardiac surgery performed in clinical practice.<sup>1</sup> Since the first CABG was performed in 1961, operative techniques and outcomes have substantially improved.<sup>2</sup> In current practice, CABG operative mortality is about 1% for elective indications, and 3% in patients presented with acute myocardial infarction.<sup>3,4</sup> Despite these excellent outcomes, patients who are referred to CABG on an emergent basis remain at higher risks of adverse events. However, contemporary data on emergent CABG are limited.<sup>5–10</sup> We sought to assess the incidence, characteristics, and long-term outcomes of emergent CABG over a 28-year period at a tertiary center.

## Methods

We retrospectively identified patients who underwent isolated CABG at Mayo Clinic between January 1993 and December 2019. The CABG operation was deemed emergent if it fulfilled one of the STS emergent status criteria: Patients who have ongoing, refractory, unrelenting cardiac compromise, with or without hemodynamic instability, and

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not responsive to any form of therapy except cardiac surgery.<sup>11</sup> Chart review was utilized to determine reasons for emergent referral to CABG. Those were grouped into 2 main categories (failure or complication of percutaneous coronary intervention [PCI], or persistent chest pain or cardiogenic shock). Long-term survival was obtained from a regularly updated institutional vital status registry for cardiac surgery patients. The study was approved by the Mayo Clinic Institutional Review Board.

The study cohort was divided into 3 groups according to temporal eras (1993 to 2000, 2001 to 2010, and 2011 to 2019). Descriptive statistics were presented as frequencies with percentages for categorical variables. Mean, standard deviation, median, and interquartile ranges (IQR) were reported for continuous measures. Baseline characteristic and in-hospital outcomes were compared between the 3 groups using a 1-way Analysis of Variance test. The probability of death during long-term follow up was graphically displayed according to the method of Kaplan and Meier for the overall cohort and for subcohorts stratified by the indication for emergent surgery. Comparison of cumulative survival across these 2 strata was performed with the log-rank test. All analyses were performed with SPSS software version 22 (IBM corporation).

## Results

A total of 14,455 patients who underwent isolated CABG between 1993 and 2019 were included. Of those, 427 (2.95%) were emergent operations. The number of

emergent CABG decreased from 222 between 1993 and 2000, to 150 between 2001 and 2010, and 55 between 2011 and 2019. The proportion of emergent CABG to all isolated CABG also decreased from 6.4% in 1993 to 2.1% in 2019,  $p$  trend  $<0.001$  (Figure 1). There was no change in mean age, proportion of females, and the prevalence of hypertension, diabetes, renal failure, and atrial fibrillation over time (Table 1). However, there was a notable increase in the prevalence of chronic congestive heart failure, and a corresponding decrease in left ventricular ejection fraction from a median (IQR) of 55 (41 to 65) in 1993 to 48 (34 to 58) in 2000 to 2010 and to 40 (28 to 55) in 2011 to 2019 ( $p = 0.002$ ).

There was a significant increase in the proportion of patients presenting with Non-ST-elevation myocardial infarction, and stable coronary disease in 2011 to 2019 compared with 1993 to 2000 ( $p < 0.001$ ). The number of diseased vessels remained stable over time, with the majority of patients ( $>70\%$ ) presenting with significant stenosis in 4 main or branch coronary vessels (Table 2). The proportion of patients referred for emergency surgery due to PCI failure or complication decreased from 38.2% in 1993 to 2000 to 22.7% in 2001 to 2010 to 25.5% in 2011 to 2019 ( $p = 0.003$ ), whereas the proportion of patients referred for emergency surgery due to persistent chest pain or cardiogenic shock increased from 61.7% to 77.3% to 74.5%, respectively.

Compared with patients who had surgery in 1993 to 2000, those who had surgery in later years had shorter perfusion times despite having more vessel bypassed (Table 3). In 2011 to 2019, 100% of patient received a mammary graft (94.3% single, 5.7% dual) compared with 75.6% in 1993 to 2000 ( $p < 0.001$ ). The utilization of balloon pumps was also substantially higher in 2011 to 2019 (74.1%) compared with 2000 to 2010 (66.0%), and 1993 to 2000 (45.1%),  $p < 0.001$ . Operative mortality overall was 8.7% (8.6% in 1993 to 2000, 10.0% in 2001 to 2010, and 5.5% in 2011 to 2019,  $p = 0.56$ ) (Figure 2). There were no differences in stroke, new onset atrial fibrillation, tamponade, cardiac arrest, GI bleeding, or reoperation across the 3 era(s) (Table 3). However, there was an increase in the incidence of postoperative

renal failure and new dialysis requirements. Length of stay remained unchanged at a median of 9 days. During median follow-up of 9.4 years (IQR 4.0 to 15.1), the predicted 10-year survival for the overall cohort of emergent CABG was 57.0% (Figure 3), with no difference between patients who had emergent CABG for PCI failure/complications, versus those who had CABG for ongoing chest pain or cardiogenic shock ( $p = 0.98$ ) (Figure 3).

## Discussion

The management of coronary artery disease has evolved considerably in the last few decades CABG remains the mainstay revascularization option for patients with severe left main multi-vessel coronary disease. Although CABG is performed with low morbidity and mortality in the vast majority of patients in contemporary practice, concerns remain about the outcomes of patients who are referred emergently for unplanned surgery.<sup>12,13</sup> However, contemporary data on the incidence, characteristic and outcomes of emergency CABG are limited.

Majority of studies on emergent CABG reported on CABG performed on an emergent basis specifically after P CI. The largest report by Haan et al included emergent CABG cases between 1994 and 2003.<sup>9</sup> In this study, the proportion of PCIs requiring emergent surgical salvage decreased from 2.9% to 0.8%, but the in-hospital mortality of these emergent operations increased (8.0% to 9.3%,  $p < 0.001$ ). A study by Roy et al.<sup>7</sup> included 21,957 patients who underwent PCI between 1994 and 2008 at Washington Hospital Center. In this study, the incidence of emergent CABG after PCI was low (0.41%), but was associated with a significant in-hospital mortality (7.8%). The reported indication for emergent CABG included coronary dissection, acute vessel closure, perforation, or failure to cross. Another study of 1,200 consecutive patients undergoing PCI at a single center in Israel documented a much higher incidence of PCI complications necessitating emergency CABG (2.6%), with a corresponding in-hospital mortality of 12.9%.<sup>6</sup>

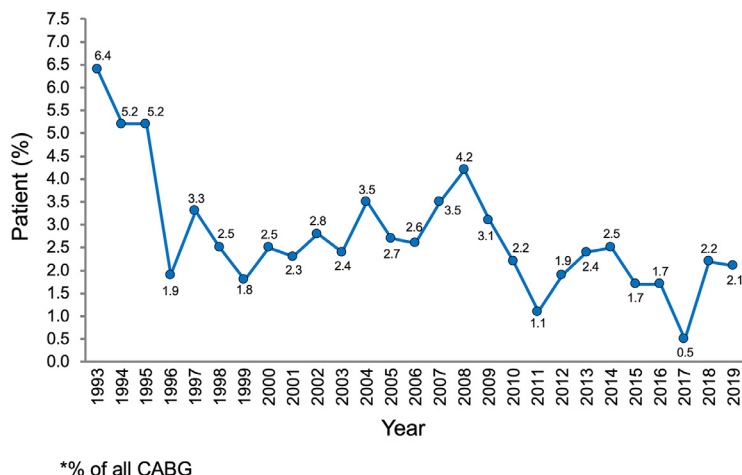


Figure 1. Trends in the incidence of emergent coronary artery bypass grafting. CABG; coronary artery bypass grafting.

Table 1  
Trends in baseline characteristics of patients undergoing emergent CABG between 1993 and 2019

Baseline Characteristics	1993–2000 (n = 222)	2001–2010 (n = 150)	2011–2019 (n = 55)	p value
Age (Mean ± SD)	66.9 ± 0.8	68.6 ± 1	65 ± 1.6	0.12
Men	157(70.7%)	117(78%)	36(65.5%)	0.13
Hypertension	80(36.0%)	29(20.3%)	15(31.3%)	0.005
Diabetes mellitus	46(20.7%)	32(22.4%)	16(33.3%)	0.19
Dyslipidemia	161(74.2%)	117(82.4%)	37(77.1%)	0.18
Smoker	43(19.4%)	31(20.7%)	12(21.8%)	0.84
Renal failure	8(3.6%)	7(4.8%)	2(4.2%)	0.85
Dialysis	2(0.9%)	3(2%)	0(0%)	0.34
Congestive heart failure	35(15.8%)	35(24.5%)	22(46%)	<0.001
Atrial fib/flutter	25(11.3%)	22(14.7%)	4(7.3%)	0.54
Creatinine (Mean ± SD)	1.9 ± 0.2	1.3 ± 0.1	1.03 ± 0.1	<0.001
STS PROM median (IQR)	5.5% [2.5–14.3]	8% [4–21.7]	5.3% [1.9–10.7]	0.002
Previous coronary bypass	11(5.0%)	4(2.7%)	3(5.5%)	0.47
Previous valve surgery	2(0.9%)	3(2%)	4(7.3%)	0.041
Previous PCI	85(38.3%)	34(22.7%)	20(36.4%)	0.005
LVEF median (IQR)	55(41–65)	48(34–58)	40(28–55%)	<0.001
Concomitant valve disease*				
Aortic valve disease	7(3.2%)	12(8%)	1(2)	0.003
Mitral valve disease	13(5.9%)	23(15.3%)	7(14)	0.08
Tricuspid valve disease	4(2%)	11(7.3%)	6(11)	<0.001

Abbreviations: AV = aortic valve; CABG = coronary artery bypass grafting; IQR = interquartile range; LVEF = left ventricular ejection fraction; MV = mitral valve; N = number; PCI = percutaneous coronary intervention; PROM = predicted risk of mortality; SD = standard deviation; STS = society of thoracic surgery; TV = tricuspid valve.

\* ≥ moderate regurgitation/stenosis.

Three studies reported the outcomes of emergent CABG for any indications. The first by Schumer et al. assessed 5,940 patients who underwent isolated CABG between 2003 and 2013, of whom 212 (3.6%) were classified as emergent. The indication for emergent CABG was mostly cardiogenic shock/ongoing pain or MI (>90% in 2003 to 2007 and 70% in 2008 to 2013). In-hospital mortality rate of 6.6% in the overall group, but was 15.0% in patients who

had emergent CABG due to angiography/PCI complications.<sup>5</sup> In another study that included 596 patients who underwent emergent CABG at 4 European centers, in-hospital mortality occurred in 60 patients (10.1%).<sup>8</sup> However, this study used a lenient definition of emergent status (an operation performed before the beginning of the next working day after decision to operate), and the majority of patients (59%) were classified as emergency class I (stable

Table 2  
Clinical presentations of patients who underwent emergent CABG

Clinical Features	1993–2000 (n = 222)	2001–2010 (n = 150)	2011–2019 (n = 55)	p value
Patient presentation		<0.001		
STEMI	71(32%)	55(36.7%)	21(38.2%)	
NSTEMI	0(0%)	17(11.3%)	17(30.9%)	
Unstable angina pectoris	124(55.9%)	32(21.3%)	4(7.3%)	
Stable coronary disease	27 (12.1%)	46(30.7%)	13(29.1%)	
Timing of MI				0.004
<6 hours	39(17.6%)	27(18%)	9(16.4%)	
6–24 hours	36(16.2%)	48(32%)	18(32.7%)	
1–7 days	44(19.8%)	34(22.7%)	11(20%)	
8–21 days	10(4.5%)	7(4.7%)	2(3.6%)	
>21 days	33(14.9%)	8(5.3%)	2(3.6%)	
Number of narrowed coronary arteries*				0.14
1	0(0%)	1(0.7%)	0(0%)	
2	18(9.2%)	4(2.7%)	4(7.7%)	
3	37(19%)	24(16.1%)	9(17.3%)	
4	140(71.8%)	120(80.5%)	39(75%)	
Left main narrowing*	92 (41%)	81(54.4%)	14(58.3%)	0.02
Reason for emergent CABG				0.003
PCI Failure/Complications	85(38.3%)	34(22.7%)	14(25.5%)	
Persistent Chest Pain/Shock	137(61.7%)	116(77.3%)	41(74.6%)	

Abbreviations: CABG = coronary artery bypass grafting; MI = myocardial infarction; N = number; NSTEMI = Non-ST elevation myocardial infarction; PCI = percutaneous coronary intervention; SD = STEMI = ST-elevation myocardial infarction.

\* 31 missing

Table 3  
Surgical techniques and short-term outcomes of emergent CABG

Surgical Technique & Outcomes	1993–2000 (n = 222)	2001–2010 (n = 150)	2011–2019 (n = 55)	p Value
<b>Surgical technique</b>				
Cross clamp time - Median (IQR)	48(33–60)	48(35–62)	54(39–68)	0.10
Perfusion time - Median (IQR)	91(66–119)	72(52–98)	76(58–110)	<0.001
<b>Number of bypassed arteries</b>				
1	17(7.7%)	13(8.7%)	8(14.6%)	
2	56(25.2%)	30(20%)	15(27.3%)	
3	82(36.9%)	80(53.3%)	23(41.8%)	
4	61(27.5%)	25(16.7%)	9(16.4%)	
5	6(2.7%)	2(1.3%)	0(0%)	
<b>Number of IMAs utilized*</b>				
0	54(24.3%)	26(17.9%)	0(0%)	
1	91(40.8%)	113(77.9%)	33(94.3%)	
2	4(1.8%)	5(3.5%)	2(5.7%)	
Sequential grafts used	43(19.4%)	22(14.7%)	14(25.5%)	
Intra-aortic balloon pump	100(45.1%)	99(66.0%)	40(74.1%)	<0.001
<b>In-hospital Outcomes</b>				
Operative mortality	19(8.6%)	15(10%)	3(5.5%)	0.56
Stroke	9(4.1%)	11(7.3%)	2(3.6%)	0.34
Acute renal failure	14(6.3%)	16(10.7%)	9(16.4%)	0.03
New dialysis	7(3.2%)	9(6%)	7(12.7%)	<0.001
New onset atrial fibrillation †	70(31.5%)	48(33.6%)	20(41.7%)	0.41
Tamponade †	1(0.5%)	5(3.5%)	1(2.1%)	0.08
Cardiac arrest †	10(4.5%)	9(6.3%)	3(6.2%)	0.73
Gastrointestinal bleeding	9(4.1%)	8(5.6%)	5(10.4%)	0.25
Reoperation	21(9.5%)	9(6%)	7(12.7%)	0.31
Length of stay- Median (IQR)	9[7–13]	8.5[6–15]	9[7–14]	0.66

Abbreviations: IMA = internal mammary artery; IQR = interquartile range; N = number.

\* 25 missing.

† 14 missing.

hemodynamics, no inotropes). Kerendi et al.<sup>10</sup> documented an overall in-hospital mortality of 5.9% in a large series of 614 patients who had emergent CABG at Emory University between 1996 and 2003. In this study about one-third of patients had emergency CABG as a result of a PCI complication.

Our study showed a decrease in number of emergency CABG operations over time from 222, to 150, and 55 between 1993 and 2000, 2001 to 2010, and 2011 to 2019, respectively. This corresponded with a respective declining proportion (relative to all isolated CABG) from 3.5%, to 3.2%, to 1.6% in those 3 consecutive eras. Potential reasons for this decline include the temporal improvements in PCI

techniques and outcomes, and the increasing tendency for earlier surgical interventions in patients with critical coronary disease and impending decompensation. This study also documented a change in the characteristics of emergent CABG over time. Patients undergoing emergent CABG in later years of the study were more likely to have a peri-operative intra-aortic balloon pump, to have more complete revascularization, and to receive internal mammary artery bypass graft.

Our study showed that emergency CABG was associated numerically but statistically insignificant decrease in in-hospital mortality the last decade (5.5%) compared with the preceding 2 decades (10.0% and 8.6%, respectively).

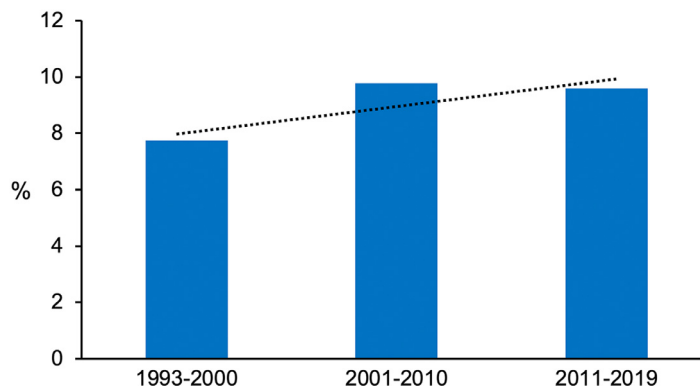


Figure 2. Trends in operative mortality after emergent coronary artery bypass grafting.

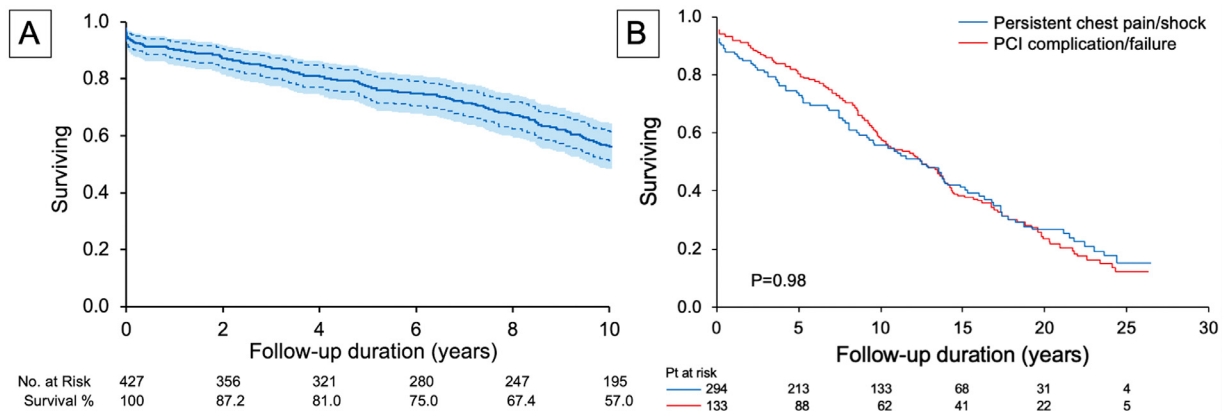


Figure 3. Kaplan Meier survival analysis for patients undergoing emergent CABG. (A) For the overall group. (B) Stratified by the indication for emergent CABG. CABG; coronary artery bypass grafting.

Nonetheless, considering the temporal increase in certain comorbidities that are known to impact CABG outcomes (left ventricular dysfunction), and certain post-operative complications (e.g., acute kidney injury), these mortality trends suggest a considerable improvement in the operative outcomes and in-hospital care of emergency CABG. The 10-year estimated survival for patients who underwent emergency CABG was 57% with no difference between patients who underwent surgery due to PCI complications versus those undergoing surgery for cardiogenic shock or ongoing chest pain. This suggests that this group of patients represent a high-risk group despite the acceptable outcomes of their emergency operations.

**Limitations** First, this is a retrospective study and is subject to the inherent limitations of observational studies. Second, classifying patients into the emergent CABG category depended on coding for "emergent status" in the STS data collection form which is subject to under or over coding. Third, there were a small number of patients with missing data related to the coronary anatomy especially in the earlier years of the study. However, those represented <10% of the study population. In addition, there were no missing data on in-hospital complications or long-term survival. Hence the impact of those missing information on the study overall should be limited.

In conclusion, the need for emergency CABG decreased over time, and the proportion of emergent operations due to PCI complications also decreased. Despite the higher prevalence of left ventricular dysfunction and the achievement of more complete revascularization in more recent years, in-hospital mortality did not increase.

#### Declaration of interests

The authors declare that they have no known competing financial interests or personal relations that could have appeared to influence the work reported in this study.

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