

Immediate rescue operations after failed diagnostic or therapeutic cardiac catheterization procedures

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Abstract

OBJECTIVES: Although rare, life-threatening complications requiring emergency cardiac surgery do occur after diagnostic and therapeutic cardiac catheterization procedures. The operative mortality has been persistently reported to remain high. The purpose of this observational study was to evaluate and report the outcomes, with particular emphasis on early mortality, of these risky operations that were performed in a single highly specialized cardiac centre.

METHODS: Between June 1997 and August 2007, 100 consecutive patients, 13 after diagnostic complicated cardiac catheterization (0.038% of 34 193 angiographies) and 87 after crashed percutaneous coronary intervention (PCI; 0.56% of 15 544 PCIs), received emergency operations at the Feiring Heart Center. In the same period, 10 192 other patients underwent open cardiac surgery. Early outcome data were analysed and compared between the cohorts. Follow-up was 100% complete.

RESULTS: The preoperative status of the 100 patients was that 4 had ongoing external cardiac massage, 24 were in cardiogenic shock, 32 had frank enduring ST-segment infarction but without shock and 40 had threatened acute myocardial infarction. There was 1% (1 patient) 30-day mortality in the study group, which is equal (0.9%, $P = 0.60$) to that of all other operations. Postoperative myocardial infarction and prolonged ventilator use were significantly higher in the crash group, whereas the rate of stroke, renal failure, reopening for bleeding and mediastinitis were similar between the groups.

CONCLUSIONS: With rapid transfer to an operation room, minimizing the time of warm myocardial ischaemia, and by performing complete coronary revascularization, it is possible to obtain equally low operative mortality in patients with life-threatening cardiac catheterization-associated complications, as is the case with open cardiac operations in general.

Keywords: Cardiac catheterization • Cardiac surgery • Early mortality • Emergency • Percutaneous coronary intervention

INTRODUCTION

Diagnostic cardiac catheterization and percutaneous coronary intervention (PCI) can cause a variety of adverse events, ranging from minor problems to major complications requiring emergency operative action. Technique and device improvements and better antiplatelet pharmacotherapy have strikingly reduced the frequency of rescue operations [1–4]. In the current stent era, there seems to be consensus that a back-up operating room is not necessary. Yet, even if the need for salvage operations is low, the early operative mortality remains more than ideal, ranging from 8 to 15% [1–6].

Our institution is a highly specialized heart clinic for adult cardiac patients and has a favourable organization and infrastructure for expeditious surgery. All surgeons, anaesthesiologists and invasive cardiologists are experienced, high-volume, board-certified specialists. The operation rooms and catheterization laboratories are located very near each other, making the transfer distance short. There is a close collaboration between surgeons

and interventionalists based on a long-term cross-speciality teamwork philosophy (heart team). The setting is ideal for obtaining high-quality results of emergency operations following iatrogenic failures in the catheterization laboratory. The aim of the investigation was to review the outcome data, with particular focus on mortality.

MATERIALS AND METHODS

The study was approved by the Institutional Review Board. From June 1997 through July 2007, 100 consecutive patients who received emergency cardiac surgery after unsuccessful diagnostic or therapeutic catheterization procedures at the Feiring Heart Center were included in an observational study. In the period up to January 1999, patient data were retrospectively retrieved from hospital charts. Thereafter, data on every patient were successively registered in a computerized database.

The mean age of patients was 63 (40–86) years, and there were 68 males and 32 females. Four patients were diagnosed with

generalized arteriosclerosis, 16 with acute coronary syndrome (unstable angina or non-ST-segment elevation infarction), none with acute ST-segment elevation infarction, 46 with prior myocardial infarction and 11 with diabetes, and 25 were current smokers. There were no redos or patients with renal failure (creatinine >200 µmol/l). That is, before the occurrence of the iatrogenic complication, all the patients belonged to a normal-risk population. It is particularly emphasized that none of these patients were admitted with acute ST-segment elevation infarction.

The intraoperative findings were classified as dissection, including abrupt vessel closure, of coronary arteries (left main stem artery [LM], left anterior descending coronary artery [LAD], circumflex coronary artery [CX] and right coronary artery [RCA]); dissection of aorta; perforation of coronary arteries; perforation (rupture) of the left or right ventricle and retained wires.

Thirty-day mortality was registered and also established through the Norwegian National Registry, assuring a complete follow-up.

Treatment policy

When the interventional cardiologist realized that rescue surgery was required, a cardiac surgeon and anaesthesiologist were called. The patients were immediately transferred to the operating room without any delay. Speed was the priority. Time was not spent on stabilization or insertion of an intra-aortic balloon pump (IABP). Perfusion catheters were not routinely used. In our institution, there are three operating rooms and one of them is solely reserved for emergency surgery. The operating room team is acknowledged nationwide for its efficiency. The operations were started within 5–30 min of the initial call.

Operative strategy

After median sternotomy, unstable patients were put on cardiopulmonary bypass (CPB) without delay. If signs of myocardial ischaemia persisted, the aorta was cross-clamped and St. Thomas II crystalloid solution was delivered antegradely and repeated every 20 min during the time of aortic cross-clamping. In some patients, those with acute occlusion of RCA or CX territories, the cardioplegia solution was also given through constructed vein grafts to shorten regional ischaemic time. Retrograde cardioplegia or blood cardioplegia, including hot-shot, was not used. In patients without signs of ongoing myocardial ischaemia, the left internal thoracic artery was harvested before aortic clamping in those with LAD pathology. Otherwise, the harvesting was done under cold cardioplegic arrest to minimize the time of warm myocardial ischaemia. Diseased circumflex or right coronary arteries were bypassed with vein grafts. All patients had complete revascularization. Four patients had iatrogenic Type A aortic dissection. Three of them underwent aortic replacement in deep hypothermic circulatory arrest. The fourth patient had a localized intramural haematoma in the proximal ascending aorta, which was left in place. The patient had bypass surgery with an uneventful follow-up. In the whole cohort of 100 patients, only 2 were treated with IABP. Retained wires were removed via short aortic incisions.

The use of stents was the routine in all PCI procedures, and the antiplatelet regime was aspirin and clopidogrel. This implied that the patients were exposed to an augmented risk of perioperative bleeding. To deal with bleeding, meticulous haemostasis was

undertaken before sternal closure. If further bleeding was observed, tranexamic acid and desmopressin were infused, blood pressure was kept in an acceptable low range, the positive end-expiratory pressure on the ventilator was increased and some of the patients had plasma infusion.

Endpoint

The primary endpoint of the study was early (30-day) mortality and major postoperative complications. The follow-up was 100% complete. Results were compared with the rest of the cardiac operations (81% coronary surgery, 18% valvular surgery and 1% aortic surgery) undertaken in the same time period.

Statistical analysis

Fisher's exact test was applied, and the assessment was conducted with the use of IBM SPSS 19.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

One hundred salvage operations were performed, representing 0.97% of 10 292 cardiac operations during the same period. Thirteen of the operations were undertaken after complicated angiographies. In the study period, 34 193 diagnostic angiographies were done. Thus, 1 per 2630 (0.038%) diagnostic angiographies resulted in emergency cardiac operation. Likewise, 15 544 PCIs were performed requiring 87 back-up operations (0.56%), i.e. 1 per 179 PCIs. The operations were distributed quite evenly throughout the decade, but with a tendency to lower the rate during the later years.

The operative procedures are listed in Table 1. The clinical presentation of the patients on arrival at the operating room is summarized in Table 2. Patients in the angiographic group were at least as circulatory compromised as those in the PCI group.

Some patients had combinations of dissection and perforation or retained wire. In some patients, the dissection involved more than one territory, e.g. the left main coronary artery and the aorta. Details are given in Table 3.

Data on perforation sites are specified in Table 4. In the diagnostic group, two of the perforations were located in the apical portion of the left ventricle. The third patient deserves special description due to rarity. The patient was admitted in stable condition and had no significant comorbidities. During the attempt to perform left ventriculography, haemodynamic collapse occurred. Tamponade was diagnosed, but could not be relieved by

Table 1: Operative procedures in 100 patients

	After PCI	After diagnostic catheterization
Coronary surgery	87	13
Aortic surgery	1	2
Closure of coronary perforation	15	0
Closure of ventricular perforation/rupture	4	3
Removal of retained wire	4	1

Table 2: Clinical presentation of patients (N = 100) during transfer from catheterization laboratory to the operating room

	After angiography	After PCI	Total number
Frank AMI and systolic blood pressure >90	3	29	32
Threatened AMI	4	36	40
Cardiogenic shock	4	20	24
Ongoing external massage	2	2	4
Sum	13	87	100

AMI: acute myocardial infarction.

Table 3: Dissected vessels in 10 patients in the angiography group and 78 in the PCI group

	After angiography	After PCI	Total
Left main stem artery	8	17	25
Left anterior descending coronary artery	1	42	43
Circumflex coronary artery	0	19	19
Right coronary artery	1	19	20
Aorta	2	2	4

Table 4: Perforation sites in 3 patients in the angiography group and 16 in the PCI group

	After angiography	After PCI	Total
Left anterior descending coronary artery	0	10	10
Circumflex artery	0	3	3
Right coronary artery	0	2	2
Left ventricle	3	2	5
Right ventricle	0	2	2

emergency subxiphoid pericardiocentesis as heavy bleeding persisted. The patient was therefore emergently operated. At operation, a transmural, horizontal rupture of the obtuse margin of the left ventricle was found and closed with felt reinforced sutures. The postoperative course was without complication.

Five patients, 1 in the diagnostic group and 4 in the PCI group, had retained wires. The trapped wire in the diagnostic group patient occurred during fractional flow reserve assessment of LAD stenosis.

One of the 100 patients (1%) died within 30 days of surgery (Table 5). The patient belonged to the cardiogenic shock group after PCI and had postoperative IABP, but could be mobilized and discharged on heart failure medication. Death occurred at the local hospital, and the cause was cardiac arrest. This 1% mortality is as low as in all other operated patients (0.9%, $P = 0.60$).

Table 5: Outcomes (%) of the study group patients (N = 100) compared with all other operated patients (N = 10 192) in the same period

	Study group	All other patients	P-value
30-day mortality	1.0	0.9	0.60
Myocardial infarction	12.0	1.0	<0.001
Stroke	2.0	0.9	0.23
Renal failure	2.0	1.2	0.34
Ventilator >24 h	7.0	1.1	<0.001
Reopening for bleeding	4.0	1.9	0.13
Reopening for mediastinitis	0	0.4	1.0

Table 6: Early mortality of emergent cardiac operations from contemporary reports in the stent era

Reference	Year published	Time period	N	Mortality (%)
[5]	2009	1999–2005	31	13
[6]	2009	1994–2008	90	8
[1]	2008	1993–2003	132	10
[2]	2006	2002–2003	985	9
[3]	2005	2000–2003	21	10
[4]	2002	1992–2000	113	15
Present study		1997–2007	100	1

Myocardial infarction and prolonged ventilation were significantly more frequent in the study group, whereas stroke, renal failure, reoperation for bleeding and revision for mediastinitis were not. None of the study group patients had deep sternal infection (Table 5).

Of the 12 patients with postoperative myocardial infarction, all but one had preoperative ST-segment elevation.

In Table 6, the mortality data of the present study are compared with other reports from the contemporary stent era.

DISCUSSION

Only 1 patient died within 30 days in this series of 100 consecutive emergency operations after crashed diagnostic or therapeutic cardiac catheterization procedures. The result is superior to other contemporary reports with a pooled mean mortality rate of 11% [1–6] (Table 6). We believe that the key factor for the low mortality rate is the very swift operative action taken for these patients.

Other authors bring up the need for preoperative stabilization and the use of IABP [5, 7]. We disagree, as these measures delay transfer to the operating room. To save time, these life-threatened patients should be brought immediately to the operating room, minimizing the time of warm myocardial ischaemia, and they should have complete coronary revascularization. The scenario is perfect for this at our institution, as argued in the introduction.

Our operative strategy is in line with a paper from the present era [8]. Prompt, aggressive and complete revascularization is also advised by these authors. Two of 74 patients died postoperatively (2.7%), and the overall rate of myocardial infarction was 8.1%.

Furthermore, in their experience, reperfusion catheter usage resulted in a longer delay in the initiation of CPB and subsequently, worse outcomes. They state that the use of reperfusion catheters may lead to a false sense of security, potentially resulting in higher rates of postoperative myocardial infarction and early mortality. Non-use of perfusion catheters was also preferred by us.

In contrast to most of the reports listed in Table 6, none of our patients were admitted with acute ST-segment elevation infarction. This is likely to be one cause of the higher operative mortality in the other series.

Twelve (12%) of the patients in our study suffered postoperative myocardial infarction when compared with 1% for the rest of 10 192 patients. However, 11 of them had preoperative ST-segment elevation. Nevertheless, it denotes that there is potential for improvement. There are no reliable data on the time elapsed from the start of trouble in the catheterization laboratory until the decision to operate was taken. We do suspect that the time in many of these cases had been so long that irreversible myocardial damage had occurred. The risk of myocardial infarction is proportional to the duration of myocardial ischaemia. The dilemma for the invasive cardiologist is the understandable struggle over potentially successful salvage with further percutaneous techniques vs the time limit for inducing irreparable myocardial injury beyond the possibility of complete recovery. Yet, and without doubt, to obtain the best surgical outcome, the limit of irreversibility must not be crossed. The timing of the operative intervention is evidently crucial to minimize ischaemic time and thereby the reduction of infarctions in number or at least in size.

We used antegrade crystalloid cardioplegia, and it remains open whether blood cardioplegia and/or retrograde delivery might have reduced the myocardial infarction rate. Many would consider these measures as mandatory in acute coronary occlusion situations. The answer is that blood cardioplegia was not available in our institution, and catheterization of the coronary sinus was not integrated in our routine during the study time.

It is noteworthy that no patient needed revision surgery for postoperative mediastinitis despite the fact that many of them were in a critical state, and hence the start of the operations was done under less-than-optimal disinfection conditions. After circulatory and cardiopulmonary stabilization was achieved, disinfection was handled with rewashing, irrigation and additional antibiotics, leading to complete success in all.

In the literature, there are few reports on iatrogenic Type A aortic dissection caused by cardiac catheterization procedures. The current study includes 4 patients, of whom all survived. Recently, a 50% operative mortality in 12 patients with catheterization-associated Type A aortic dissection has been reported [9]. The patients were collected from 135 262 who underwent cardiac catheterization from 1995 to 2010. The authors point out that the high mortality rate is discouraging when considering that the indication for the diagnostic procedure was elective in the majority of patients. We were fortunate to have no deaths, but the number of patients with iatrogenic aortic dissection is so low in our study that comparison is not really justified.

However, diagnostic cardiac catheterization resulted in 11 more patients with life-threatening complications. As summarized in Table 2, their haemodynamic situation was at least as grave as for the post-PCI patients. Two of them were massaged onto CPB after wire-induced left main artery dissection with occlusion. It is as expected that intima tear with vessel lumen occlusion located in the left or right coronary ostium induced severe haemodynamic instability.

Three of our patients in the diagnostic group had perforations of the left ventricle. It occurs infrequently without a myocardial infarction. Echocardiographically guided pericardiocentesis is the primary measure [10]. If haemodynamic stability is not restored, surgery is necessary as was the case with our patients.

One other difficult complication in the diagnostic catheterization group was that of the patient with fractional flow reserve measurement of stenotic LAD. A fractional flow reserve-specific wire became stuck, and the manipulations resulted in a localized dissection with threatened anterior wall infarction, which was why emergency surgery was undertaken. The case demonstrates that even this type of invasive investigation may result in a major complication.

In conclusion, life-threatening complications associated with cardiac catheterization procedures requiring emergency operative action are infrequent. When they do occur, it is possible to obtain a low mortality (1%) rate by immediate operative intervention, avoiding any delays in care delivery.

Conflict of interest: none declared.

REFERENCES

- [1] Mattichak SJ, Dixon SR, Shannon F, Boura JA, Safian RD. Failed percutaneous coronary intervention: a decade of experience in 21000 patients. *Catheter Cardiovasc Interv* 2008;71:131-7.
- [2] Haan CK, O'Brien S, Edwards FH, Peterson ED, Ferguson TB. Trends in emergency coronary artery bypass grafting after percutaneous coronary intervention, 1994-2003. *Ann Thorac Surg* 2006;81:1658-65.
- [3] Yang EH, Gumina RJ, Lennon RJ, Holmes DR, Rihal CS, Singh M. Emergency coronary artery bypass surgery for percutaneous coronary interventions. Changes in the incidence, clinical characteristics, and indications from 1979 to 2003. *J Am Coll Cardiol* 2005;46:2004-9.
- [4] Seshadri N, Whitlow PL, Acharya N, Houghtaling P, Blackstone EH, Ellis SG. Emergency coronary artery bypass surgery in the contemporary percutaneous coronary intervention era. *Circulation* 2002;106:2346-50.
- [5] Darwazah AK, Islim I, Hanbali B, Shama RA, Aloul J. Emergency coronary artery bypass surgery after failed percutaneous coronary intervention. *J Cardiovasc Surg* 2009;50:795-800.
- [6] Roy P, de Labriolle A, Hanna N, Bonello L, Okabe T, Slottow TLP *et al.* Requirement for emergent coronary artery bypass surgery following percutaneous coronary intervention in the stent era. *Am J Cardiol* 2009;103:950-3.
- [7] Reinecke H, Fetsch T, Roeder N, Schmid C, Winter A, Ribbing M *et al.* Emergency coronary artery bypass grafting after failed coronary angioplasty: what has changed in a decade? *Ann Thorac Surg* 2000;70:1997-2003.
- [8] Barakate MS, Bannon PG, Hughes CF, Horton MD, Callaway A, Hurst T. Emergency surgery after unsuccessful coronary angioplasty: a review of 15 years' experience. *Ann Thorac Surg* 2003;75:1400-5.
- [9] Leontyev S, Borger MA, Legare J-F, Merk D, Hahn J, Seeburger J *et al.* Iatrogenic type A aortic dissection during cardiac procedures: early and late outcome in 48 patients. *Eur J Cardiothorac Surg* 2012;41:641-6.
- [10] Tsang TS, Freeman WK, Barnes ME, Reeder GS, Packer DL, Seward JB. Rescue echocardiographically guided pericardiocentesis for cardiac perforation complicating catheter-based procedures. *J Am Coll Cardiol* 1998;32:1345-50.

eComment. Management of percutaneous coronary intervention complications

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We read with great interest the article by Almdahl *et al.*, regarding the cardiac surgical outcome of patients with complications of percutaneous coronary intervention