# Emergency Surgery for Iatrogenic Injuries attributable to Percutaneous Coronary Interventions: When Planning and Time Matter

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Iatrogenic injuries have accompanied percutaneous coronary intervention (PCI) since the beginning of this modality. These complications comprise a spectrum of different anatomic lesions, such as coronary perforation, occlusion or dissection, and aortic dissection. Depending on the severity of the injury, the clinical presentation can be indolent or can rapidly deteriorate because of cardiac tamponade, acute myocardial infarction, or cardiogenic shock.

Coronary perforation has an incidence ranging from 0.19% to 0.71%, according to the largest contemporary series.[1] It was more common in the past, when atheroablative devices were more frequently used.[2]

Among risk factors, type C lesions were shown to be the strongest predictor of perforation in a multicenter, retrospective analysis performed by Parsh et al.[3] Patel et al, in 2013, reported an overall 2.9% incidence of coronary perforation secondary to chronic total occlusion interventions.[4]

Iatrogenic coronary dissection was also frequent in the prestent era, reaching an incidence of ≈30% of cases.[5] Nowadays, with the newer drug-eluting stents, it became a rare complication, with an incidence <0.1%.[6] Recently, Hiraide and coworkers,[7] analyzing a multicenter PCI registry, found that female sex, complex PCI (such as those on chronic total occlusion and bifurcation lesions), and proximal lesions were independent risk factors for iatrogenic coronary dissection. Notably, these factors are also predictive of adverse in-hospital cardiovascular events, including new onset of cardiogenic shock or heart failure, regardless of whether adequate flow was restored or not. One possible explanation is the one offered by Eeckhout, who demonstrated that ≈40% of patients with normalized TIMI (Thrombolysis in Myocardial Infarction) flow after bailout PCI for coronary dissection were estimated to have insufficient perfusion at the microvascular level.[8]

Iatrogenic aortic dissection is an even more dramatic complication after coronary percutaneous procedures; it is generally attributable to retrograde extension of an endothelial tear toward the aortic root.

Its incidence is ≈0.01% to 0.04%, according to the German Registry for Acute Aortic Dissection Type A.[9]

The Table provides a description of the main characteristics of these lesions.[10,11]

Iatrogenic dissections are usually treated with a more conservative surgical approach, compared with spontaneous ones, which usually require supracoronary ascending aorta replacement, with or without aortic arch surgery and complex aortic root reconstruction. This is, in part, attributable to the generally less extended scope of aortic dissection in PCI injuries, but could also reflect a more conservative approach in a population of patients who often present with severely impaired clinical status.

All iatrogenic lesions after coronary procedures present with a low incidence because of the dramatic technical and procedural advancements in this field over recent decades. On the other hand, these improvements have led interventional cardiologists to perform PCI in patients with higher-risk anatomic features, such as chronic total occlusion, bifurcations, and left main lesions. The overall comorbid complexity of patients with PCI also has increased over recent years, and percutaneous procedures are nowadays performed in older patients, with more frequent comorbidities and heavily calcified coronary arteries.

Percutaneous cardiac interventions are also exponentially expanding into the valvular and electrophysiological fields. Consequently, iatrogenic lesions to cardiac structures will continue to be a possible, although uncommon, complication to be expected in the contemporary interventional cardiology era.

As a consequence of the low incidence of presentation, iatrogenic injuries after percutaneous coronary procedures are described in the literature only in small retrospective series or in

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**Table.** Main Characteristics of Iatrogenic Lesions After PCI

| Characteristic | Incidence, % | Main Features | Possible Risk Factors | Clinical Presentation | Possible Surgical Treatment |
|---|---|---|---|---|---|
| Coronary perforation | 0.19–0.71% | Ellis classification[10]:<br>Grade I<br>crater extending outside of the lumen without angiographic contrast extravasation<br>May be angiographically undistinguishable from localized dissections<br>Grade II<br>pericardial/myocardial blush without angiographic contrast jet extravasation<br>Grade III<br>extravasation of blood through a frank perforation (≥1 mm) or spilling into an anatomic cavity chamber (right ventricle, coronary sinus)<br>Demonstrated independent predictor of mortality[2] | Female sex<br>Older age<br>Hypertension<br>Lower BMI<br>Unstable angina<br>NSTEMI<br>Right coronary artery intervention<br>Type C lesions: calcified or CTO[4,5] | Grade I<br>usually not associated with cardiac tamponade or ischemia<br>Grade II<br>may be associated with cardiac tamponade (including delayed) or ischemia<br>Grade III<br>frequently associated with cardiac tamponade and/or myocardial ischemia and/or cardiogenic shock | More frequently necessary for grade III lesions<br>• Pericardiocentesis<br>• Surgical repair of the lesion<br>• Emergency CABG<br>• Mechanical circulatory support (IABP, VA ECMO, Impella) *in case of cardiogenic shock to maintain hemodynamic stability before surgery or to allow percutaneous repair of the lesion* |
| Coronary dissection | <0.1% | May remain limited to a segment of the coronary artery, with or without residual flow, or extend to the aortic root and ascending aorta | PCI on complex lesions (CTO, bifurcations)[7]<br>Heavy calcification<br>Proximal lesions<br>Small coronary<br>Unusual anatomic characteristics<br>Operator inexperience<br>Older age<br>Root calcification<br>Connective tissue disorders<br>Use of some types of catheters and wires (eg, pressure wires) | Depends essentially on the extension and on the presence of residual flow or not<br>Hemodynamic stability may be maintained, or dissection may cause abrupt coronary occlusion with myocardial ischemia, cardiogenic shock, or cardiac arrest | • Pericardiocentesis<br>• Emergency CABG<br>• Mechanical circulatory support (IABP, VA ECMO, Impella) *in case of cardiogenic shock to maintain hemodynamic stability before surgery or to allow percutaneous repair of the lesion*<br>• Aortic surgery in case of extension of the dissection |
| Aortic dissection | 0.01%–0.04% | Dunning classification[11]:<br>Class I: limited to the corresponding sinus of Valsalva<br>Class II: extension in the aorta <40 mm<br>Class III: extension in the aorta >40 mm | Right coronary artery cannulation<br>PCI on CTO<br>Root calcification<br>Connective tissue disorders<br>Nonconventional catheters | Depends essentially on the extent of the dissection and on the presence of associated myocardial ischemia or not | Aortic surgery: complexity depends on the extent of the dissection<br>Frequently associated with CABG (75% of cases according to GERAADA)[9] |

BMI indicates body mass index; CABG, coronary artery bypass grafting; CTO, chronic total occlusion; GERAADA, German Registry for Acute Aortic Dissection Type A; IABP, intraortic balloon pump; NSTEMI, non–ST-segment–elevation myocardial infarction; PCI, percutaneous coronary intervention; VA ECMO, venoarterial extracorporeal membrane oxygenation.

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single-center case reports. Specific guidelines or recommendations on the proper management of these potentially life-threatening complications do not exist. There is general consensus that most patients can be initially treated conservatively or by PCIs (bail-out stenting), which can be performed quickly in the catheterization laboratory, immediately after an iatrogenic injury occurs. Surgical treatment is required in only a minority of cases, when bail-out procedures have failed or are not feasible because of the severity of the iatrogenic or native lesion. These operations, however, are associated with high morbidity and mortality rates.

Many of those cases present with a "worst scenario" clinical picture: the combination of severe ongoing myocardial ischemia and deep hemodynamic impairment, with compromised anatomic integrity, thus often requiring mechanical ventilation, high-dose inotropic support, or even cardiopulmonary resuscitation. It must also be considered that because of their emergent nature, these surgical procedures lack presurgical evaluation and adequate preoperative management. Most of these patients received a loading dose of antiaggregants or have not discontinued anticoagulation, and many may be actively bleeding. This, in turn, results in a high risk of severe bleeding and of subsequent multiple blood product transfusions. This can play an important role in determining infection and multiorgan failure, further increasing morbidity and mortality rates.[12,13]

In this issue of the *Journal of the American Heart Association* (*JAHA*), Verevkin and colleagues[14] present their series of patients who underwent emergency cardiac surgery for iatrogenic lesions after coronary percutaneous intervention. The authors report a 30-day mortality of 20.8%. Compellingly, the authors also provide information on long-term survival at 1, 5, 10, and 12 years: 71.8±4%, 63.9±4%, 49.6±5%, and 44.6±6%, respectively. As the authors point out, if patients who died within 30 days are excluded, the long-term survival increases dramatically (89.8±3%, 79.0±4%, 64.0±6%, and 60.0±6% at 1, 5, 10, and 12 years, respectively), and therefore it justifies tremendous efforts at performing these emergency operations. A critical preoperative state (hazard ratio, 3.5; $P<0.0001$) and coronary artery occlusion during PCI (hazard ratio, 2.6; $P=0.002$) were identified as 2 independent risk factors for long-term mortality.

These data underline the importance of 2 key points in this clinical setting: prevention and timing.

First, prevention is of paramount importance in minimizing the incidence of iatrogenic injuries after a percutaneous procedure. It may reduce the severity of clinical presentation in the event that a lesion occurs. Prevention can be realized through the identification of risk factors, by means of an accurate, thorough, and multidisciplinary preprocedural evaluation of patients. From this perspective, the recommendations of a Heart Team may play a crucial role: when a high-risk procedure is identified, the best treatment strategy can be planned appropriately. For instance, a surgical backup or a hybrid procedure can be set up, or perhaps mechanical circulatory support systems, such as venoarterial extracorporeal membrane oxygenation or Impella, can be used to maintain adequate hemodynamic status.[15] As suggested by Slottosch et al, a reasonable alternative approach also would be to transfer patients for high-risk, nonemergent PCI to a hospital with on-site cardiac surgery available.[16]

Second, the timing of emergency surgery constitutes another key point. Because most patients who require surgery after iatrogenic lesions present with poor clinical status, the time interval between the occurrence of the injury and the surgical treatment must be minimized. Verevkin and colleagues[14] found a significantly longer time interval from PCI to surgery in patients referred from external hospitals compared with that of internal patients (306±111 versus 160±102 minutes; $P<0.001$). However, they reported an in-hospital mortality that is 12-fold higher in the in-hospital patient group. The authors indicate that these data could be biased by the fact that the subpopulation of patients transferred from an external hospital selected those with a more stable clinical profile, as those with a more impaired clinical status were not in a condition to be transferred or, possibly, died shortly after the percutaneous procedure.

In the MASS COMM (The Randomized Trial to Compare Percutaneous Coronary Intervention between Massachusetts Hospitals with Cardiac Surgery On-Site and Community Hospitals without Cardiac Surgery On-Site) randomized trial,[17] 3691 patients undergoing emergency PCI in nonsurgical versus surgical centers were analyzed. The study demonstrated no difference in the primary safety end point of 30-day major adverse cardiac events (death, myocardial infarction, repeated revascularization, and stroke; 9.2% versus 9.1%; $P<0.001$), nor in the need for emergency coronary artery bypass grafting (0.3% versus 0.1%; $P<0.001$). However, the study was designed to evaluate patients who required surgery after failed PCI, and not for the evaluation of iatrogenic lesions.

Because the incidence of severe complications after percutaneous intervention is extremely low, current American College of Cardiology Foundation/American Heart Association/Society for Cardiovascular Angiography and Interventions Guidelines for Percutaneous Coronary Intervention do not recommend on-site cardiac surgery for elective procedures. However, the guidelines state that "Primary or elective PCI should not be performed in hospitals without on-site cardiac surgery capabilities without a proven plan for rapid transport to a cardiac surgery operating room in a nearby hospital or without appropriate hemodynamic support capability for transfer" (Class III: HARM, Level of Evidence: C).[18] In

other words, the guidelines stress the importance of having a standardized, reliable, and efficient route for patient transfer to a cardiac surgery facility if such a facility is not present on-site. A similar position is also endorsed by the British Cardiovascular Intervention Society.[19] Interestingly, the European Society of Cardiology/European Association for Cardio-Thoracic Surgery guidelines on myocardial revascularization do not address this logistical issue.[20] Besides a plan for the fast transfer of patients to a cardiac surgery unit in case of failed angioplasty, establishing an extracorporeal membrane oxygenation–based program for the retrieval of hemodynamically unstable patients could improve outcomes and expand the number of cases treated successfully.[16]

In conclusion, iatrogenic lesions after percutaneous coronary procedures are uncommon nowadays. Among them, those requiring emergency surgery are even less frequent. However, because morbidity and mortality in this subpopulation of patients remain significantly high, it is of uttermost importance to have well-established protocols for fast and effective transfer to a cardiac surgical facility, be it in hospital or off site. On the basis of the data presented by Verevkin and colleagues,[14] such efforts are likely to be worthwhile and lead to prolonged survival.

## Disclosures

None.

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