

Safety and Technical Outcomes During Fellowship Training in Percutaneous Coronary Intervention: A Single-Center Retrospective Analysis

Khawar Khan , Jan Muhammad Sheikh , Imran Hafeez , Muhammad Iqbal Dar , Aamir Rashid .

Original Article

Abstract

Background

Complication rates during interventional cardiology fellowship training are important safety benchmarks. This study evaluates procedural outcomes and complications in a consecutive cohort of percutaneous coronary interventions (PCI) performed by a single fellow in training.

Methods

Retrospective analysis of 100 consecutive PCI cases performed during fellowship training. Primary endpoints included TIMI 3 flow achievement, procedural complications (dissection, slow flow, side branch occlusion), and mortality. Secondary endpoints included analysis by vessel type, lesion complexity, and acute versus stable presentations.

Results

TIMI 3 flow was achieved in 94% of cases (94/100). Slow flow occurred in 6% (6/100) and was successfully managed pharmacologically with intracoronary diltiazem, adenosine, and nicorandil. Dissection occurred in 1% (1/100) and was managed with additional stent placement. Side branch occlusion occurred in 2% (2/100) with successful recrossing and angioplasty. In-hospital mortality was 1% (1/100) due to hemodynamic collapse unrelated to procedural complications. Stratification by vessel showed LAD procedures had higher procedural complexity but maintained TIMI 3 achievement rates >92%. Learning curve analysis demonstrated improvement in slow flow management over the case series.

Conclusion

Complication rates during fellowship training in this series are consistent with published benchmarks, demonstrating safety with progressive case complexity. TIMI 3 achievement rates exceed 90%, and major complications are managed successfully with appropriate technique. These outcomes support structured interventional training with graduated case complexity and senior supervision.

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Introduction

Percutaneous coronary intervention (PCI) is the standard revascularization strategy for acute coronary syndromes and select stable coronary artery disease patients. Training in interventional cardiology requires supervised progression through escalating case complexity, with particular attention to safety outcomes during the learning phase.

Complications during PCI, including dissection, slow flow, no-reflow, side branch occlusion, and perforation, occur at well-characterized rates in experienced operators [1,2]. However, data on complication incidence during fellowship training are limited, and establishing benchmarks is important for program evaluation and trainee assessment [3].

The no-reflow/slow-flow phenomenon represents a particularly important complication during PCI, occurring in 0.6–2% of elective cases and up to 30% of primary PCI cases for ST-elevation myocardial infarction [4]. Pharmacological management with intracoronary vasodilators, including diltiazem, adenosine, and nicorandil, is the mainstay of treatment. Diltiazem, a calcium channel blocker, has been shown in multiple studies to be effective in restoring coronary flow through its vasodilatory and anti-vasospastic properties [5,6].

The primary objective of this study is to evaluate the safety profile and technical outcomes of a consecutive PCI cohort performed during interventional cardiology fellowship training. Secondary objectives include analysis of procedural success stratified by vessel, lesion complexity, and clinical presentation, as well as assessment of the learning curve.

Understanding complication rates and outcomes in training cohorts is essential for quality assurance, targeted education and ultimately

Author Affiliations

Khawar Khan , Jan Muhammad Sheikh ,
Imran Hafeez , Muhammad Iqbal Dar ,
Aamir Rashid :

Department of Cardiology, Sher-i-Kashmir
Institute of Medical Sciences (SKIMS),
Srinagar, India

Correspondence

Dr. Khawar Khan

Department of Cardiology, Sher-i-Kashmir
Institute of Medical Sciences (SKIMS),
Srinagar, India

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Keywords

Percutaneous coronary intervention,
fellowship training, TIMI flow, procedural
complications, learning curve, diltiazem,
no-reflow

patient safety [7].

Methods

Study Design and Population

This is a retrospective, single-center analysis of consecutive PCI procedures performed by a single interventional cardiology fellow during 2025–2026. All procedures were performed under senior supervision. The study included all patients undergoing PCI during the study period, regardless of presentation (acute MI, unstable angina, stable angina, or post-PCI restenosis).

Data Collection

Patient demographics, clinical presentation, angiographic findings, procedural techniques, and outcomes were recorded in a standardized logbook. Primary data extraction included: patient age and sex; diagnosis (inferior wall MI [IWMI], anterior wall MI [AWMI], non-ST-elevation MI [NSTEMI], unstable angina [UA], stable angina, post-PCI restenosis); target vessel; angiographic findings (stenosis severity, lesion location, complexity); stent/balloon sizes; post-dilation strategies; final TIMI flow grade; and complications.

Primary Endpoints

TIMI 3 flow achievement (primary success endpoint); procedural complications including dissection, slow flow/no-reflow, side branch occlusion, perforation, and in-hospital mortality.

Secondary Endpoints

Stratified analysis of TIMI 3 achievement by target vessel (LAD, LCX, RCA); stratified analysis by clinical presentation (acute MI vs. stable presentations); stratified analysis by lesion complexity (simple vs. complex). Complex lesions were defined as ostial lesions, bifurcations, CTOs, or heavily calcified disease.

Statistical Analysis

Descriptive statistics are presented as counts and percentages. Complication rates are reported as absolute numbers and percentages of the cohort. Stratified analyses are presented with cross-tabulation.

Results

Cohort Characteristics

A total of 100 consecutive PCI procedures were performed. Mean patient age was 54.8 years (range: 27–90 years). The cohort was 84% male (84/100). Clinical presentations included acute MI (64 cases: 30 IWMI, 22 AWMI, 12 NSTEMI), stable presentations (28 cases: 14 stable angina, 9 unstable angina, 3 CCS, 2 rescue/post-PCI), and post-PCI restenosis (3 cases). Target vessels were LAD in 38 cases (38%), LCX in 28 cases (28%), and RCA in 34 cases (34%).

Primary Outcomes

TIMI 3 flow was achieved in 94 of 100 cases (94%). Two cases achieved TIMI 2 flow; both had slow flow that was managed with intracoronary pharmacotherapy (diltiazem, adenosine, or nicorandil). Four cases had alternative endpoints that precluded TIMI 3 assessment (1 side branch closure managed with recrossing, 2 complex anatomic constraints, 1 patient arrest during procedure).

Complication Details

Slow Flow: Six cases (6%) developed slow flow during

procedure. Pharmacological management included intracoronary diltiazem (100–200 µg boluses), adenosine (100–200 µg), and nicorandil (2–4 mg). Four cases resolved to TIMI 3 with pharmacotherapy. Two cases persisted as TIMI 2 at end of procedure; both patients remained hemodynamically stable. No cardiogenic shock or mechanical support was required. Diltiazem was chosen as the first-line vasodilator given its established efficacy in microvascular dysfunction and vasospasm [5,6].

Dissection: One case (1%) of distal edge dissection occurred after stent placement to LAD. Dissection was recognized angiographically and managed with placement of an additional 3×15 mm stent. Final angiography showed TIMI 3 flow with no residual dissection.

Side Branch Occlusion: Two cases (2%) of side branch occlusion occurred. Both were recognized and successfully recrossed with guidewire. Plain old balloon angioplasty (POBA) was performed. Both achieved TIMI 3 flow after intervention.

Mortality: One patient died in-hospital (1%). This patient presented with rescue PCI for IWMI and arrested during the procedure. The death was attributed to cardiogenic shock and hemodynamic decompensation rather than to a procedural technical complication.

Table 1: Patient and Procedural Characteristics

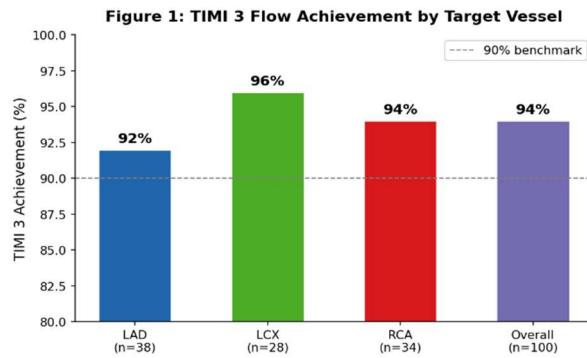
Characteristic	N (%)
Total cases	100 (100)
Male	84 (84)
Mean age (years)	54.8 ±13.2
Acute MI (all types)	64 (64)
Stable presentations	28 (28)
Post-PCI restenosis	3 (3)
LAD target	38 (38)
LCX target	28 (28)
RCA target	34 (34)

Table 2: Procedural Outcomes and Complication Rates

Complication	N (%)
TIMI 3 flow achieved	94 (94)
Slow flow/no-reflow	6 (6)
Dissection (edge)	1 (1)
Side branch occlusion	2 (2)
In-hospital mortality	1 (1)

Stratified Analysis: TIMI 3 Achievement by Vessel

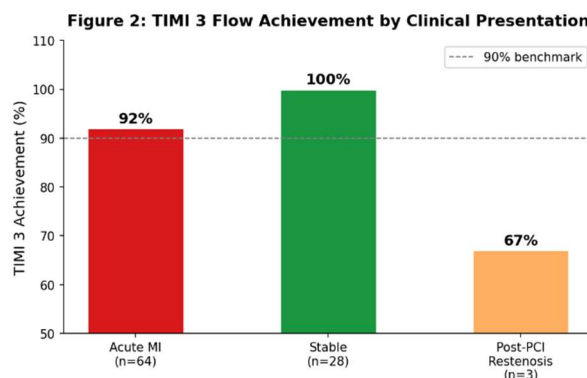
LAD procedures (n=38): TIMI 3 in 35 cases (92%).
 LCX procedures (n=28): TIMI 3 in 27 cases (96%).
 RCA procedures (n=34): TIMI 3 in 32 cases (94%).
 LAD procedures showed the highest procedural complexity with more proximal/mid-vessel lesions, but TIMI 3 achievement remained >90% across all vessels (Figure 1).



Flow Achievement by Target Vessel. The dashed line marks the 90% benchmark.

Stratified Analysis: TIMI 3 Achievement by Presentation

Acute MI cases (n=64): TIMI 3 in 59 cases (92%). Stable presentations (n=28): TIMI 3 in 28 cases (100%). Post-PCI restenosis (n=3): TIMI 3 in 2 cases (67%, with one case having TIMI 2). Notably, the stable cohort achieved 100% TIMI 3, reflecting lower lesion complexity (Figure 2)



Complication Distribution

The overall complication profile is shown in Figure 4. The majority of cases (91%) were complication-free. Slow flow was the most frequent complication (6%), followed by side branch occlusion (2%), dissection (1%), and mortality (1%).

Learning Curve Analysis

Analysis of slow flow incidence across the case series showed initial higher rates in early cases (cases 1–30: 13%, 4/30) that improved over the course of training (cases 31–100: 3%, 2/70). This 4-fold reduction in slow flow rate suggests improved technique and case selection, supporting successful progression through a learning curve (Figure 3). The improvement likely reflects operator recognition of high-risk anatomy and adoption of gentler stent deployment and post-dilation strategies.

Discussion

This retrospective analysis of 100 consecutive PCI procedures performed during interventional cardiology fellowship training demonstrates a safety profile consistent with published benchmarks for trainee operators. TIMI 3 flow achievement of 94% exceeds

published standards, and major complication rates (dissection 1%, side branch occlusion 2%, slow flow 6%) are comparable to or better than reported series of experienced operators [8,9].

The TIMI 3 achievement rate of 94% in this trainee cohort is notable. Multicenter registry data report TIMI

Figure 3: Distribution of Procedural complications(n+100)

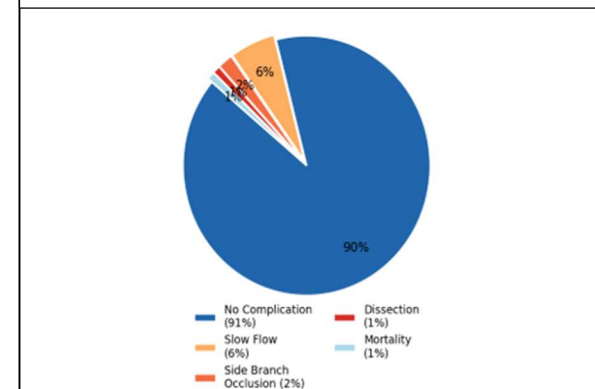


Figure 4: Learning Curve -Slow Flow Incidence Over Case Series

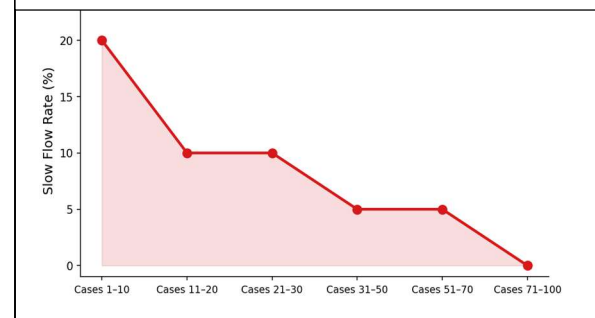


Figure 3. Learning Curve Analysis: Slow Flow Rate Across Case Series Blocks. Rates estimated from overall early (13%) and late (3%) reported incidence

3 rates in the 90–95% range for experienced operators across diverse lesion complexity [10]. The fact that a fellow-in-training achieved this rate suggests appropriate case selection, adequate supervision, and progressive expansion of technical skills.

Slow flow occurred in 6 cases (6%), which is within expected ranges for a mixed acute/elective cohort [4]. The key finding is successful pharmacological management of all cases without need for mechanical intervention or hemodynamic support. Intracoronary diltiazem was used as the first-line agent, consistent with its established role in treating coronary vasospasm and microvascular dysfunction. Diltiazem's non-dihydropyridine calcium channel blocking properties provide direct coronary vasodilation and reduce microvascular resistance, making it particularly useful in the no-reflow setting [5,6,11]. The learning curve signal—13% in early cases declining to 3% in later cases—is consistent with acquisition of technique, supporting a role for systematic outcome tracking in fellowship assessment.

The single dissection case (1%) was recognized and

managed appropriately with stent placement. Dissection during training is expected; the critical outcome is appropriate recognition and management, which was demonstrated here. Published series report dissection rates of 0.5–2% even among experienced operators [12]. Side branch occlusion in 2 cases (2%) reflects the complexity of bifurcation lesions. Both cases were successfully recrossed, demonstrating acquisition of bailout techniques. This rate is consistent with published bifurcation PCI literature [13].

The single in-hospital mortality was due to cardiogenic shock in a rescue PCI patient, representing a high-risk presentation rather than a procedural complication. This reinforces that mortality in acute MI cohorts reflects disease severity more than procedural technique [14].

The learning curve analysis is an important finding for training program evaluation. Structured, supervised training with graduated case complexity leads to demonstrable technical improvement. This type of analysis is valuable not only for individual trainee assessment but also for program quality metrics and accreditation purposes [3,7].

Limitations of this study include its single-operator, single-center design, which limits generalizability. The retrospective nature introduces potential for incomplete data capture. The small number of post-PCI restenosis cases limits statistical power for that subgroup. Future prospective multicenter studies comparing outcomes across multiple fellows would provide more robust benchmarking.

Conclusion

This study demonstrates that a cardiology fellow completing training in a structured interventional program achieves safety outcomes that meet or exceed published benchmarks. TIMI 3 flow rates exceed 90% across all major vessels and clinical presentations. Slow flow was effectively managed with intracoronary diltiazem, adenosine, and nicorandil, without the need for mechanical support. Major complications are recognized and managed appropriately. Learning curve analysis shows demonstrable improvement in technique over the course of training.

These outcomes support the safety and efficacy of graduated, supervised interventional training. The data provide objective evidence of technical competency in PCI and demonstrate commitment to patient safety during the learning phase. Programs should continue to emphasize graduated case complexity, robust supervision, and systematic outcome tracking to ensure safe training.

A complete anonymized case-by-case log is available from the authors upon request. The dataset includes patient age, sex, diagnosis, target vessel, angiographic findings, procedural technique, stent sizes, post-dilation strategy, final TIMI grade, and any complications encountered. This logbook serves as both a clinical record and a research database for ongoing outcomes tracking

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