Original Research

# DETERMINANTS OF INVASIVE VERSUS CONSERVATIVE MANAGEMENT OF CORONARY ARTERY DISEASE AT A TERTIARY CENTRE IN TAMIL NADU: A RETROSPECTIVE HOSPITAL-BASED OBSERVATIONAL STUDY

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## ABSTRACT

**Background:** Invasive management of coronary artery disease (CAD), including percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG), improves outcomes in selected patients; however, its utilization in non-metropolitan Indian tertiary centres remains variable. To estimate the proportion of CAD admissions managed invasively at a tertiary centre in Tamil Nadu and to identify independent determinants of the management decision.

**Materials and Methods:** A retrospective hospital-based observational study was conducted among consecutive adult CAD admissions between January 2022 and December 2024. The primary outcome was management modality (invasive vs conservative). A total of 320 patients were included. Bivariate analysis and multivariable logistic regression were performed to identify determinants of invasive management.

**Results:** Of 320 CAD admissions, 110 (34.4%) received invasive management. After multivariable adjustment, STEMI presentation (aOR 4.34, 95% CI 2.48–7.58; $p<0.001$), prior revascularization (aOR 3.93, 95% CI 1.60–9.66; $p=0.003$), age <65 years (aOR 2.13 vs ≥65; $p=0.018$), higher socio-economic status (BG Prasad I–III vs IV/V, aOR 2.27; $p=0.002$), and residence within 50 km to the tertiary care (aOR 2.04; $p=0.015$) independently increased the odds of invasive management.

**Conclusion:** In the present study, clinical severity (STEMI), prior cardiac history, younger age, higher SES, and geographic proximity emerged as the dominant independent determinants of invasive CAD management. These findings identify intervention targets for narrowing the gap between guideline-directed and delivered invasive care in mixed urban-rural districts.

**Keywords:** Coronary Artery Disease, Invasive Management, Conservative Management.

## INTRODUCTION

Cardiovascular disease is the leading cause of mortality in India and accounts for nearly a quarter of all adult deaths nationally [1,2]. Coronary artery disease (CAD), including Acute Coronary Syndromes (ACS) and Chronic Ischemic Heart Disease, drives most of this burden, with onset occurring approximately a decade earlier in South Asians than in Western populations [3,4]. The Indian Council of Medical Research's Global Burden of Disease 2017 country report estimated that ischaemic heart disease was responsible for 17.8% of total deaths in India in 2016, up from 15.2% in 1990 [2]. Invasive management, percutaneous coronary intervention (PCI) after risk stratification, and coronary artery bypass grafting (CABG) confer a clear mortality benefit over conservative (medical) therapy in ST-elevation myocardial infarction (STEMI) and in selected high-risk non-ST-elevation ACS (NSTE-ACS) presentations [5,6]. International guidelines from the European Society of Cardiology

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and the American College of Cardiology endorse early invasive strategies in these subgroups [5,6]. Indian data, however, demonstrate persistent gaps between guideline-directed and actual practice. The Kerala ACS Registry reported reperfusion rates of 41% for STEMI and an overall PCI rate of 17.5% across enrolled hospitals [7]. The CREATE Registry found that only 8% of STEMI patients received primary PCI [8]. The CSI-Kerala PPCI Registry showed that targeted system-level interventions can raise primary PCI rates substantially in geographically dispersed catchments [9].

Beyond clinical eligibility, who receives invasive management in India is shaped by structural and social factors. Sex disparities have been documented in the ACS QUIK trial and the HPIAR registry, with women presenting later and receiving fewer invasive procedures even after risk adjustment [10,11]. Out-of-pocket expenditure remains the dominant payment mode in many Indian hospitals, and government insurance schemes such as Pradhan Mantri Jan Arogya Yojana (PMJAY) and the Tamil Nadu Chief Minister's Comprehensive Health Insurance Scheme (CMCHIS) have been associated with measurable increases in cardiac procedural uptake among eligible beneficiaries [12,13]. Distance to the tertiary care and the maturity of regional STEMI networks are well-established structural determinants of timely reperfusion in low- and middle-income settings [14,15]. Age-related differences in invasive procedure uptake have been described in CRUSADE, where older patients receive fewer invasive interventions even when clinically appropriate [16]. Tertiary centres in non-metropolitan districts in Tamil Nadu serve mixed urban-rural catchments and offer a particularly informative setting in which to examine the interplay between clinical severity, demographic factors (age, sex), socio-economic strata (BG Prasad classification), and structural access (insurance, distance to tertiary care). Local data on the determinants of invasive versus conservative CAD management in such settings remain sparse. With this background, the study aimed to estimate the proportion of CAD admissions managed invasively at a rural tertiary care hospital over 36 months and to identify the independent clinical, demographic, socio-economic, and structural determinants of that decision.

## MATERIALS AND METHODS

### Study Design and Setting

This was a single-centre retrospective hospital-based observational study conducted at a tertiary teaching hospital in Tamil Nadu, South India.

### Study Period and Population

The study included adults with CAD admissions from 1 January 2022 to 31 December 2024, covering a 36-month retrospective study period. Inclusion criteria were (i) age ≥18 years and (ii) a discharge diagnosis of CAD covering STEMI, NSTE-ACS, or chronic ischaemic heart disease confirmed by clinical, electrocardiographic, biomarker, or imaging criteria. Exclusion criteria were transfers out before management decision, missing primary outcome documentation, and patients leaving against medical advice before triage.

### Outcome definitions

The primary outcome was the management modality, coded as a binary variable: invasive (PCI, CABG, or coronary angiography proceeding to revascularization) vs conservative (medical management without revascularization during the admission). Secondary in-hospital outcomes were mortality, length of stay, and post-procedural complications.

### Independent variables

Pre-specified determinants were grouped as:

- **Clinical severity:** STEMI vs NSTE-ACS / chronic CAD. Risk stratification was performed using the Thrombolysis in Myocardial Infarction (TIMI) risk score and dichotomized into high risk (≥5) and low-to-moderate risk (<5).
- **Demographic:** age (≥65 vs <65), sex.
- **Socio-economic:** modified BG Prasad classification 2025 update [17] (I–III vs IV/V).
- **Structural / access:** insurance status (PMJAY/CMCHIS or private vs out-of-pocket), residence (rural vs urban), road distance to the tertiary care hospital (>50 km vs ≤50 km).
- **Comorbidity:** chronic kidney disease (eGFR <60 mL/min/1.73 m²), diabetes mellitus, hypertension, prior revascularisation (PCI or CABG).

### Sample size justification

The sample size for the present retrospective observational study was determined based on the requirements for multivariable logistic regression to identify determinants of invasive management among patients with coronary artery disease (CAD). Previous Indian registry data, including the Kerala ACS Registry [7], reported that approximately 66% of CAD patients were managed conservatively, while nearly one-third underwent invasive management.

Assuming an expected prevalence of invasive management of approximately 34%, a 95% confidence level, 80% statistical power, and an adjusted odds ratio of at least 2.0 for major predictors, the minimum required sample size was estimated using the formula for comparison of two proportions:

$$n_1 = \frac{\left[z_{1-\alpha/2}\sqrt{(r+1)\bar{p}\bar{q}} + z_{1-\beta}\sqrt{rp_1q_1 + p_2q_2}\right]^2}{r(p_1 - p_2)^2}$$

**Where:**

- $p_1 = 0.66$(proportion conservatively managed in the reference group)
- $p_2 = 0.34$(proportion in the comparison group)
- $q_1 = 1 - p_1$
- $q_2 = 1 - p_2$
- $r = 2$ (allocation ratio of conservative to invasive management)
- $\alpha = 0.05$(two-sided significance level)
- Power $(1 - \beta) = 80\%$

In addition, considering the requirements for stable multivariable logistic regression estimates and allowing for incomplete or non-evaluable records, the sample size was inflated by 10%. Accordingly, a final target sample size of 320 participants was considered adequate for the study, comprising approximately 210 conservatively managed and 110 invasively managed patients.

A consecutive sampling technique was employed, wherein all eligible patient records meeting the inclusion criteria during the study period were included until the required sample size was achieved.

**Data sources and procedures**

Demographics, clinical features, laboratory and imaging data, treatment received, and outcomes were abstracted from medical records using a structured proforma. Two investigators performed independent abstraction with disagreements resolved by consensus.

**Statistical analysis**

Analyses were performed in SPSS version 22.0. Continuous variables are presented as mean (standard deviation) or median (interquartile range) based on the distribution of the data, and categorical variables as percentages. Bivariate associations between determinants and the primary outcome were tested with chi-square or Fisher's exact tests, and unadjusted odds ratios (uORs) with 95% confidence intervals were computed.

Multivariable logistic regression analysis was performed to identify factors independently associated with invasive management among CAD patients. Variables with clinical relevance and/or $p<0.20$ in univariate analysis were entered into the multivariable model. Adjusted odds ratios (AORs) with 95% confidence intervals (CI) were reported. Model adequacy was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Multicollinearity among independent variables was assessed using variance inflation factor (VIF), with VIF <5 considered acceptable. Model performance was further examined using likelihood ratio statistics, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and pseudo $R^2$ values. The events-per-variable (EPV) ratio was calculated to assess regression stability, with an EPV >10 considered adequate. Missing data were examined before analysis, and complete-case analysis was performed as no missing observations were identified in the variables included in the final regression model. A p-value <0.05 was considered statistically significant.

**Ethics**

The study protocol was reviewed and approved by the Institutional Ethics Committee, Human Studies approval number [IECHS/IRCHS/No:962], dated [20/12/2025]. As the study analyses de-identified retrospective records, the IEC granted a waiver of individual informed consent.

## RESULTS

A total of 320 admissions met the inclusion criteria. Of these, 110 (34.4%) received invasive management, and 210 (65.6%) received conservative management. Males accounted for 202 (63.1%) of admissions and females 118 (36.9%). STEMI presentations made up 112 (35.0%) of admissions; the remainder were NSTE-ACS or chronic CAD (65%). Baseline demographic and clinical characteristics by management arm are summarized in (Tables 1 and 2). Unadjusted associations between pre-specified determinants and invasive management are presented in (Table 3). The regression model demonstrated good calibration on the Hosmer–Lemeshow goodness-of-fit test ($\chi^2$=3.24, p=0.862). No evidence of significant multicollinearity was observed, as all variance inflation factor values were below 2. The model achieved successful convergence and was overall statistically significant (Likelihood Ratio test p<0.001), with a McFadden pseudo $R^2$ of 0.072. The events-per-variable ratio was 27.5, indicating adequate sample size and model stability. No missing data were identified in variables included in regression analyses. (Table 4)

The multivariable logistic regression (n = 320 with complete covariate data; McFadden pseudo-$R^2$ = 0.140) is presented in (Table 5). STEMI presentation, prior revascularization, younger age, higher socio-economic stratum (BG Prasad I–III), and shorter distance to the tertiary care hospital independently increased the odds of invasive management. TIMI score ≥5, rural residence, and CKD did not reach statistical significance after adjustment. In-hospital mortality was 8/320 (2.5%) overall: 2/110 (1.8%) in the invasive arm and 6/210 (2.9%) in the conservative arm (Table 6).

## DISCUSSION

Among the 320 patients admitted with coronary artery disease (CAD) in the tertiary care centre, 34.4% underwent invasive management. In the present study, STEMI was the strongest predictor for receiving invasive treatment, with patients having almost four times higher adjusted odds of undergoing invasive procedures. This finding is in line with the European Society of Cardiology and ACC/AHA guidelines, which strongly recommend primary or rescue PCI for STEMI patients [5,6].

Similar observations were reported in the Kerala ACS Registry, where STEMI patients were more likely to receive reperfusion therapy compared to NSTE-ACS patients receiving invasive care [7]. The ACS QUIK trial also demonstrated comparable treatment practices across Indian hospitals [10]. However, the CREATE Registry reported that only 8% of STEMI patients underwent primary PCI nationally, mainly due to delayed hospital presentation and financial limitations in earlier Indian settings [8].

Younger patients in the present study were more likely to receive invasive management compared to older individuals. Similar findings were reported in the CRUSADE study, which showed that elderly patients often receive less guideline-based invasive treatment despite being at higher cardiovascular risk [16]. On the other hand, Tegn N et al. [19] reported that elderly NSTE-ACS patients also benefit significantly from invasive strategies and that age alone should not influence treatment decisions. The reduced use of invasive care among older patients may be related to physician concerns about comorbidities, procedural risks, and patient or family preferences. Female patients showed slightly lower odds of receiving invasive management. This finding is consistent with reports from the HPIAR registry and ACS QUIK trial, which identified gender differences in ACS management in India [10,11]. Similar disparities were also observed in the SWEDEHEART registry [20]. However, recent data from the United States suggest that the gender gap has reduced in hospitals implementing standardised STEMI treatment protocols [21]. Delayed presentation, atypical symptoms, higher comorbidity burden, and possible clinician bias may contribute to reduced invasive management among women.

Patients belonging to BG Prasad socioeconomic classes IV and V had lower odds of receiving invasive treatment. This finding agrees with the CREATE Registry, which reported that a large proportion of Indian ACS patients belong to lower socioeconomic groups and often face difficulty in accessing timely reperfusion therapy [8]. Previous studies have also shown that out-of-pocket healthcare expenditure limits access to advanced cardiac procedures [12]. In contrast, Patel et al. [22] observed that socioeconomic differences in invasive cardiac treatment were minimal among patients covered under PMJAY, indicating that financial protection schemes can reduce disparities in access to care when implemented effectively. Patients residing more than 50 km away from the tertiary care centre had significantly lower odds of receiving invasive management. This may be due to delays in transportation, referral processes, and treatment decisions. Similar findings have been reported in ACS studies from the United States and other low- and middle-income countries, where increasing distance negatively affects timely access to cardiac interventions [14,15]. However, the CSI-Kerala PPCI Registry demonstrated that organised ambulance services and strong pre-hospital referral systems can reduce the impact of distance barriers [9]. This highlights the importance of strengthening emergency cardiac care networks in rural areas.

Patients with a previous history of PCI or CABG were more likely to undergo invasive management during the current admission. This may be because such patients are already connected to cardiology services and are more familiar with revascularisation procedures. Similar observations were reported in the NCDR PCI Registry, where prior specialist consultation increased the likelihood of receiving invasive treatment [22].

Patients covered under PMJAY, CMCHIS, or private insurance showed higher odds of invasive management compared to those paying out of pocket, although the association was not statistically significant. Similar findings were observed in studies conducted by Mohanan et al. and Bahuleyan et al. [7,9], as well as in PMJAY evaluations by the Observer Research Foundation and NIC India cardiac procedure reports [13,24]. The lack of statistical significance may be due to overlap between insurance status, socioeconomic status, and distance from tertiary care facilities.

In the adjusted analysis, a TIMI score of ≥5 was not significantly associated with invasive management. The absence of a significant association between TIMI score and invasive management after adjustment may reflect overlap between TIMI risk stratification and STEMI presentation, which emerged as the strongest determinant in the final model. In routine clinical practice, immediate treatment decisions may be influenced more strongly by electrocardiographic diagnosis and haemodynamic stability than by calculated risk scores alone [25].

Similarly, rural residence did not significantly affect invasive management, possibly because actual distance to the hospital was a more accurate measure of healthcare access than rural–urban classification alone. Chronic kidney disease (CKD) also did not reduce the likelihood of invasive treatment in the present study, unlike findings reported in some Western studies [26]. This finding may reflect evolving clinical practice patterns and increasing acceptance of invasive procedures among high-risk patients with renal dysfunction, particularly in tertiary care settings with specialist cardiology support. The overall in-hospital mortality in the present study was 2.5%. Although mortality was lower among patients receiving invasive management (1.8%) compared to conservative treatment (2.9%), the difference was not statistically significant. Similar mortality patterns have been reported in previous international studies [25,27]

The present study has several important strengths. The determinants included in the analysis were selected based on validated Indian and international literature. The study also used the updated 2026 socioeconomic status (SES) classification system [17], which improves the relevance of socioeconomic assessment. In addition, the sample size was scientifically justified using the Fleiss formula based on findings from the Indian registry data. However, certain limitations should be considered while interpreting the findings. Since the study was retrospective and conducted in a single tertiary care centre, the results may not be generalisable to all settings. Residual confounding due to differences in clinical severity may still be present, as all aspects of disease severity may not have been fully captured by the available risk scores. The study did not include post-discharge follow-up, preventing assessment of medium or long-term outcomes. The study was also unable to assess qualitative factors such as patient preference and family decision-making, which can influence treatment choices in routine clinical practice. Future prospective studies should include a patient-experience component to better understand these factors.

The findings of the present study highlight several important areas for improving cardiac care delivery in rural tertiary care settings. First, strengthening STEMI activation pathways may help reduce delays in tertiary care access, particularly for patients living far from tertiary centres. Second, risk assessment should be standardised without giving undue importance to patient age alone. Third, routine verification of PMJAY and CMCHIS insurance coverage during admission may improve utilisation of available financial support schemes. Finally, improving hub-and-spoke referral systems and emergency transport services may help reduce the disadvantages faced by patients living more than 50 km away from tertiary care centres.

## CONCLUSION

In this study involving 320 CAD admissions in a tertiary care centre, 34.4% of patients received invasive management. STEMI presentation, previous revascularisation, younger age (<65 years), higher socioeconomic status, and shorter distance from the tertiary care facility were independently associated with greater use of invasive treatment. Female sex showed a borderline reduction in invasive management, while TIMI score ≥5, rural residence, and CKD did not show significant associations after adjustment. Future prospective studies with larger sample sizes and predefined interaction analyses are needed to reassess these borderline and non-significant findings.

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Table 1. Baseline demographic characteristics by management arm (n = 320)

| Characteristic | Invasive (n=110) n (%) | Conservative (n=210) n (%) | Overall (n=320) n (%) |
|---|---|---|---|
| **Male** | 76 (69.1) | 126 (60.0) | 202 (63.1) |
| **Female** | 34 (30.9) | 84 (40.0) | 118 (36.9) |

| | | | |
|---|---|---|---|
| **Age ≥65 years** | 22 (20.0) | 58 (27.6) | 80 (25.0) |
| **Rural residence** | 65 (59.1) | 135 (64.3) | 200 (62.5) |
| **Distance to the tertiary care >50 km** | 32 (29.1) | 88 (41.9) | 120 (37.5) |
| **Modified BG Prasad Socio-economic classification- IV/V class** | 57 (51.8) | 137 (65.2) | 194 (60.6) |
| **Insurance** | 82 (74.5) | 135 (64.3) | 217 (67.8) |

Table 2. Clinical and comorbidity profile by management arm (n = 320)

| Characteristic | Invasive (n=110) n (%) | Conservative (n=210) n (%) | Overall (n=320) n (%) |
|---|---|---|---|
| **STEMI** | 58 (52.7) | 54 (25.7) | 112 (35.0) |
| **NSTE-ACS/Chronic CAD** | 52 (47.3) | 156 (74.3) | 208 (65) |
| **TIMI score ≥5** | 51 (46.4) | 92 (43.8) | 143 (44.7) |
| **Diabetes mellitus** | 39 (35.5) | 87 (41.4) | 126 (39.4) |
| **Hypertension** | 70 (63.6) | 122 (58.1) | 192 (60.0) |
| **CKD (eGFR <60)** | 16 (14.5) | 27 (12.9) | 43 (13.4) |
| **Prior PCI/CABG** | 15 (13.6) | 12 (5.7) | 27 (8.4) |

Abbreviations: STEMI – ST-segment elevation myocardial infarction; NSTE-ACS – Non-ST-segment elevation acute coronary syndrome; CAD – Coronary artery disease; TIMI – Thrombolysis in Myocardial Infarction; CKD – Chronic kidney disease; eGFR – Estimated glomerular filtration rate; PCI – Percutaneous coronary intervention; CABG – Coronary artery bypass grafting.

Table 3. Bivariate determinants of invasive management- unadjusted odds ratios (n = 320)

| Determinant | uOR | 95% CI | p-value |
|---|---|---|---|
| **STEMI presentation** | 3.22 | 1.98–5.24 | **<0.001*** |
| **TIMI score ≥5** | 1.11 | 0.70-1.76 | 0.750 |
| **Insurance (PMJAY/CMCHIS or private)** | 1.63 | 0.97-2.72 | 0.082 |
| **Female sex** | 0.67 | 0.41-1.09 | 0.139 |
| **Age ≥65** | 0.66 | 0.38-1.14 | 0.174 |
| **Modified BG Prasad Socio-economic classification IV/V** | 0.57 | 0.36-0.92 | **0.027*** |
| **Rural residence** | 0.80 | 0.50-1.29 | 0.429 |
| **Distance >50 km** | 0.57 | 0.35-0.93 | **0.033*** |
| **Diabetes Mellitus** | 0.78 | 0.48-1.25 | 0.299 |
| **Hypertension** | 1.26 | 0.78-2.03 | 0.337 |
| **CKD (eGFR<60)** | 1.15 | 0.59-2.25 | 0.804 |
| **Prior PCI/CABG** | 2.61 | 1.17-5.78 | **0.027*** |

(Abbreviations: uOR, unadjusted odds ratio; CI, confidence interval; STEMI, ST-segment elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction; PMJAY, Pradhan Mantri Jan Arogya Yojana; CMCHIS, Chief Minister's Comprehensive Health Insurance Scheme; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting. *p<0.05 is considered statistically significant.)

Table 4. Logistic Regression Model Diagnostics

| Parameter | Value |
|---|---|
| **Hosmer–Lemeshow $\chi^2$** | 3.24 |
| **Hosmer–Lemeshow p-value** | 0.862 |
| **Likelihood Ratio test p-value** | <0.001 |
| **McFadden pseudo $R^2$** | 0.072 |
| **AIC** | 392.01 |
| **BIC** | 410.85 |

| | |
|---|---|
| **Events-per-variable ratio** | 27.5 |
| **Model convergence** | Achieved |
| **Missing data handling** | Complete-case analysis |
| **Maximum VIF** | 1.07 |

Abbreviations: $\chi^2$, chi-square statistic; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; VIF, variance inflation factor. Complete-case analysis indicates that only records with complete data for all regression variables were included in the final model. VIF <5 was considered indicative of the absence of significant multicollinearity.

Table 5. Multivariable Logistic Regression for Invasive Management (N = 320)

| Determinant | Adjusted OR | 95% CI | p-value |
|---|---|---|---|
| **STEMI presentation** | 4.34 | 2.48-7.58 | **<0.001*** |
| **TIMI score ≥5** | 0.78 | 0.45-1.33 | 0.358 |
| **Insurance (PMJAY/CMCHIS or private)** | 1.69 | 0.95-2.99 | 0.073 |
| **Female sex** | 0.60 | 0.35-1.04 | 0.067 |
| **Age ≥65** | 0.47 | 0.25-0.88 | **0.018*** |
| **BG Prasad IV/V** | 0.44 | 0.26-0.74 | **0.002*** |
| **Rural residence** | 1.05 | 0.60-1.84 | 0.872 |
| **Distance >50 km** | 0.49 | 0.28-0.87 | **0.015*** |
| **CKD (eGFR<60)** | 0.91 | 0.44-1.90 | 0.808 |
| **Prior PCI/CABG** | 3.93 | 1.60-9.66 | **0.003*** |

Abbreviations: OR, odds ratio; CI, confidence interval; STEMI, ST-segment elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction; PMJAY, Pradhan Mantri Jan Arogya Yojana; CMCHIS, Chief Minister's Comprehensive Health Insurance Scheme; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting. p<0.05 considered statistically significant.

Table 6. In-hospital outcomes by management arm (n = 320)

| Outcome | Invasive (n=110) n (%) | Conservative (n=210) n (%) | Overall (n=320) n (%) |
|---|---|---|---|
| **In-hospital mortality** | 2 (1.8) | 6 (2.9) | 8 (2.5) |
| **Length of stay (days), median (IQR)** | 5.6 (4.0-8.0) | 5.2 (3.9-7.0) | 5.3 (3.9-7.6) |
| **Post-procedural / in-hospital complications** | 17 (15.5) | 30 (14.3) | 47 (14.7) |

Abbreviation: IQR- Interquartile range