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Real-World Patterns of Peri-Procedural Antiplatelet Therapy and Concomitant Verapamil Use During Transradial Percutaneous Coronary Intervention

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Research Article

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Abstract

Background

Antiplatelet therapy is routinely used during transradial percutaneous coronary intervention (PCI). Verapamil is commonly administered peri-procedurally to prevent radial artery spasm; however, real-world data describing antiplatelet therapy patterns and concomitant verapamil exposure during PCI remain limited. This study aimed to characterize peri-procedural medication exposure patterns, with particular focus on the co-occurrence of ticagrelor and verapamil.

Methods

This single-center retrospective study analyzed PCI encounters between 2024 and 2025 using routinely collected hospital data. Peri-procedural antiplatelet therapy was classified by P2Y12 inhibitor use (ticagrelor, clopidogrel, or none). Verapamil and other concomitant medications were identified from medication records using a predefined keyword dictionary. The primary outcome was the prevalence of concomitant ticagrelor and verapamil exposure.

Results

A total of 204 PCI cases were included. Clopidogrel was the most frequently used P2Y12 inhibitor (104/204, 51.0%), followed by ticagrelor (68/204, 33.3%) and no P2Y12 inhibitor (32/204, 15.7%). Verapamil was administered in 98.5% (201/204) of cases. The co-occurrence of ticagrelor and verapamil was observed in 32.4% (66/204) of all cases and 97.1% (66/68) of ticagrelor users. Patients receiving ticagrelor were younger (median 61.0 vs 68.5 years) and more often male (85.3% vs 66.3%) compared with clopidogrel users. The proportion of ticagrelor use declined from 43.2% in 2024 to 27.7% in 2025.

Conclusions

In this real-world cohort of transradial PCI cases, verapamil was near-universally administered peri-procedurally, and concomitant exposure with ticagrelor was common. These findings provide empirical evidence that ticagrelor–verapamil co-exposure occurs frequently in routine practice and may inform the design of future pharmacokinetic or outcome-focused studies.

Introduction

Antiplatelet therapy is a cornerstone of percutaneous coronary intervention (PCI) and is routinely administered during transradial procedures to reduce the risk of thrombotic complications.[1,2] In contemporary practice, dual antiplatelet therapy (DAPT) consisting of aspirin and a P2Y12 inhibitor remains the standard peri-procedural strategy, with clopidogrel and ticagrelor being the most commonly

used agents.[3–5] Although clinical guidelines provide recommendations on antiplatelet selection, real-world prescribing patterns may vary according to patient characteristics, institutional practice, and temporal trends.[6,7]

During transradial PCI, verapamil is frequently administered peri-procedurally to prevent or relieve radial artery spasm.[8–10] This use typically involves short-duration, intra-arterial administration at doses ranging from 2.5 to 5 mg rather than chronic systemic therapy.[11] However, verapamil is also recognized as a CYP3A4 inhibitor, and drug information resources often highlight a potential interaction with ticagrelor, which is primarily metabolized via this pathway.[12,13] These interaction warnings are largely derived from pharmacokinetic studies involving sustained oral or intravenous exposure and may not accurately reflect routine peri-procedural practice during PCI.[14,15]

Despite the widespread use of both antiplatelet agents and verapamil in transradial PCI, data describing their real-world co-occurrence and overall exposure patterns remain limited. Most existing studies have focused on clinical outcomes or pharmacologic mechanisms, while descriptive evidence on how these medications are actually combined in daily practice is scarce.[16,17] Such information is essential for contextualizing pharmacokinetic concerns and for designing future studies that aim to evaluate clinical relevance.

Therefore, the present study aimed to characterize real-world peri-procedural antiplatelet therapy patterns and concomitant medication exposure during transradial PCI, with a particular focus on the prevalence of ticagrelor–verapamil co-occurrence. By providing a descriptive overview of contemporary practice across two consecutive years, this study seeks to establish an empirical foundation for subsequent pharmacokinetic or outcome-oriented investigations.

Methods

Study Design and Data Source

This study was a single-center, retrospective, real-world observational analysis. Data were extracted from the hospital information system, including electronic medical records, medication orders, and billing records, covering PCI-related hospitalizations between January 2024 and December 2025. All data were de-identified prior to analysis. The study was conducted in accordance with institutional policies for retrospective analyses of routinely collected clinical data. [Ethics committee name and approval/waiver number to be inserted].

Study Population

All hospitalized encounters related to coronary procedures during the study period were screened. Cases were included if they met the following criteria: (1) PCI performed via the transradial approach; (2)

implantation of at least one drug-eluting stent; and (3) availability of peri-procedural medication records sufficient to identify antiplatelet therapy and concomitant drug exposure. Cases were excluded if they involved diagnostic coronary angiography without PCI, non–drug-eluting stents, or insufficient medication documentation to ascertain P2Y12 inhibitor or verapamil exposure. The cohort selection process is illustrated in Figure 1.

Medication Exposure Definitions

P2Y12 inhibitor exposure was classified into mutually exclusive categories based on peri-procedural medication records: ticagrelor, clopidogrel, or no P2Y12 inhibitor. Aspirin exposure was identified separately. Dual antiplatelet therapy was defined as concomitant exposure to aspirin and any P2Y12 inhibitor during the peri-procedural period.

Verapamil exposure was identified from medication orders and billing descriptions and reflected peri-procedural administration during transradial PCI. Additional concomitant medications potentially related to bleeding risk, including anticoagulants (unfractionated heparin and low-molecular-weight heparin) and glycoprotein IIb/IIIa inhibitors, were identified using predefined keyword lists and categorized as present or absent per case.

Medication identification relied on a frozen dictionary of generic names, brand names, and commonly used abbreviations (Supplementary Table S1). The peri-procedural exposure window was defined as the entire index hospitalization from admission to discharge.

Outcome Measures

The primary outcome was the prevalence of concomitant ticagrelor and verapamil exposure during transradial PCI. Secondary outcomes included overall distributions of P2Y12 inhibitor use, year-specific temporal patterns, and patterns of other concomitant medication exposure. No clinical efficacy or safety outcomes were evaluated.

Statistical Analysis

Descriptive statistics were used to summarize patient and case characteristics. Continuous variables were reported as medians with interquartile ranges (IQRs), and categorical variables as counts and percentages with 95% Wilson confidence intervals.

Comparisons of baseline characteristics and concomitant medication exposure were conducted descriptively across P2Y12 inhibitor groups and study years. To explore factors associated with ticagrelor versus clopidogrel use, logistic regression models were constructed with P2Y12 inhibitor type as the dependent variable. Covariates included age, sex, and study year (minimally adjusted model), with

additional adjustment for concomitant medications in an extended model. Results were reported as odds ratios (ORs) with 95% confidence intervals.

All analyses were prespecified and performed using R (version 4.3.2). Data processing scripts are provided in the Supplementary Materials (Scripts S1–S4). No imputation was conducted for missing data. Statistical analyses were exploratory and descriptive in nature.

Results

Study Population

A total of 214 encounters recorded between 2024 and 2025 were initially screened. After exclusion of non-PCI records (n=10), 204 PCI cases meeting inclusion criteria were included in the final analysis (Figure 1). Of these, 74 cases (36.3%) were from 2024 and 130 cases (63.7%) were from 2025.

Baseline Characteristics by P2Y12 Inhibitor Use

Baseline demographic characteristics stratified by P2Y12 inhibitor exposure are shown in Table 1. Among the 204 PCI cases, 104 (51.0%) received clopidogrel, 68 (33.3%) received ticagrelor, and 32 (15.7%) received no P2Y12 inhibitor.

Patients receiving ticagrelor were younger, with a median age of 61.0 years (IQR 54.5–71.0), compared with 68.5 years (IQR 60.0–75.0) in the clopidogrel group. The proportion of female patients was 14.7% in the ticagrelor group and 33.7% in the clopidogrel group.

Table 1. Baseline Characteristics of PCI Cases Stratified by P2Y12 Inhibitor Use

Characteristic	Overall (N=204)	Clopidogrel (n=104)	Ticagrelor (n=68)	No P2Y12 (n=32)
Age, years, median [IQR]	65.0 [58.0, 73.0]	68.5 [60.0, 75.0]	61.0 [54.5, 71.0]	63.5 [59.0, 69.0]
Female, n (%)	54 (26.5)	35 (33.7)	10 (14.7)	9 (28.1)
Study year				
2024, n (%)	74 (36.3)	37 (35.6)	32 (47.1)	5 (15.6)
2025, n (%)	130 (63.7)	67 (64.4)	36 (52.9)	27 (84.4)

Abbreviations: IQR, interquartile range; P2Y12, purinergic receptor P2Y12. Values are n (%) or median [IQR].

Primary Outcome: Ticagrelor–Verapamil Co-occurrence

The prevalence of ticagrelor–verapamil co-exposure and related exposure patterns are shown in Table 2 and Table 3. Verapamil was administered in 201 of 204 cases (98.5%), reflecting near-universal peri-procedural use for radial artery spasm prevention.

Concomitant ticagrelor and verapamil exposure was observed in 66 cases (32.4% of all cases). Among ticagrelor users specifically, 66 of 68 (97.1%) received concomitant verapamil. Only 2 cases (1.0%) received ticagrelor without verapamil. The co-occurrence rate was higher in 2024 (41.9%) than in 2025 (26.9%), primarily reflecting the declining proportion of ticagrelor use overall.

Table 2. Concomitant Medication Exposure by P2Y12 Inhibitor Group

Medication	Overall (N=204)	Clopidogrel (n=104)	Ticagrelor (n=68)	No P2Y12 (n=32)
Verapamil, n (%)	201 (98.5)	104 (100.0)	66 (97.1)	31 (96.9)
Aspirin, n (%)	68 (33.3)	33 (31.7)	31 (45.6)	4 (12.5)
Dual antiplatelet therapy, n (%)	64 (31.4)	33 (31.7)	31 (45.6)	0 (0.0)
Any anticoagulant, n (%)	50 (24.5)	25 (24.0)	23 (33.8)	2 (6.2)
Unfractionated heparin, n (%)	40 (19.6)	22 (21.2)	16 (23.5)	2 (6.2)
Low-molecular-weight heparin, n (%)	24 (11.8)	7 (6.7)	15 (22.1)	2 (6.2)
Glycoprotein IIb/IIIa inhibitors, n (%)	2 (1.0)	1 (1.0)	1 (1.5)	0 (0.0)
Proton pump inhibitors, n (%)	173 (84.8)	88 (84.6)	61 (89.7)	24 (75.0)
Triple antithrombotic therapy, n (%)	44 (21.6)	23 (22.1)	21 (30.9)	0 (0.0)

Abbreviations: DAPT, dual antiplatelet therapy; LMWH, low-molecular-weight heparin; PPI, proton pump inhibitor; UFH, unfractionated heparin. Triple antithrombotic therapy defined as DAPT plus any anticoagulant.

Table 3. Primary Outcome: Ticagrelor–Verapamil Co-occurrence Patterns

Exposure Pattern	Overall (N=204)	2024 (n=74)	2025 (n=130)
Ticagrelor + Verapamil, n (%)	66 (32.4)	31 (41.9)	35 (26.9)
Ticagrelor without Verapamil, n (%)	2 (1.0)	1 (1.4)	1 (0.8)
Verapamil without Ticagrelor, n (%)	135 (66.2)	41 (55.4)	94 (72.3)
Neither Ticagrelor nor Verapamil, n (%)	1 (0.5)	1 (1.4)	0 (0.0)

Values are n (%). The primary outcome was the prevalence of concomitant ticagrelor and verapamil exposure during the peri-procedural period.

Temporal Patterns of P2Y12 Inhibitor Use

Year-specific distributions of P2Y12 inhibitor use are presented in Table 4. In 2024, ticagrelor and clopidogrel accounted for 43.2% and 50.0% of PCI cases, respectively. In 2025, clopidogrel remained the most frequently used P2Y12 inhibitor (51.5%), while the proportion of ticagrelor use declined to 27.7%. The proportion of cases without any P2Y12 inhibitor increased from 6.8% in 2024 to 20.8% in 2025.

Table 4. Distribution of P2Y12 Inhibitor Use by Study Year

P2Y12 Inhibitor	2024 (n=74)	2025 (n=130)
Ticagrelor, n (%)	32 (43.2)	36 (27.7)
Clopidogrel, n (%)	37 (50.0)	67 (51.5)
No P2Y12 inhibitor, n (%)	5 (6.8)	27 (20.8)

Values are n (%). Percentages are calculated within each study year.

Concomitant Medication Patterns

Aspirin was administered in 45.6% of ticagrelor-treated cases and 31.7% of clopidogrel-treated cases (Table 2). The corresponding rates of DAPT were 45.6% and 31.7%, respectively. Anticoagulant exposure occurred in 33.8% of ticagrelor-treated cases and 24.0% of clopidogrel-treated cases, with low-molecular-weight heparin use being more frequent in the ticagrelor group (22.1% vs 6.7%). Use of glycoprotein IIb/IIIa inhibitors was infrequent across all groups (overall 1.0%). Proton pump inhibitors were used in 84.8% of all cases.

Factors Associated with Ticagrelor versus Clopidogrel Use

Multivariable logistic regression results comparing ticagrelor versus clopidogrel use are presented in Table 5. In the minimally adjusted model, increasing age was associated with lower odds of ticagrelor use (OR 0.96 per year, 95% CI 0.93–0.99). Male sex was associated with higher odds of ticagrelor use (OR 2.20, 95% CI 0.98–5.23). Use of ticagrelor was numerically less frequent in 2025 compared with 2024 (OR 0.55, 95% CI 0.28–1.06). Similar patterns were observed in the extended model with additional adjustment for PPI use and LMWH.

Table 5. Logistic Regression Analysis: Factors Associated with Ticagrelor vs Clopidogrel Use

Variable	OR	95% CI	Model
Model 1: Minimally Adjusted			
Age (per year)	0.96	0.93–0.99	Minimal
Male (vs Female)	2.20	0.98–5.23	Minimal
Year 2025 (vs 2024)	0.55	0.28–1.06	Minimal
Model 2: Extended Adjusted			
Age (per year)	0.96	0.93–0.99	Extended
Male (vs Female)	2.39	1.04–5.90	Extended
Year 2025 (vs 2024)	0.66	0.27–1.60	Extended
PPI use	1.41	0.53–4.09	Extended
LMWH	4.37	1.42–14.71	Extended

Abbreviations: CI, confidence interval; LMWH, low-molecular-weight heparin; OR, odds ratio; PPI, proton pump inhibitor. The outcome was ticagrelor use (vs clopidogrel as reference). Analysis restricted to cases receiving either ticagrelor or clopidogrel (n=172).

Discussion

In this real-world, single-center retrospective analysis of transradial PCI cases, we systematically characterized peri-procedural antiplatelet therapy patterns and concomitant medication exposure, with a particular focus on the co-occurrence of ticagrelor and verapamil. The key finding was that concomitant ticagrelor–verapamil exposure occurred in approximately one-third of all PCI cases and in virtually all ticagrelor users, reflecting the near-universal use of peri-procedural verapamil for radial artery spasm prevention.[8,9]

The high rate of ticagrelor–verapamil co-occurrence observed in this study has important implications for contextualizing drug–drug interaction concerns. Verapamil is a moderate CYP3A4 inhibitor, and ticagrelor undergoes significant CYP3A4-mediated metabolism.[12,13] Drug information resources

frequently warn of potential interactions between these agents based on pharmacokinetic modeling and studies involving sustained systemic exposure.[14,18] However, peri-procedural verapamil administration during transradial PCI typically involves a single, low-dose (2.5–5 mg) intra-arterial bolus, which differs substantially from chronic oral therapy scenarios.[11] Our findings provide empirical evidence that this combination occurs commonly in routine practice, establishing a foundation for future pharmacokinetic studies to determine whether such brief, local verapamil exposure meaningfully affects ticagrelor antiplatelet activity.

Clopidogrel remained the most frequently used P2Y12 inhibitor across the study period, while ticagrelor was prescribed in approximately one-third of PCI cases. This distribution is consistent with routine clinical practice in which clopidogrel continues to be widely used, particularly among older patients.[6,19] In our cohort, patients receiving ticagrelor were younger and more frequently male, a pattern that persisted after adjustment and aligns with prescribing preferences rather than protocol-driven allocation.

Temporal analysis revealed a relative decline in ticagrelor use in 2025 compared with 2024, accompanied by an increase in cases without documented P2Y12 inhibitor exposure. Several factors may contribute to this pattern, including changes in institutional formulary, cost considerations, or evolving clinical preferences.[20] The increase in cases without P2Y12 inhibitor documentation warrants careful interpretation; while this may reflect true variability in prescribing practices, it could also be influenced by changes in electronic documentation systems or medication coding between years. This observation underscores the importance of considering calendar effects and data capture variability when interpreting real-world exposure data.

The observed aspirin use rate (33.3% overall) appears lower than expected for a PCI cohort, which merits discussion. Several factors may contribute to this finding. First, our medication identification relied on peri-procedural medication records captured in the hospital information system; aspirin administered as pre-existing chronic therapy or dispensed separately from the index hospitalization may not have been consistently captured.[17] Second, the keyword-based extraction approach, while using a comprehensive dictionary, may have missed certain documentation formats. Third, institutional practices regarding aspirin documentation during PCI encounters may vary. To address this limitation, we provide the complete medication keyword dictionary in the Supplementary Materials (Table S1) to enable reproducibility and allow readers to assess potential capture gaps. Future studies using linked pharmacy dispensing data or manual chart review would provide more complete ascertainment.

From a pharmacoepidemiologic perspective, our findings provide quantitative evidence on exposure combinations that occur in routine practice. However, this analysis was intentionally limited to exposure characterization and does not assess pharmacokinetic effects or clinical outcomes. The observed medication co-occurrence patterns should be interpreted as descriptive rather than evaluative, and no inferences regarding safety or efficacy should be drawn.

Limitations

Several limitations should be acknowledged. First, this was a single-center retrospective study, and prescribing patterns may not be generalizable to other institutions or healthcare systems. Second, medication exposure was identified from electronic medical records and billing data using keyword-based extraction, which may be subject to misclassification or incomplete capture despite the use of predefined dictionaries and quality control procedures. Third, the peri-procedural exposure window was defined based on hospitalization records rather than precise intra-procedural timestamps, which may introduce temporal imprecision. Fourth, as noted above, aspirin capture may be incomplete, limiting interpretation of DAPT rates. Fifth, verapamil dose information could not be reliably extracted for all cases, precluding dose-response analyses. Finally, because no clinical outcomes were analyzed, the findings should not be interpreted as evidence of benefit or harm.

Despite these limitations, this study has important strengths. By focusing on clearly defined exposure patterns and providing transparent, reproducible data processing steps, it offers a pragmatic overview of real-world antiplatelet and concomitant medication use during transradial PCI.[16,17] The results may serve as a foundation for future pharmacokinetic investigations or outcome-oriented studies designed to evaluate the clinical relevance of specific drug combinations observed in routine practice.

Conclusion

In this single-center retrospective study, peri-procedural antiplatelet therapy patterns and concomitant medication exposure during transradial PCI were systematically characterized. Verapamil was near-universally administered peri-procedurally, and concomitant exposure with ticagrelor was observed in approximately one-third of all cases and virtually all ticagrelor users. Clopidogrel remained the most frequently used P2Y12 inhibitor, while ticagrelor was prescribed in a substantial proportion of cases and was more common among younger, male patients. These findings provide real-world evidence on exposure patterns and may inform the design of future pharmacokinetic or outcome-focused studies to determine whether brief peri-procedural verapamil exposure meaningfully affects ticagrelor antiplatelet activity.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of The Second Affiliated Hospital of Wannan Medical College.

As this was a retrospective study based on de-identified routinely collected clinical data, the requirement for informed consent was waived by the Ethics Committee.

The study was conducted in accordance with the Declaration of Helsinki and relevant institutional guidelines.

Consent for publication

Not applicable.

This manuscript does not contain any individual person's identifiable data in any form.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to institutional data protection policies involving patient-level clinical records but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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The funding bodies had no role in the design of the study; collection, analysis, or interpretation of data; or in writing the manuscript.

Authors' contributions

JX and LY conceived and designed the study.
JX and XS performed data extraction and statistical analysis.
LY (Linfei Yang) contributed to clinical interpretation of the findings.
LY (Laxi Yang) assisted in data validation and quality control.
QY supervised the study and was a major contributor in revising the manuscript.

JX and LY contributed equally to this work.

All authors read and approved the final manuscript.

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Figures

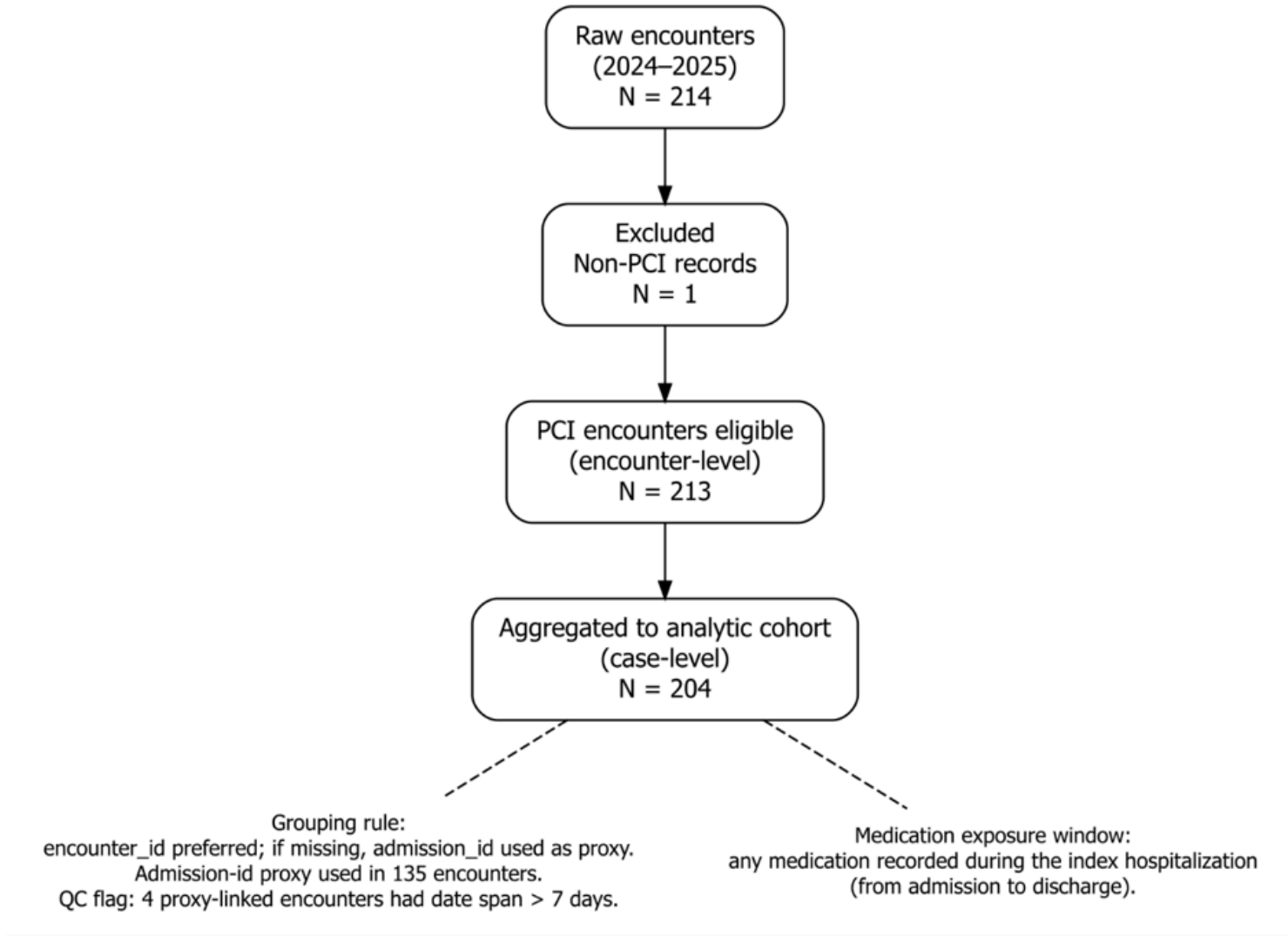


Figure 1

Flow diagram of cohort construction. A total of 214 encounters from 2024 to 2025 were initially identified. After exclusion of non–percutaneous coronary intervention (PCI) records (n=10), 204 PCI cases meeting inclusion criteria were included in the final analysis. Cases were included if they involved transradial PCI with drug-eluting stent implantation and had sufficient medication documentation to ascertain P2Y12 inhibitor and verapamil exposure.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterials.docx