Impact of combined baseline and postprocedural troponin values on clinical outcome following the MitraClip procedure

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Abstract
Objectives: The purpose of this study was to investigate the impact of periprocedural troponin levels on clinical outcome following the MitraClip procedure.

Background: Cardiac troponin is known to be a predictive biomarker for various clinical outcomes; however, data about its predictive value in patients undergoing transcatheter mitral valve repair are limited.

Methods: Consecutive patients undergoing the MitraClip procedure were enrolled. Serum cardiac troponin I concentrations were measured before and after the procedure, and the maximal value recorded within 72 hr after the procedure was used for the postprocedural values. The clinical outcome was all-cause mortality within a 1-year follow-up.

Results: Out of 354 patients, 29 patients (8.2%) were deceased within 1 year. Patients who died had significantly higher baseline (0.05 [0.01–0.08] vs. 0.01 [0.01–0.03] ng/ml; \(p < .001\)) and postprocedural troponin I values (0.51 [0.30–1.42] vs. 0.20 [0.33–0.55] ng/ml; \(p = .005\)). A Kaplan–Meier analysis showed that patients with higher baseline troponin I values had a significantly worse prognosis than those with lower values (log-rank \(p < .001\)), and similarly, 1-year mortality was significantly higher in patients with higher postprocedural troponin I than those with lower levels (log-rank \(p = .021\)). Moreover, the highest mortality rate was observed in patients with both elevated baseline and postprocedural troponin I values (log-rank \(p = .001\)), which was found to be an independent predictor of mortality by multivariable analyses.

Conclusions: The present study suggests that combined baseline and postprocedural troponin measurements are useful for risk stratification of 1-year mortality following the MitraClip procedure.

KEYWORDS
biomarkers, mitral valve disease, percutaneous intervention
1 | INTRODUCTION

Transcatheter mitral valve repair (TMVR) is a less invasive therapeutic option for symptomatic mitral regurgitation (MR) in patients with an increased surgical risk. The most widely used technique is edge-to-edge repair, using the MitraClip system, and its safety and effectiveness have already been established.\(^1\,2\) Recently, the results of two randomized controlled trials to investigate the role of MitraClip treatment in addition to guideline-directed medical therapy were published.\(^3\,4\) The cardiovascular outcomes assessment of the MitraClip percutaneous therapy for heart failure patients with functional mitral regurgitation study showed the effectiveness of this procedure in reducing mortality and hospitalization due to heart failure,\(^5\) while the multicentre study of percutaneous mitral valve repair MitraClip device in patients with severe secondary mitral regurgitation study could not demonstrate that clinical outcomes had improved with the procedure.\(^6\) Thus, it is crucial to know which patients would benefit from this procedure and to have predictors of clinical outcome in the patients undergoing these procedures, which may be important to improve their prognosis.

To date, various factors, such as the baseline New York Heart Association (NYHA) classification,\(^5\,6\) renal function,\(^5\,7\) left-ventricular ejection fraction (LVEF),\(^5\) N-terminal-pro b-type natriuretic peptide (NT-proBNP) levels,\(^8\) ischemic etiology,\(^8\) concomitant tricuspid regurgitation (TR),\(^9\) and postprocedural residual MR\(^5\,8\) have been reported to be associated with 1-year mortality following the MitraClip procedure. Cardiac troponin has been well established as a biomarker for diagnosing acute coronary syndrome (ACS),\(^9\) as well as predicting future cardiovascular events in both acute and chronic heart failure.\(^10\) It has also been shown that an elevated postoperative troponin level correlates with a worse clinical outcome after vascular surgery as well as nonvascular operations.\(^11\)-\(^13\) It has been previously reported that baseline cardiac troponin levels were useful for predicting better or worse clinical outcomes after the MitraClip procedure,\(^14\) however, data on the importance of postprocedural cardiac troponin levels following TMVR are limited.

Thus, in the present study, we investigated baseline and postprocedural cardiac troponin values and their impact on clinical outcomes in patients undergoing TMVR using the MitraClip system.

2 | MATERIALS AND METHODS

2.1 | Study population and clinical characteristics

This was a single-center and observational study. All procedures were conducted in accordance with the Declaration of Helsinki and its amendments. Consecutive patients undergoing transcatheter mitral valve interventions in the Heart Center Bonn between September 2010 and August 2017 were included in the study. Patients were excluded that underwent techniques other than the MitraClip alone or had a redo MitraClip procedure. Baseline demographic data, previous medical histories, echocardiographic parameters, and peri-procedural characteristics were examined via interview and/or by examining medical records. The severity of MR was classified as 0 (none-trivial), 1+ (mild), 2+ (moderate), 3+ (moderate–severe), or 4+ (severe).

2.2 | Baseline and postprocedural troponin I

Baseline and postprocedural serum cardiac troponin I levels were collected from a peripheral blood sample before and after the MitraClip procedures, by using a cardiac troponin I immunoassay (Dimension Vista CTNI Flex reagent cartridge, Siemens Healthcare Diagnostics, Munich, Germany). The baseline troponin I level was measured upon admission or before the day of the procedure. Postprocedural troponin I values were evaluated over time following the procedure, and the maximal value for postprocedural troponin I within 72 hr after the procedure was taken as the value for the study analysis. For values less than the analytical detection limit (DL), we substituted the DL value divided by two (DL/2), as was previously described.\(^15\) Patients were divided into groups with higher or lower troponin values, both for baseline and postprocedural troponin levels, according to the median values. Myocardial injury was defined as a peak troponin I value that exceeded 15 times the upper reference limit (URL; 0.10 ng/ml) during the 72 hr after the procedure, as previously described.\(^16\)

2.3 | Follow-up and clinical outcome

After the TMVR procedure, patients were followed up at the outpatient clinic of the University Hospital Bonn or other hospitals until either the clinical endpoint occurred or the 1-year follow-up was reached. The primary endpoint of the present study was all-cause death. Investigators that were blinded to the study performed the observations, and information regarding death was ascertained by reviewing the medical records of patients and/or was confirmed by direct contact with the families or physicians of the patients.

2.4 | Statistical analysis

Continuous variables with skewed distributions were expressed as median values with their interquartile ranges. Categorical data are presented as numbers or percentages, and differences between two groups were tested using Fisher’s exact test or a chi-square test for categorical variables. Differences in continuous variables were analyzed with a Mann–Whitney U test. Clinical parameters associated with baseline and postprocedural troponin I levels were examined using the multivariable stepwise linear regression analyses. We used the Kaplan–Meier method to estimate the mortality probabilities at 365 days and a log-rank test to compare the distributions of survival times. Cox proportional hazard analyses were used to calculate the hazard ratio (HR) for clinical outcomes. We performed the multivariable analyses using the focused inclusion method, and well-known predictive factors for adverse events following the MitraClip procedure were selected to adjust for.\(^5\)-\(^8\) A p value < .05
was considered to denote statistical significance. Statistical analyses were performed using SPSS version 25 (IBM Inc., Armonk, NY).

3 | RESULTS

3.1 | Clinical characteristics of the study participants

From 466 consecutive patients undergoing transcatheter mitral valve interventions, we excluded 108 patients that underwent techniques other than the MitraClip system alone and four patients that were missing values for troponin I and/or follow-up data. As a result, 354 patients undergoing the MitraClip procedure were enrolled in the study (Figure 1). Among them, 29 patients (8.2%) (Supplemental Table) became deceased within the 1-year follow-up period (Figure 1), and we divided our cohort into two groups according to this 1-year mortality. The baseline clinical characteristics between patients who died and those who survived are shown in Table 1. Compared with patients who survived, patients who died within the follow-up period had a significantly lower estimated glomerular filtration rate (eGFR, 30.7 [21.5–59.5] vs. 47.1 [34.8–57.5] ml/min/1.73m²; p = .044), higher rates of NYHA classification IV (42.3 vs. 20.5%; p = .024) and prior cardiac resynchronization therapy (CRT, 20.7 vs. 8.3%; p = .041), and higher levels of C-reactive protein (CRP, 13.7 [9.5–21.7] vs. 9.8 [5.2–21.9] mg/L; p = .038) and N-terminal-pro b-type natriuretic peptide (NT-proBNP, 7,643 [3983–21,692] vs. 3,168 [1535–6,942] pg/ml; p < .001). Table 2 shows the echocardiographic parameters and procedural results. In the present study, 21 (5.9%) patients had an unsuccessful clip implantation (0 clips) (Table 2). Patients who died within 1-year had significantly higher rates of concomitant aortic stenosis (AS) ≥ moderate (16.0 vs. 2.4%; p = .007), no clip implantation (20.7 vs. 4.6%; p = .004), postprocedural MR ≥ 2+ (60.0 vs. 29.2%; p = .003), lower rates of P2Y12 inhibitor use upon discharge (35.0 vs. 67.7%; p = .006), and a longer procedure duration (99 [64–149] vs. 69 [44–98] minutes; p = .005) than those who survived (Table 2).

3.2 | Baseline and postprocedural troponin I

Figure 2 summarizes the results for baseline and postprocedural troponin I values. Compared with patients who survived, those who died within the follow-up period had significantly higher levels of baseline troponin I (0.05 [0.01–0.08] vs. 0.01 [0.01–0.03] ng/ml; p < .001) and postprocedural troponin I (0.51 [0.30–1.42] vs. 0.20 [0.33–0.55] ng/ml; p = .005). The same overall results were still observed when the DL value was used as a substitute for values less than the analytical DL (data not shown). Patients who died within the first year had a significantly larger troponin increase (Δtroponin I) than those who survived (0.40 [0.24–1.32] ng/m vs. 0.29 [0.15–0.52]; p = .024). Myocardial injury occurred in 19 (5.6%) patients and deceased patients had a higher rate of myocardial injury than the surviving patients (25.0 vs. 3.9%; p < .001).

Multivariable stepwise linear regression analyses were performed to detect factors that were associated with baseline and postprocedural troponin I levels (Table 3). Factors included in the stepwise analyses are described in the footnote of Table 3; for the postprocedural troponin I measurement, procedure duration, and hypotension due to complications have also been included. NYHA classification III or IV, previous myocardial infarction (MI), prior CRT, and effective regurgitant orifice area of MR were associated with elevated baseline troponin I levels, while concomitant AS ≥ moderate, chronic obstructive pulmonary disease (COPD), procedure duration, and hypotension due to complications were correlated with elevated postprocedural troponin I levels (Table 3).

3.3 | Clinical outcome at 1-year follow-up by troponin value

Clinical outcomes, as stratified by baseline and postprocedural troponin I values, are summarized in Figure 3. At 1-year follow-up, patients with higher baseline troponin I values had a significantly worse
prognosis than those with lower values (log-rank $p < .001$; Figure 3, top). Similarly, 1-year mortality was significantly higher in patients with higher postprocedural troponin I values than those with lower values (log-rank $p = .021$; Figure 3, bottom). Our cohort was divided into four groups according to higher or lower values (above or below the median values) for the two troponin I time points, and as a result, the highest mortality rate was found to be in patients with elevated levels of both baseline and postprocedural troponin I (log-rank $p = .001$; Figure 4). Table 4 shows the results of multivariable Cox proportional hazards regression analyses for 1-year mortality by models that included well-known predictive factors for adverse events following the MitraClip procedure (model 1: eGFR < 30, NYHA IV; model 2: NT-proBNP > 5,000, LVEF < 30; model 3: ESV > 110, TR ≥ 2; model 4: postprocedural MR ≥ 2, no clip implantation). By using four models, both elevated baseline and postprocedural troponin I levels independently predicted 1-year mortality (model 1: HR, 4.63, $p = .020$; model 2: HR 4.16, $p = .033$; model 3: HR 5.14, $p = .013$; model 4: HR 4.80, $p = .017$). Moreover, multivariable
|               | Total (n = 354) | Death (n = 29) | Nondeath (n = 325) | p value |
|---------------|----------------|----------------|--------------------|---------|
| **MR etiology (%)** |                |                |                    |         |
| Primary MR    | 150 (42.7)     | 11 (37.9)      | 139 (43.2)         | .70     |
| Secondary MR  | 166 (47.3)     | 15 (51.7)      | 151 (46.9)         | .70     |
| Mixed MR      | 35 (10.0)      | 3 (10.3)       | 32 (9.9)           | 1       |
| **Ejection fraction, % (median range)** | 46.0 (32.7–59.1) | 52.8 (28.4–60.0) | 45.8 (33.1–59.0) | .86     |
| **EDV, mm³ (median range)** | 135.0 (94.8–183.6) | 136.0 (99.3–186.4) | 134.4 (94.7–183.1) | .56     |
| **ESV, mm³ (median range)** | 67.9 (37.5–115.5) | 72.6 (40.9–122.8) | 67.5 (37.2–115.5) | .58     |
| **LAV, mm³ (median range)** | 100.0 (70.1–130.0) | 101.4 (70.0–155.0) | 100.0 (74.7–129.4) | .63     |
| **E/e’, (median range)** | 18.3 (13.8–24.0) | 19.8 (16.5–22.1) | 18.3 (13.6–24.0) | .42     |
| **MR quantitative parameters** |                |                |                    |         |
| PISA, cm (median range) | 0.75 (0.63–0.88) | 0.74 (0.60–0.90) | 0.75 (0.64–0.88) | .96     |
| VC, cm (median range) | 0.63 (0.52–0.74) | 0.60 (0.46–0.73) | 0.63 (0.52–0.74) | .25     |
| RV, mm³ (median range) | 47.3 (37.9–61.5) | 45.4 (35.8–61.6) | 47.6 (38.0–61.4) | .98     |
| ERO, cm² (median range) | 0.30 (0.22–0.40) | 0.35 (0.20–0.59) | 0.30 (0.22–0.40) | .39     |
| AS ≥ moderate (%) | 11 (3.5)       | 4 (16.0)       | 7 (2.4)            | .007    |
| AR ≥ moderate (%) | 32 (10.3)      | 2 (8.0)        | 30 (10.5)          | 1       |
| TR ≥ moderate (%) | 223 (63.2)     | 20 (69.0)      | 203 (62.7)         | .55     |
| TRPG, mmHg (median range) | 43.0 (33.0–52.0) | 37.0 (32.6–53.3) | 43.2 (33.1–52.0) | .39     |
| TAPSE, mm (median range) | 17.0 (14.0–21.0) | 18.0 (14.0–21.5) | 17.0 (13.0–21.0) | .57     |
| **Number of clips implanted (%)** |                |                |                    |         |
| 0 clips       | 21 (5.9)       | 6 (20.7)       | 15 (4.6)           | .004    |
| 1 clip        | 147 (41.5)     | 5 (17.2)       | 142 (43.7)         | .005    |
| 2 clips       | 165 (46.6)     | 13 (44.8)      | 152 (46.8)         | 1       |
| 3 clips       | 21 (5.9)       | 5 (17.2)       | 16 (4.9)           | .021    |
| **Procedure duration, min (median range)** | 70 (46–100) | 99 (64–149) | 69 (44–98) | .005 |
| **Hypotension due to complication (%)** | 9 (2.5) | 2 (6.9) | 7 (2.2) | .16 |
| **Postprocedural MR ≥2+ (%)** | 108 (31.5) | 15 (60.0) | 93 (29.2) | .003 |
| **Postprocedural MR ≥3+ (%)** | 27 (7.9) | 2 (8.0) | 25 (7.9) | 1 |
| **Medications upon discharge (%)** |                |                |                    |         |
| Aspirin       | 204 (59.1)     | 13 (65.0)      | 191 (58.8)         | .65     |
| P2Y12 inhibitor | 227 (65.8)     | 7 (35.0)       | 220 (67.7)         | .006    |
| Oral anticoagulant | 226 (66.5) | 13 (65.0) | 213 (66.6) | 1 |
| Beta blocker  | 296 (85.8)     | 18 (90.0)      | 278 (85.5)         | .75     |
| ARB           | 87 (25.2)      | 3 (15.0)       | 84 (25.8)          | .43     |
| ACE-I         | 173 (50.1)     | 10 (50.0)      | 163 (50.2)         | 1       |
| Diuretics     | 281 (81.4)     | 17 (85.0)      | 264 (81.2)         | 1       |
| MRA           | 188 (54.7)     | 10 (50.0)      | 178 (54.9)         | .82     |
| Statin        | 229 (66.4)     | 12 (60.0)      | 217 (66.8)         | .63     |
| Digitalis     | 52 (15.1)      | 4 (20.0)       | 48 (14.8)          | .52     |
| Oral hypoglycemic agent | 45 (13.0) | 2 (10.0) | 43 (13.2) | 1 |
| Insulin       | 15 (4.3)       | 1 (5.0)        | 14 (4.3)           | .60     |
| PPI           | 267 (77.4)     | 13 (65.0)      | 254 (78.2)         | .18     |

Abbreviations: ACE-I, angiotensin converting enzyme inhibitor; AR, aortic regurgitation; ARB, angiotensin receptor blocker; AS, aortic stenosis; EDV, end-diastolic volume; ERO, effective regurgitant orifice; ESV, end-systolic volume; LAV, left atrium volume; MR, mitral regurgitation; MRA, mineralocorticoid receptor antagonist; PISA, proximal isovelocity surface area; PPI, proton pump inhibitor; RV, regurgitant volume; TAPSE, tricuspid annular plane systolic excursion; TR, tricuspid regurgitation; TRPG, tricuspid regurgitation peak gradient; VC, vena contracta.
analyses revealed that the troponin increase (Δtroponin I) and myocardial injury were also associated with the clinical outcome (Table 4).

4 | DISCUSSION

In the present study, we investigated baseline and postprocedural troponin I levels and their impact on clinical outcomes following TMVR. The main findings of the present study were as follows: (a) Previous histories of MI and CRT implantation, NYHA classification, and MR severity were predictors for elevated baseline troponin I values, while COPD, eGFR, and concomitant AS ≥ moderate are correlated with elevated postprocedural troponin I, (b) Patients who died within 1-year had significantly higher baseline and postprocedural troponin I values, (c) Patients with both elevated baseline and postprocedural troponin I values had the highest mortality rate for the first year, (d) Besides baseline and postprocedural values, the troponin increase (Δtroponin I) and myocardial injury were also associated with the clinical outcome.

4.1 | Elevated baseline cardiac troponin in patients undergoing the MitraClip

The main purpose of the present study was to investigate the baseline and postprocedural cardiac troponin I levels in patients undergoing the MitraClip procedure, and interestingly, patients who died within the 1-year follow-up had significantly higher levels of troponin I at both of these time points. Cardiac troponins, such as troponin T and troponin I are well-established diagnostic tools for ACS, and they have been shown to be of prognostic value in patients with ACS. However, elevated cardiac troponins can be found in other chronic conditions, such as heart failure, valvular heart disease, and chronic kidney disease.

**FIGURE 2** Baseline and postprocedural troponin I values. Compared with the patients who survived, those who died within the follow-up period had significantly higher levels of baseline troponin I (0.05 [0.01–0.08] vs. 0.01 [0.01–0.03] ng/ml; p < .001) and postprocedural troponin I (0.51 [0.30–1.42] vs. 0.20 [0.33–0.55] ng/ml; p = .005)

**TABLE 3** Multivariable stepwise linear regression analyses for baseline and postprocedural troponin I

| Variable     | Baseline troponin I | Postprocedural troponin I |
|--------------|---------------------|----------------------------|
|              | Unstandardized      | Standardized               | p  | Unstandardized | Standardized | p  |
|              | regression coefficient | regression coefficient |     | coefficient  | regression coefficient |     |
| NYHA III/IV  | 0.036               | 0.18                       | .032| 5.52          | 0.30          | <.001|
| Previous MI  | 0.045               | 0.28                       | .001| COPD          | 1.46          | .019 |
| Prior CRT    | 0.066               | 0.27                       | .002| Procedure time | 0.014         | .20  | .010|
| ERO          | 0.091               | 0.20                       | .014| Hypotension due to complications | 8.67 | 0.39 | <.001|

Note: Factors included in the stepwise analyses for baseline troponin I were male sex, age, BMI, diabetes, hypertension, dyslipidemia, eGFR, current smoking, prior PCI, prior CABG, previous MI, previous stroke, AF, PAD, NYHA III or IV, prior ICD, prior CRT, COPD, STS score, NT-proBNP, FMR, LVEF, EDV, ERO, AS ≥ 2, AR ≥ 2, (moderate) TR ≥ 2 (moderate), TRPG, and TAPSE. For postprocedural troponin I, procedure duration and hypotension due to complications were also included. Abbreviations are as shown in Tables 1 and 2.
Cardiac troponins are often observed to be elevated in patients with acute, as well as chronic, heart failure with or without concomitant coronary artery diseases, and it is well known that higher levels of cardiac troponins predict a worse clinical outcome, both in patients with acute and chronic heart failure. Previous studies reported that elevated baseline troponin levels in patients that were admitted due to acute heart failure were associated with in-hospital mortality, as well as short-term and long-term mortality. Elevated baseline troponin levels in patients with chronic heart failure were also reported to predict long-term mortality. Moreover, one report suggested that an elevated baseline cardiac troponin level predicted a worse prognosis in patients undergoing the MitraClip procedure. The study presented here included a relatively larger number of MitraClip patients than the previous report and helps to validate the predictive ability of baseline cardiac troponin levels for mortality following this procedure.

4.2 MitraClip and postprocedural cardiac troponin

It is also known that the elevation of postoperative cardiac troponin levels is correlated with poor prognosis following vascular surgery, as well as nonvascular operations. In the present study, procedure time and hypotension due to complication were independent predictors for postprocedural troponin elevation. It has been reported that procedural stresses can initiate endocrine metabolic changes and trigger the activation of several biological cascades, such as cytokines, nitric oxide, and free oxygen radicals. In addition, perioperative hypotension (bleeding, hypovolemia, and systemic vasodilation), anemia, transient hypoxia, and tachycardia can result in myocardial hypoperfusion and a prolonged imbalance in the myocardial oxygen supply, which leads to myocardial injury. Thus, elevation of postprocedural troponin levels could be associated with the interventional procedure itself as well as the patient’s condition.

**FIGURE 3** Clinical outcome at 1-year follow-up stratified by troponin I values. At 1-year follow-up, patients with higher baseline troponin I values (above the median value) had a significantly worse prognosis than those with lower values (log-rank p < .001). Similarly, 1-year mortality was significantly higher in patients with a higher postprocedural troponin I level (above the median value) than those with lower values (log-rank p = .021).

**FIGURE 4** Kaplan–Meier curves for four groups according to higher or lower baseline and postprocedural troponin I. We divided our cohort into four groups according to higher or lower values for the two troponin I values (above or below the median values), and as a result, the highest mortality rate was observed in patients with elevated levels of both baseline and postprocedural troponin I (log-rank p = .001).
A previous study suggested that a periprocedural myocardial infarction (PMI) itself could lead to future major cardiovascular events. However, there is also a possibility that PMI was not the cause of the clinical outcome, but postprocedural elevation of troponin I could be a marker of severe underlying cardiac conditions, which might lead to a worse prognosis even without being the cause. It is difficult to confirm which mechanisms led to the results of the present study, but nonetheless, the results of the present study suggest an association of postprocedural troponin I levels with clinical outcomes following the MitraClip procedure.

### 4.3 Combined baseline and postprocedural cardiac troponins

In the present study, we divided our subjects into four groups according to the baseline and postprocedural troponin I levels and found that patients with elevated troponin levels at both time points had the worst prognosis upon undergoing the MitraClip procedure. Moreover, the overall increase in troponin (Δtroponin) and myocardial injury might also help to predict the clinical outcome. To the best of our knowledge, this is the first report to evaluate the impact of combined baseline and postprocedural troponin values on clinical outcomes following this procedure. The results of the present study suggest that not only baseline but also postprocedural troponin measurements may be useful in risk stratification and provide physicians with important prognostic information following the procedure. Without monitoring the postprocedural troponin levels, subclinical myocardial injuries and a patient’s poor prognosis might remain undetected. Thus, the present study underlines the importance of periprocedural troponin levels as valuable risk markers that are frequently encountered in daily clinical practice. There has been little evidence that medication can prevent postoperative troponin elevation; however, Ausset and colleagues have reported that optimizing perioperative management by reducing hypoxia, hypothermia, anemia, hypotension, tachycardia, hypoglycemia, and pain might prevent postoperative troponin elevation and therefore, decrease major cardiovascular events. Moreover, results of the present study suggest that factors associated with the procedure may be associated with postprocedural troponin elevation. Perioperative factors such as procedure duration and complications could be lessened as there are improvements made to the devices and procedural techniques. Thus, the present study underlines the importance of measuring postprocedural troponin levels in order to know the subclinical myocardial injury associated with the procedure as well as the patient’s underlying condition.

### 4.4 Study limitations of the present study

There are several limitations to the present study. First, it was a single-center observational study, which included a relatively small number of patients. Second, we included all-comer TMVR patients, but excluded those who had missing troponin I values or follow-up data, which could lead to some bias. Third, we enrolled patients with both primary and secondary MR as well as ischemic and nonischemic etiologies. Fourth, we did not investigate the mechanism for why troponin values were elevated following the procedures, and the etiology of higher cardiac troponin values for these patients is unclear. Fifth, surgical risk scores in the present study are relatively low for a MitraClip population and therefore, the results of the present study

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**TABLE 4** Multivariable Cox proportional hazards regression analyses for 1-year mortality

| Variable | Multivariate regression forced inclusion model 1 | Multivariate regression forced inclusion model 2 |
|----------|-----------------------------------------------|-----------------------------------------------|
|          | HR    | 95% CI | p     | HR    | 95% CI | p     |
| Baseline/post troponin I (vs. low/low) | | | | | | |
| High baseline/low post | 1.96 | 0.43–8.93 | .38 | 2.20 | 0.48–10.07 | .31 |
| Low baseline/high post | 1.22 | 0.24–6.08 | .81 | 1.31 | 0.27–6.51 | .74 |
| High baseline/high post | 4.63 | 1.28–16.78 | .020 | 4.16 | 1.12–15.39 | .033 |
| Troponin increase (per 1 ng/ml) | 1.02 | 1.01–1.03 | <.001 | 1.02 | 1.01–1.03 | .001 |
| Myocardial injury (yes) | 4.71 | 1.74–12.76 | .002 | 3.25 | 1.05–10.10 | .042 |

Note: Adjusted values are as follows: Model 1, eGFR < 30, NYHA IV; Model 2, NT-proBNP > 5,000, LVEF < 30; Model 3, ESV > 110, TR ≥ 2; Model 4, postprocedural MR ≥ 2, no clip implantation. Abbreviations are as shown in Tables 1 and 2.
might not be generally applicable. Moreover, we defined the clinical outcome as all-cause death within 1-year follow-up, and we could not evaluate the impact of periprocedural troponin I levels on other future cardiac events like myocardial infarction or rehospitalization.

5 | CONCLUSION

In conclusion, the results of the present study suggest that the combined baseline and postprocedural troponin I values are useful for risk stratification of 1-year mortality following the MitraClip procedure.

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CONFLICT OF INTEREST

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SUPPORTING INFORMATION

Additional supporting information may be found in the Supporting Information section at the end of this article.