Further Validation of a Novel Acute Myocardial Infarction Risk Stratification (nARS) System for Patients with Acute Myocardial Infarction

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Summary

Recently, we developed a novel acute myocardial infarction (AMI) risk stratification system (nARS), which stratifies AMI patients into low- (L), intermediate- (I), and high- (H) risk groups. We have shown that the nARS shortened the length of intensive care unit (ICU) stay as well as that of hospitalization. However, the incidence of AMI-related adverse outcomes has not been fully investigated. The purpose of this study was to investigate the incidence of severe complications requiring ICU care among the 3 risk groups stratified by nARS. We retrospectively reviewed AMI patients between October 2016 and December 2018. A total of 592 patients were divided into the L- (n = 285), I- (n = 124), and H- (n = 183) risk groups. The primary endpoint was in-hospital complications requiring ICU care defined as death/cardiopulmonary arrest, shock, stroke, atrioventricular block, and respiratory failure. Among 592 patients, 239 (40.4%) developed at least 1 complication requiring ICU care, but only 28 (11.7%) developed complications in general wards. Complications requiring ICU care were most frequently observed in the H-risk group (68.9%), followed by the I-risk group (50.8%), and least in the L-risk group (17.5%) (P < 0.001). Complications requiring ICU care that occurred in the general wards were more frequently observed in the H-risk group (8.7%) compared to the I-risk (3.2%) and L-risk (2.8%) groups (P = 0.009). In conclusion, complications requiring ICU care rarely happened in the general wards, and were less in the I- and L-risk groups than in the H-risk group. These results validated the nARS, and might support the widespread use of nARS.

Key words: Coronary care unit, Length of hospitalization

Since acute myocardial infarction (AMI) is associated with high morbidity and mortality,1 hospitalization, including an intensive care unit (ICU)/coronary care unit (CCU) stay, is still mandatory.2 However, the length of hospitalization for AMI differs widely among developed countries.3 In fact, the length of hospitalization for AMI was remarkably longer in Japan than in most Western countries.4,5 Because medical resources will become more limited in the future, even in Japan, it is important to minimize the length of hospitalization without sacrificing safety.6 Recently, we have developed a novel AMI Risk Stratification (nARS) system linked to an in-hospital rehabilitation program, which stratifies AMI patients into low- (L), intermediate- (I), and high- (H) risk groups according to our own criteria.7 We have shown that nARS could shorten the length of ICU/CCU stay as well as the length of hospitalization.8

Although the introduction of nARS may shorten the length of an ICU/CCU stay and save medical costs, there is concern that severe complications may happen in the general cardiology ward due to premature discharge from the ICU/CCU. Premature discharge may imperil the patient’s life, and might increase preventable death.9 Thus, before adopting the widespread use of nARS, it is necessary to confirm that severe complications do not frequently occur in the general cardiology ward after discharge from the ICU/CCU. The purpose of this study was to investigate the incidence of severe complications in general cardiology wards as well as in the ICU/CCU among the 3 risk groups stratified by nARS, and to validate the nARS.

Methods

Study design: We reviewed AMI patients treated at our institution between October 2016 and December 2018. AMI was defined according to the universal definition.10 We excluded AMI patients who underwent emergency or urgent coronary bypass grafting surgery or emergency surgery for mechanical complications during hospitalization.
We excluded AMI caused by complications following cardiac surgery, and AMI caused by coronary artery spasm. We also excluded AMI patients who did not undergo coronary angiography and who were not classified according to the nARS.

The AMI risk for each patient was discussed and determined in our daily CCU conference according to the nARS criteria on the day after primary percutaneous coronary intervention (PCI) or coronary angiography. Each patient was assigned to the L-, I-, or H-risk group as previously described. In brief, the L-risk patients needed to satisfy all of the following criteria: (1) primary PCI > 24 hours from onset of symptoms; (2) final TIMI criteria: (1) primary PCI > 24 hours from onset of symptoms; (2) final TIMI ≤ 2 flow grade on primary PCI; (3) global ejection fraction (EF) > 40%; (4) unsuccessful rehabilitation test caused by residual stenosis; (5) right ventricular (RV) infarction that worsens hemodynamic status; (6) > 10 mm pericardial effusion on echocardiography; (7) apical aneurysm requiring anticoagulation therapy; (8) presence of a high-grade atrioventricular block; and (9) presence of a pericardial effusion on echocardiography; (7) apical aneurysm requiring anticoagulation therapy; (8) presence of a mechanical complication; and (9) requiring IABP support.

The typical length of hospitalization for the L-, I-, and H-risk patients was 5 days, 7 days, and 10 days, respectively. Patients in the L-risk group had to undergo a 2-minute standing test on the day after primary PCI, followed by a 200m walk test on the day after the successful 2-minute standing test, and then a 500m walk test on the day after the successful 200m walk test, followed by discharge on the day after a successful 500m walk test. Patients in the I-risk group had a 1-day interval between each test, and patients in the H-risk group typically underwent a 2-minute standing test on day 3, and had a 2-day interval between each test. Each patient could be transferred from the ICU/CCU after a successful 2-minute standing test if a bed was available in the general cardiology ward. If the patient required IABP support, mechanical ventilation, or veno-arterial extracorporeal membrane oxygenation, the rehabilitation program was postponed until the mechanical support was no longer required. Risk stratification transition (from L-risk to H-risk or from I-risk to H-risk) occurred when the patient could not pass the scheduled rehabilitation test.

The primary endpoint was in-hospital complications defined as cardiopulmonary arrest (CPA)/death, shock, stroke, atrioventricular block, and respiratory failure. This study was approved by the institutional review board, and written informed consent was waived because of the retrospective study design. Data collection and storage were performed anonymously, according to the Japan Ministry of Health, Labour and Welfare guidelines. Definitions: Hypertension was defined as systolic blood pressure (SBP) > 140 mmHg, diastolic blood pressure > 90 mmHg, or medical treatment for hypertension. Diabetes mellitus was defined as hemoglobin A1c > 6.5% or treatment for diabetes mellitus. Hyperlipidemia was defined as total cholesterol > 220 mg/dL, low-density lipoprotein cholesterol > 140 mg/dL, or treatment for hyperlipidemia. We also calculated the estimated glomerular filtration rate (eGFR) using serum creatinine (Cr), age, weight, and gender according to the following formula: eGFR = 194 × Cr − 1.094 × age − 0.287 (male), or eGFR = 194 × Cr − 1.094 × age − 0.287 × 0.739 (female). In-hospital complications potentially requiring ICU care included any of the following: CPA/death, post-admission shock, stroke, high-grade atrioventricular block, or post-admission respiratory failure. Shock was defined as SBP < 90 mmHg, vasopressors required to maintain blood pressure, or attempted cardiopulmonary resuscitation. Stroke was an acute episode of focal or global neurological dysfunction caused by brain, spinal cord, or retinal vascular injury as a result of hemorrhage or infarction. High-grade atrioventricular block was defined as third degree atrioventricular block, insertion of a temporary transvenous pacemaker system, or permanent pacemaker implantation. Respiratory failure was arterial pO2 on room air less than 60 mmHg and the use of mechanical ventilation. Major bleeding was defined as a drop of ≥ 2 g/dL in hemoglobin level or administration of ≥ 2 units of packed red blood cells. In echocardiography, ejection fraction (EF) was measured using a modified Simpson method. The Teichholz method was adopted only when a modified Simpson method was not available. RV infarction was defined as ST-segment elevation in V4R (≥ 1 mm) or abnormal RV wall motion on echocardiography, accompanying clinical symptoms such as hypotension.

Statistical analysis: We compared the clinical characteristics among the L-, I- and H-risk groups. Data are expressed as the mean ± SD or percentage. Categorical variables are presented as numbers (percentage) and were compared with the Pearson’s chi square test. For continuous variables, the Shapiro-Wilk test was performed to determine whether the continuous variables were normally distributed or not. Normally distributed continuous variables were compared using a one-way ANOVA. Otherwise, continuous variables were compared using a Kruskal-Wallis test. Statistical significance was defined as a 2-sided P < 0.05. Statistical analyses were performed with SPSS 25.0 for Windows (SPSS, Chicago, IL, USA).

Results

Between October 2016 and December 2018, a total of 653 patients were diagnosed as AMI. Sixty one patients were excluded as previously described (20 patients underwent emergency or urgent coronary bypass grafting surgery, 8 underwent emergency surgery for mechanical complications during hospitalization, 2 had AMI caused by complications following cardiac surgery, 3 did not undergo coronary angiography, 14 had AMI caused by coronary artery spasm, and 14 were not classified according to the nARS). As a result, 592 patients were included as the final study population, and were assigned to the L-risk (n = 285), I-risk (n = 124), or H-risk (n = 183) group (Figure).

The clinical characteristics of the 3 groups are shown
The prevalences of shock and CPA, and the values of heart rate on admission, peak-CK, peak-CKMB, and BNP were the highest in the H-risk group, followed by the I-risk group, and then the L-risk group. The prevalence of Killip class 1/2, systolic blood pressure, ejection fraction, and eGFR were the highest in the L-risk group, followed by the I-risk group, and then the H-risk group. Medications at admission were comparable, except for aspirin, thienopyridine, and calcium channel blockers. The lesion and procedural characteristics of the 3 groups are shown in Table II. The prevalence of final TIMI flow grade-3 was significantly higher in the L-risk group (98.6%), followed by the I-risk group (97.6%), and then the H-risk group (87.9%) ($P < 0.001$). Chronic total occlusion (CTO) at the non-culprit site was most frequently observed in the H-risk group (20.2%), followed by the I-risk group (12.9%), and was the least in the L-risk group (10.9%) ($P = 0.017$).

Complications requiring ICU care among the 3 groups are shown in Table III. The length of ICU/CCU stay was significantly longer in the H-risk group (3.9 ± 4.7 days) than in the I-risk group (1.9 ± 1.4) and L-risk group (0.9 ± 0.9) ($P < 0.001$). Among the 592 patients with AMI, 239 (40.4%) developed at least 1 complication requiring ICU care. Of the 239 patients with at least 1 complication requiring ICU care, 211 (88.3%) developed complications in the ICU, whereas only 28 (11.7%) developed complications in a general ward. Complications requiring ICU care were most frequently observed in the H-risk group (68.9%), followed by the I-risk group (50.8%), and then the L-risk group (17.5%) ($P < 0.001$). Complications requiring ICU care that occurred in the general wards were more frequently observed in the H-risk group (8.7%) as compared to the I-risk (3.2%) and L-risk (2.8%) groups ($P = 0.009$). The incidences of CPA/death that occurred in the general wards were equally low in the L-risk (0.7%), I-risk (1.6%), and H-risk (1.6%) groups ($P = 0.581$). The incidence of shock in the general wards was highest in the H-risk group (6.0%), followed by the L-risk group (1.8%), and then the I-risk group (0.8%) ($P = 0.008$). Atrioventricular block did not occur in the general wards in any group. The incidence of respiratory failure in the general wards was low in the L-risk (1.8%), I-risk (2.4%), and H-risk (2.7%) groups ($P = 0.76$).

**Discussion**

The present study included 592 patients with AMI who were divided into the L-risk, I-risk, and H-risk groups according to the nARS, and then the incidences of complications requiring ICU care were compared between the 3 groups. Complications requiring ICU care were defined as either CPA/death, shock, stroke, AVB, or respiratory failure. Although 239 patients (40.4%) develop-
Table I. Comparison of Clinical Characteristics among the L, I and H Risk Groups

| Variable | All (n = 592) | L-risk (n = 285) | I-risk (n = 124) | H-risk (n = 183) | P value |
|----------|--------------|-----------------|-----------------|-----------------|---------|
| Age, (years) | 70 ± 13 | 69 ± 13 | 72 ± 13 | 71 ± 14 | 0.049 |
| Male sex, (n %) | 450 (76.0%) | 224 (78.6%) | 90 (72.6%) | 136 (74.3%) | 0.344 |
| Body Mass Index, (Kg/m²) | 23.7 ± 3.7 (n = 583) | 24.1 ± 3.6 (n = 283) | 23.5 ± 3.9 (n = 123) | 23.6 ± 3.6 (n = 177) | 0.046 |
| STEMI, (n %) | 325 (54.9%) | 126 (44.2%) | 84 (67.7%) | 115 (62.8%) | < 0.001 |
| Hypertension, (n %) | 470 (80.5%) | 241 (85.2%) | 100 (82.0%) | 129 (72.1%) | 0.002 |
| Diabetes mellitus, (n %) | 258 / 581 (44.4%) | 126 / 282 (44.7%) | 47 / 123 (38.2%) | 85 / 176 (48.3%) | 0.223 |
| Dyslipidemia, (n %) | 346 / 571 (60.6%) | 180 / 278 (64.7%) | 78 / 120 (65.0%) | 88 / 173 (50.9%) | 0.007 |
| Current smoker, (n %) | 173 / 576 (29.3%) | 82 / 280 (29.3%) | 35 / 123 (28.5%) | 56 / 173 (32.4%) | 0.715 |
| Creatinine on admission, (mg/dL) | 1.74 ± 2.40 | 1.71 ± 2.56 | 1.87 ± 2.50 | 1.72 ± 2.06 | < 0.001 |
| Hemodialysis on admission, (n %) | 65 (11.0%) | 35 (12.3%) | 17 (13.7%) | 13 (11.1%) | 0.119 |
| History of previous MI, (n %) | 94 (15.9%) | 55 (19.3%) | 14 (11.3%) | 25 (13.7%) | 0.077 |
| History of previous PCI, (n %) | 134 (22.6%) | 78 (27.4%) | 22 (17.7%) | 34 (18.6%) | 0.029 |
| History of previous CABG, (n %) | 23 (3.9%) | 14 (4.9%) | 2 (1.6%) | 7 (3.8%) | 0.283 |
| Killip class (1 or 2, 3 or 4) | 456 (77.0%) | 219 (76.8%) | 114 (91.9%) | 123 (67.2%) | < 0.001 |
| Systolic Blood Pressure on admission, (mmHg) | 141 ± 34 | 148 ± 30 | 143 ± 31 | 129 ± 37 | < 0.001 |
| Diastolic Blood Pressure on admission, (mmHg) | 82 ± 20 (n = 589) | 84 ± 19 (n = 285) | 83 ± 18 (n = 124) | 78 ± 24 (n = 181) | 0.023 |
| Heart rate on admission, (bpm) | 83 ± 22 (n = 590) | 78 ± 18 (n = 285) | 85 ± 25 (n = 124) | 92 ± 25 (n = 181) | < 0.001 |
| Ejection fraction, (%) | 52 ± 14 (n = 565) | 58 ± 11 (n = 284) | 50 ± 13 (n = 121) | 42 ± 15 (n = 160) | < 0.001 |
| IABP, (n %) | 61 (10.3%) | 48 (1.4%) | 8 (6.5%) | 49 (26.8%) | < 0.001 |
| V-A ECMO, (n %) | 29 (4.9%) | 2 (0.7%) | 1 (0.8%) | 26 (14.2%) | < 0.001 |
| Peak CK, (mU/mL) | 1652 ± 2830 | 1029 ± 1432 | 1644 ± 1802 | 2626 ± 4366 | < 0.001 |
| Peak CK-MB, (mU/mL) | 146 ± 219 (n = 589) | 104 ± 151 (n = 285) | 162 ± 197 (n = 122) | 202 ± 297 (n = 182) | < 0.001 |
| eGFR, (mL/minute/1.73 m²) | 60 ± 34 (n = 591) | 64 ± 30 (n = 284) | 59 ± 33 (n = 124) | 54 ± 39 (n = 183) | < 0.001 |
| BNP, (pg/mL) | 492 ± 777 (n = 564) | 299 ± 650 (n = 270) | 544 ± 825 (n = 121) | 756 ± 844 (n = 173) | < 0.001 |
| Medication at admission | | | | | |
| Aspirin, (n %) | 184 / 566 (32.5%) | 103 / 276 (37.3%) | 31 / 121 (25.6%) | 50 / 169 (29.6%) | 0.045 |
| Thienopyridine, (n %) | 118 / 566 (20.8%) | 70 / 276 (25.4%) | 21 / 122 (17.4%) | 27 / 169 (16.0%) | 0.034 |
| Statin, (n %) | 208 / 564 (36.9%) | 111 / 275 (40.4%) | 41 / 120 (34.2%) | 56 / 169 (33.1%) | 0.243 |
| ACE- inhibitor or ARB, (n %) | 220 / 563 (39.1%) | 115 / 274 (42.0%) | 40 / 120 (33.3%) | 65 / 169 (38.5%) | 0.265 |
| Beta blocker, (n %) | 145 / 563 (25.8%) | 75 / 274 (27.4%) | 28 / 120 (23.3%) | 42 / 169 (24.9%) | 0.665 |
| Calcium channel blocker, (n %) | 209 / 563 (37.1%) | 92 / 274 (33.6%) | 57 / 120 (47.5%) | 60 / 169 (35.5%) | 0.027 |
| Diuretics, (n %) | 79 / 565 (14.0%) | 31 / 275 (11.3%) | 21 / 121 (17.4%) | 27 / 169 (16.0%) | 0.184 |
| Oral antidiabetic drug, (n %) | 148 / 565 (26.2%) | 73 / 275 (26.5%) | 30 / 121 (24.8%) | 45 / 169 (26.6%) | 0.925 |
| Insulin, (n %) | 44 / 567 (7.8%) | 17 / 275 (6.2%) | 12 / 121 (9.9%) | 15 / 171 (8.8%) | 0.370 |

Data are expressed as the mean ± SD or number (percentage). Pearson’s chi-square test was used for categorical variables. Normally distributed continuous variables were compared by one-way ANOVA and Kruskal-Wallis test was performed for abnormally distributed continuous variables. STEMI indicates ST elevated myocardial infarction; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; EF, ejection fraction; IABP, intra-aortic balloon pumping; V-A ECMO, veno-arterial extracorporeal membrane oxygenation; CK, creatine kinase; CK-MB, creatine kinase-muscle/brain; eGFR, estimated glomerular filtration rate; BNP, brain natriuretic peptide; ACE, angiotensin-converting enzyme; and ARB, angiotensin II receptor blocker.

oped at least 1 complication requiring ICU care, only 28 patients (4.7%) developed such complications in general cardiology wards. Complications requiring ICU care were most frequently observed in the H-risk group, followed by the I-risk group, and then the L-risk group (P < 0.001), which supports the utility of nARS for risk stratification of AMI. Furthermore, complications requiring ICU care that developed in the general wards were more frequently observed in the H-risk group as compared to the I-risk and L-risk groups (P = 0.009), which implies that the nARS facilitates the transfer of L- and I-risk patients from the ICU/CCU to general wards without sacrificing safety.

We should discuss why complications requiring ICU care rarely happened in nARS. As a prerequisite for being discharged from the ICU/CCU, patients had to pass a 2-minute standing test, undergo checks of their symptoms and vital signs, and an ECG at 3 points (before test, just after test, 3-minute after test). If a patient could not pass the 2-minute standing test, discharge was postponed. Moreover, patients who could not pass the test would
have further treatment including PCI to non-culprit lesions, an increase in the dose of optimal medical therapy, or the addition of diuretics. Therefore, patients who passed the 2-minute standing test were safely transferred to a general cardiology ward. In other words, the 2-minute standing test might be useful for stratifying high-risk patients into general ward care.

The frequency of complications requiring ICU care was highest in the H-risk group, followed by the I-risk group, and the lowest in the L-risk group. We previously reported that the H-risk group had poorer mid-term clinical outcomes compared to the I-risk or L-risk groups. In the present study, we showed that the H-risk group had more in-hospital complications requiring ICU care than the I-risk or L-risk groups. Because the H-risk group was classified as the most serious patients in nARS, it was reasonable that the H-risk group had more in-hospital complications than the 2 other groups. The results of the present study further validated nARS for risk stratification of AMI.

Since it is difficult to make a timely response for severe complications requiring ICU care in general wards, it should be important for patient outcomes to minimize the incidence of complications requiring ICU care that develop in general wards. Our results showed that complications requiring ICU care that occurred in general wards were more frequently observed in the H-risk group than in the I- or L-risk groups. In nARS, since patients in the I- or L-risk groups were allowed to leave the ICU/CCU after a successful 2-minute standing test, we should be important for patient outcomes to minimize the incidence of complications requiring ICU care that occurred in general wards.

### Table II. Comparison of Lesion and Procedural Characteristics among the L, I, and H Risk Groups

| Variables | All (n = 592) | L-risk (n = 285) | I-risk (n = 124) | H-risk (n = 183) | P value |
|-----------|--------------|-----------------|-----------------|-----------------|---------|
| Site of infarction | | | | | |
| Anterior, n (%) | 305 (51.5%) | 140 (49.1%) | 66 (53.2%) | 99 (54.1%) | 0.808 |
| Inferior, n (%) | 174 (29.4%) | 84 (29.5%) | 38 (30.6%) | 52 (28.4%) | |
| Posterior, n (%) | 89 (15.0%) | 48 (16.8%) | 17 (13.7%) | 24 (13.1%) | |
| Not determined, n (%) | 24 (4.1%) | 13 (4.6%) | 3 (2.4%) | 8 (4.4%) | |
| Number of diseased vessels | | | | | |
| Single, n (%) | 251 / 591 (42.5%) | 144 / 285 (50.5%) | 42 / 124 (33.9%) | 65 / 182 (35.7%) | < 0.001 |
| Double, n (%) | 191 / 591 (32.3%) | 74 / 285 (26.0%) | 55 / 124 (44.4%) | 62 / 182 (34.1%) | |
| Triple, n (%) | 149 / 591 (25.2%) | 67 / 285 (23.5%) | 27 / 124 (21.8%) | 55 / 182 (30.8%) | |
| Treatment for Culprit vessel (PCI or Medication) | | | | | |
| PCI, n (%) | 575 (97.1%) | 281 (98.6%) | 119 (96.0%) | 175 (95.6%) | 0.118 |
| Medication only, n (%) | 17 (2.9%) | 4 (1.4%) | 5 (4.0%) | 8 (4.4%) | |
| First TIMI flow (0, 1, 2, 3) | | | | | |
| 0 or 1, n (%) | 260 (44.1%) | 106 (37.2%) | 65 (52.4%) | 89 (48.6%) | 0.005 |
| 2 or 3, n (%) | 332 (56.0%) | 179 (62.8%) | 59 (47.6%) | 94 (51.4%) | |
| Final TIMI flow (0, 1, 2 or 3) | | | | | |
| 0 or 1 or 2, n (%) | 29 / 591 (4.9%) | 4 / 285 (1.4%) | 3 / 124 (2.4%) | 22 / 182 (12.1%) | < 0.001 |
| 3, n (%) | 562 / 591 (95.1%) | 281 / 285 (98.6%) | 121 / 124 (97.6%) | 160 / 182 (87.9%) | |
| AMI with non-culprit CTO, n (%) | 84 (14.2%) | 31 (10.9%) | 16 (12.9%) | 37 (20.2%) | 0.017 |
| Use of aspiration catheter, n (%) | 52 (8.8%) | 14 (4.9%) | 13 (10.5%) | 25 (13.7%) | 0.004 |
| Final PCI procedure | | | | | |
| Percutaneous old balloon angioplasty, n (%) | 37 / 575 (6.4%) | 8 / 281 (2.8%) | 7 / 119 (5.9%) | 22 / 175 (12.6%) | < 0.001 |
| Aspiration only, n (%) | 3 / 575 (0.5%) | 1 / 281 (0.4%) | 0 (0%) | 2 / 175 (1.1%) | |
| Drug Coated Balloon, n (%) | 34 / 575 (5.9%) | 22 / 281 (7.8%) | 4 / 119 (3.4%) | 8 / 175 (4.6%) | |
| Bare-metal stent, n (%) | 11 / 575 (1.9%) | 4 / 281 (1.4%) | 5 / 119 (4.2%) | 2 / 175 (1.1%) | |
| Drug-eluting stent, n (%) | 486 / 575 (84.4%) | 246 / 281 (87.2%) | 103 / 119 (86.6%) | 137 / 175 (78.3%) | |
| Percutaneous old balloon angioplasty + aspiration, n (%) | 2 / 575 (0.3%) | 0 (0%) | 0 (0%) | 2 / 175 (1.1%) | |
| Others, n (%) | 2 / 575 (0.3%) | 0 (0%) | 0 (0%) | 2 / 175 (1.1%) | |
| Access site | | | | | |
| Radial, n (%) | 396 / 575 (68.9%) | 209 / 281 (74.4%) | 75 / 119 (63.0%) | 112 / 175 (64.0%) | 0.015 |
| Brachial, n (%) | 15 / 575 (2.6%) | 10 / 281 (3.6%) | 2 / 119 (1.7%) | 3 / 175 (1.7%) | |
| Femoral, n (%) | 164 / 575 (28.5%) | 62 / 281 (22.1%) | 42 / 119 (35.3%) | 60 / 175 (34.3%) | |
| Catheter size (Fr) | | | | | |
| 6 Fr, n (%) | 358 / 575 (62.3%) | 192 / 281 (68.3%) | 80 / 119 (67.2%) | 86 / 175 (49.1%) | < 0.001 |
| 7 Fr, n (%) | 211 / 575 (36.7%) | 87 / 281 (31.0%) | 37 / 119 (31.1%) | 87 / 175 (49.7%) | |
| 8 Fr, n (%) | 6 / 575 (1.0%) | 2 / 281 (0.3%) | 2 / 119 (1.7%) | 2 / 175 (1.1%) | |

Data are expressed as number (percentage). Pearson’s chi-square test was used for categorical variables. PCI indicates percutaneous coronary intervention; TIMI, Thrombolysis in Myocardial Infarction; AMI, acute myocardial infarction; and CTO, chronic total occlusion.
shown that complications requiring ICU care rarely happened in the general wards in nARS and that any complications that did occur in the general wards were fewer in the I- and L-risk groups than in the H-risk group. The present study supports the widespread use of nARS.

**Study limitations:** The present study has the following limitations. First, it was a single-center, retrospective study. Second, nARS was defined not for the purpose of the present study, but for the purpose of clinical stratification of patients with AMI. Although we prospectively assigned AMI patients to each risk group according to nARS, the present study analyzed these clinical data retrospectively. Therefore, there were risks of patient selection bias and group selection bias due to the retrospective study design. Third, although we evaluated major complications potentially requiring ICU care in daily practice, there may be other clinical indications requiring ICU care (e.g., arrhythmia not leading to cardiac arrest or overnight management of vascular access sites). Fourth, the length of ICU/CCU stay was affected by the bed situation because patients who had passed the 2-minute standing test could not be transferred from the ICU/CCU to the general cardiology ward when beds were occupied by other patients. Fifth, there were some patients who skipped ICU/CCU care or the 2-minute standing test and were admitted directly to the general wards, which was typical when a patient had a type 2 myocardial infarction according to the universal definition.

**Conclusions**

Complications requiring ICU care rarely occurred in

| Complications | All (n = 592) | L-risk (n = 285) | I-risk (n = 124) | H-risk (n = 183) | P value |
|---------------|-------------|----------------|----------------|----------------|---------|
| Complications requiring ICU care (either CPA/death, shock, stroke, AVB or respiratory failure), n (%) | 239 (40.4%) | 50 (17.5%) | 63 (50.8%) | 126 (68.9%) | < 0.001 |
| Complications requiring ICU care that occurred in ICU setting | 211 (35.6%) | 42 (14.7%) | 59 (47.6%) | 110 (60.1%) | < 0.001 |
| Complications requiring ICU care that occurred in general wards | 28 (4.7%) | 8 (2.8%) | 4 (3.2%) | 16 (8.7%) | 0.009 |
| CPA/Death, n (%) | 45 (7.6%) | 4 (1.4%) | 8 (6.5%) | 33 (18.0%) | < 0.001 |
| CPA/Death in ICU setting | 38 (6.4%) | 2 (0.7%) | 6 (4.8%) | 30 (16.4%) | < 0.001 |
| CPA/Death in general wards | 7 (1.2%) | 2 (0.7%) | 2 (1.6%) | 3 (1.6%) | 0.581 |
| Shock, n (%) | 107 (18.1%) | 16 (5.6%) | 17 (13.7%) | 74 (40.4%) | < 0.001 |
| Shock in ICU setting | 90 (15.2%) | 11 (3.9%) | 16 (12.9%) | 63 (34.4%) | < 0.001 |
| Shock in general wards | 17 (2.9%) | 5 (1.8%) | 1 (0.8%) | 11 (6.0%) | 0.008 |
| Stroke, n (%) | 9 (1.5%) | 0 (0%) | 0 (0%) | 9 (1.5%) | < 0.001 |
| Stroke in ICU setting | 7 (1.2%) | 0 (0%) | 0 (0%) | 7 (3.8%) | < 0.001 |
| Stroke in general wards | 2 (0.3%) | 0 (0%) | 0 (0%) | 2 (1.1%) | 0.106 |
| AVB, n (%) | 11 (1.9%) | 2 (0.7%) | 3 (2.4%) | 6 (3.3%) | 0.08 |
| AVB in ICU setting | 11 (1.9%) | 2 (0.7%) | 3 (2.4%) | 6 (3.3%) | 0.115 |
| AVB in general wards | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | |
| Respiratory failure, n (%) | 212 (35.8%) | 38 (13.3%) | 56 (45.2%) | 118 (64.5%) | < 0.001 |
| Respiratory failure in ICU setting | 199 (33.6%) | 33 (11.6%) | 53 (42.7%) | 113 (61.7%) | < 0.001 |
| Respiratory failure in general wards | 13 (2.2%) | 5 (1.8%) | 3 (2.4%) | 5 (2.7%) | 0.76 |
| Major bleeding, n (%) | 95 (16.0%) | 15 (5.3%) | 19 (15.3%) | 61 (33.3%) | < 0.001 |
| Major bleeding in ICU setting | 81 (13.7%) | 10 (3.5%) | 16 (12.9%) | 55 (30.1%) | < 0.001 |
| Major bleeding in general wards | 14 (2.4%) | 5 (1.8%) | 3 (2.4%) | 6 (3.3%) | 0.526 |

Data are expressed as the mean ± SD or number (percentage). Pearson’s chi-square test was used for categorical variables. Normally distributed continuous variables were compared by one-way ANOVA, and Kruskal-Wallis test was performed for abnormally distributed continuous variables. CPA indicates cardiopulmonary arrest; AVB, atrioventricular block; ICU, intensive care unit; and CCU, coronary care unit.
the general wards in nARS, and there were fewer in the I- and L-risk groups than in the H-risk group. These results validated the nARS system, and might support the widespread use of nARS for sparing medical resources without sacrificing safety.

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Disclosure

Conflicts of interest: Dr. Sakakura has received speaking honoraria from Abbott Vascular, Boston Scientific, Medtronic Cardiovascular, Terumo, OrbusNeich, Japan Lifeline, Kaneka, and NIPRO; he has served as a proctor for Rotablator for Boston Scientific, and he has served as a consultant for Abbott Vascular and Boston Scientific. Prof. Fujita has served as a consultant for Mehergen Group Holdings, Inc.

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