Vascular Health and Risk Management

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ORIGINAL RESEARCH

Universal Early Discharge Protocol for Acute Myocardial Infarction: A Single-Center Prospective Validation

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Background and Aims: Selected low-risk myocardial infarction (MI) patients may be safely discharged within 72 hours. The aim was to prospectively validate a previously created protocol for selecting low-risk MI patients and to assess their safety.

Methods: We have previously proposed an early discharge protocol (EDP) for selecting low-risk acute coronary syndrome patients. We implemented EDP in July 2021 and selected patients were discharged within 72 hours. Survival was verified by the National Office of Health and Statistical Information. Finally, we compared all low-risk MI patients prior to (October 2018 to July 2021, Group A) and after (July 2021 to October 2023, Group B) EDP implementation in terms of length of hospital stay and financial costs.

Results: From July 2021 to September 2024, we selected 101 low-risk MI patients treated by percutaneous coronary intervention. There were 41.6% STEMI (n = 42). We report 100% survival at 30 days. Only a single death occurred in an average follow-up of 1.9 years (± 0.9). Discharge within 3 days was more often after EDP implementation, with the mean hospital stay of 4.7 days (95% CI = 4.4 to 4.9) and 4.2 days (95% CI = 4.0 to 4.4) in Group A and Group B, respectively, p = 0.053. Department-associated healthcare costs decreased from 2,105.4 euros (95% CI = 1,922.6 to 2,288.3) in Group A to 1,557.9 euros (95% CI = 1,428.5 to 1,946.1) in Group B, p = 0.016.

Conclusion: Implementation of a simple, universal protocol for selecting low-risk MI patients is feasible, represents excellent mid-term safety, and is associated with a decrease in healthcare-associated costs during index hospitalization.

Keywords: low risk, early discharge, myocardial infarction, percutaneous coronary intervention

Introduction

Acute coronary syndrome (ACS) represents a wide spectrum of clinical scenarios. From hemodynamically unstable patients in cardiogenic shock with an unfavorable prognosis and complex treatment requirements[1,2] to stable patients with an uncomplicated clinical course after percutaneous coronary intervention (PCI).

As a result, tailored healthcare and hospitalization approaches are required. Risk assessment is a fundamental tool in clinical and therapeutic workup. In the last decades, several risk scores have focused on identifying low-risk myocardial infarction (MI) patients treated by PCI.[3–7] European and American guidelines support this approach.[8,9] However, differences among scoring systems and complexity often limit their daily clinical use. As recently documented by PragueMi score, a personalized approach with periodical follow-up after discharge improved discrimination power compared to established risk scores.[10]

Our study group recently proposed a simple and universal scoring model for selecting low-risk ACS patients. In retrospective analysis, a combination of basic clinical, laboratory, echocardiography and angiography findings showed very promising results.[11]

https://doi.org/10.2147/VHRM.S581820
Received: 28 November 2025
Accepted: 12 March 2026
Published: 9 April 2026

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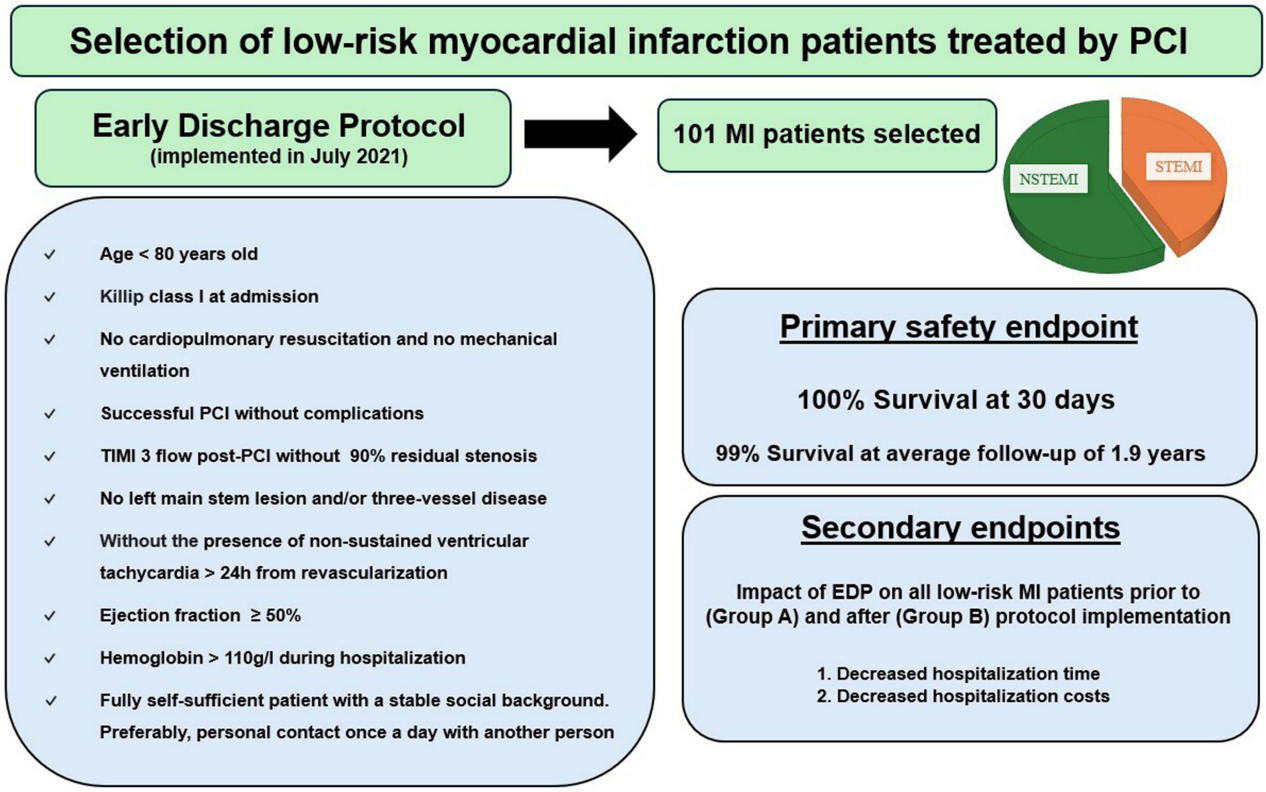
Graphical Abstract



We thought to prospectively validate this early discharge protocol (EDP) in low-risk MI patients in our high-volume cardiocentre. An integral part of EDP was personal education and periodical telephone follow-up. Furthermore, we thought to analyse the financial benefit and assess mid-term clinical safety for these patients.

Methodology

A prospective registry of patients with ACS admitted to the University Hospital Královské Vinohrady Cardiocentre, in Prague, Czech Republic, was created in 2018 and was previously described in detail.[12] ACS was defined based on, at that time, current European guidelines for patients with myocardial infarction (MI) with ST segment elevation (STEMI) and ACS without ST elevation (NSTE-ACS).[13,14] When the time from symptom onset to first medical contact, including electrocardiogram (ECG) results with typical features with ST elevation, exceeded 24 h, patients were characterized as having subacute STEMI. There were no exclusion criteria for patients admitted with a final diagnosis of ACS. The registry was approved by the local ethics committee.

We initially analysed 1420 consecutive patients with ACS admitted to our cardiology department between 1 October 2018 and 31 December 2020 and correlated 27 clinical, laboratory, echocardiographic and angiographic variables to 30-day survival. Based on these previously reported results, we created a protocol using the most relevant variables for selecting low-risk ACS patients. In the retrospective registry analysis, this combination of variables demonstrated excellent discriminatory power, identifying patients with a 100% survival rate within the first 30 days following ACS.[11]

In July 2021, we implemented this protocol into clinical practice in the University Hospital Královské Vinohrady Cardiocentre, Prague, Czech Republic. Each patient with an MI diagnosis was screened between 24 and 36 hours after

admission, with all relevant clinical data available. Patients were selected as low-risk when all criteria per protocol were fulfilled. Prior to discharge, an experienced nurse educated each patient with a dedicated booklet created by our institution for this purpose. If the treating physician did not find any clinically significant obstacle, the patient was discharged from the hospital within 48–72 hours of admission.

Subsequently, a patient's follow-up was arranged. An experienced nurse contacted patients by phone within 7 days, 30 days and 1 year after hospital discharge to collect relevant treatment data and rehabilitation progress. All patients' concerns were addressed in cooperation with an experienced physician.

We analysed all collected data, complemented by survival data with the cooperation of the National Office of Health and Statistical Information (date of censoring 31st of December 2024). We aimed to prove the safety of the early discharge approach; therefore, 30-day survival and mid-term survival data were of primary interest. Secondly, we recorded the rehospitalization rate assessed by telephonic follow-up. A flowchart of patient selection and the primary safety endpoint is shown in Figure 1. Patient compliance was assessed by the National Prescription Service, where the data on prescribed and collected medication were evaluated. We focused on regular (>50%) antithrombotic treatment, since other medications may vary over time. Finally, we analysed the hospitalization stay and potential reduction in healthcare resources. Two different time periods were compared: 33 months (from October 2018 to July 2021) prior to (Group A) and 28 months (from July 2021 to October 2023) after the EDP

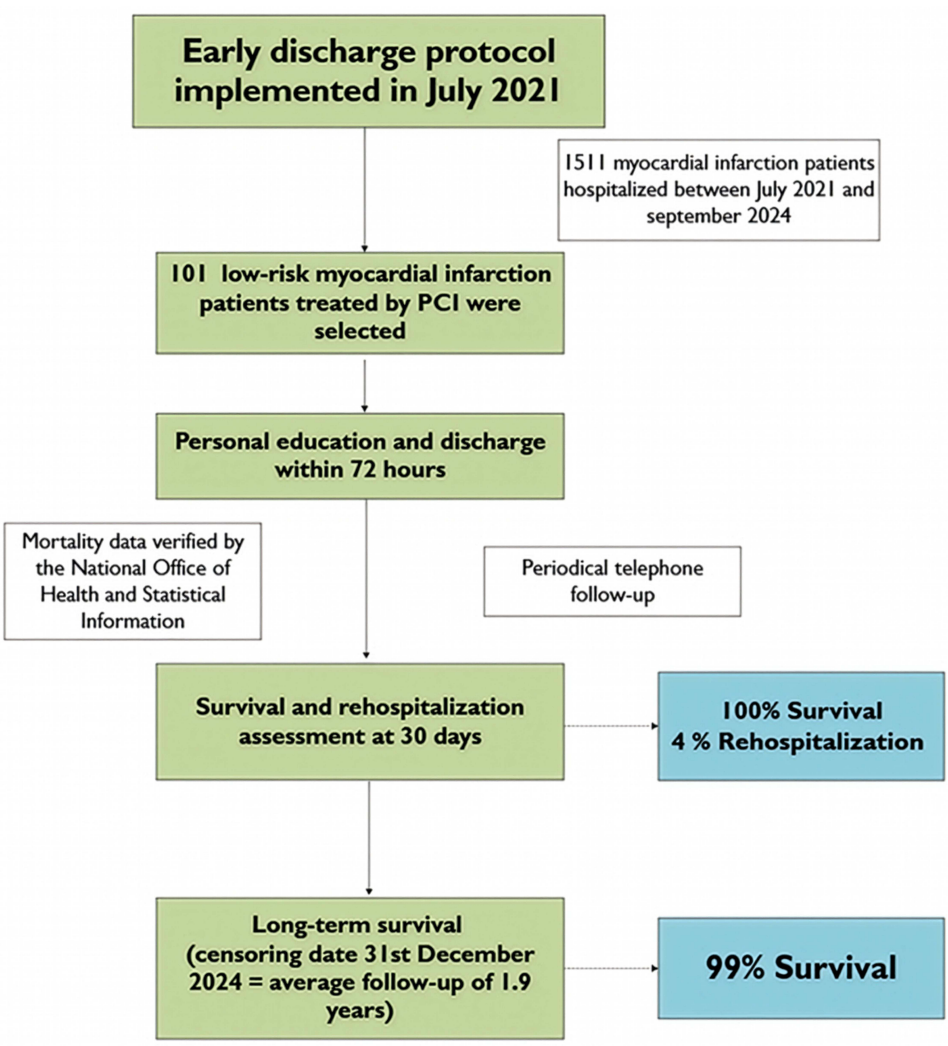


Figure 1 A flowchart of low-risk MI patients' selection for early discharge, follow-up and survival.

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implementation (Group B). Department-associated healthcare expenses analysis included direct and indirect costs for hospital stay, with exclusion of cathlab-associated expenses, which do not significantly differ among low-risk MI patients. Direct costs were calculated by identifying the medications and materials each patient consumed. Indirect costs were those not directly related to patients, such as the emoluments of medical staff, the amortization of devices, and materials. Indirect costs were allocated to patients using the cost drivers that best expressed the relationships between costs and the health services provided (number of days in the coronary care unit, number of days in the standard ward and point values of health services provided by other medical departments). Calculations in Czech crowns were converted into euros according to the exchange rate of the Czech National Bank on 29 June 2025.

Statistical Analysis

Descriptive statistics were used, with categorical variables expressed as counts and percentages, and continuous variables presented as medians with interquartile ranges or as means ± standard deviations, where appropriate. To compare continuous variables between two independent groups, the non-parametric Mann–Whitney *U*-test was applied. Statistical significance was assessed using p-values, with a significance threshold set at 0.05. Ninety-five percent confidence intervals were reported where applicable. Statistical analyses were performed using MedCalc software (version 22.009) and SigmaPlot (version 15.0.0.13).

Results

There were 1511 patients hospitalized with MI in our center between July 2021 and September 2024. We implemented the early discharge protocol into clinical practice and identified 101 low-risk patients with MI (42 STEMI and 59 NSTEMI). Basic clinical characteristics and pharmacotherapy at discharge are shown in Table 1.

Table 1 Clinical Characteristics of Low-Risk Myocardial Infarction Patients Discharged Within 72 hours

	Low-Risk Patients with Myocardial Infarction n=101
Age	58.2 ± 10.3
Men	76 (75.2%)
History of PCI	7 (6.9%)
History of MI	5 (4.9%)
History of CABG	0 (0%)
History of stroke	1 (1%)
Hypertension	44 (43.6%)
Dyslipidemia	34 (33.7%)
Diabetes	17 (16.8%)
ECG rhythm	
Sinus	99 (98%)
Atrial fibrillation/flutter	2 (2%)

(*Continued*)

Table 1 (Continued).

	Low-Risk Patients with Myocardial Infarction n=101
Pharmacotherapy at discharge	
ACE inhibitors/sartans	93 (92.1%)
Beta-blockers	55 (54.5%)
Acetylsalicylic acid	100 (99%)
Clopidogrel	11 (10.9%)
Ticagrelor	89 (88.1%)
Anticoagulation (DOAC)	2 (2%)

Abbreviations: PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft surgery; ECG, electrocardiogram; ACE, angiotensin-converting enzyme; DOAC, direct oral anticoagulants.

All of these patients were successfully discharged from the hospital within 72 hours of admission. Average hospitalization time was 2.5 days (± 0.6), in STEMI 2.7 (± 0.7) and NSTEMI 2.3 (± 0.7) days.

Follow-up

Rehospitalization occurred in 4 patients within 30 days, of which 2 were due to cardiovascular causes. First was an unstable angina pectoris with PCI, and the second was due to syncope of unknown origin. Two other re-hospitalizations occurred due to non-cardiovascular causes. During the average follow-up of 1.9 years (± 0.9), there was a single death, 627 days (1.7 years) after discharge. The electronic data of pharmacological compliance was obtained retrospectively from 93 patients. Eighty-nine patients (95%) took the prescribed medication regularly, 4 patients less than 50% of the time. In 8 cases, we were not able to access personal data.

Impact of the Implemented Early Discharge Protocol

We conducted a retrospective analysis to evaluate the impact of the implemented early discharge protocol (EDP) on clinical practice. Two different time periods were compared: prior to (Group A) and after the EDP implementation (Group B). In both groups, only low-risk patients were retrospectively selected based on our standardized EDP (Supplementary Figure 1). There were 245 low-risk MI (17.9% of all MI) and 205 low-risk MI patients (19.3% of all MI) in Group A and Group B, respectively. Figure 2 documents the positive impact of EDP with a higher percentage of low-risk MI patients discharged within 3 days (32.7% in Group A vs. 49.3% in Group B).

Subsequently, we conducted a more detailed analysis to describe the impact of EDP on the general hospitalization length and cost of all low-risk MI patients. In order to get precise data, low-risk MI patients transferred to the referring hospital were excluded from the analysis. The total hospitalization length for Group A and Group B is shown in Figure 3. In both groups, 158 patients were analysed. The mean hospital stay in Group A was 4.7 days (95% confidence interval [CI] = 4.4 to 4.9) and in Group B, 4.2 days (95% CI = 4.0 to 4.4), p = 0.053. (The mean hospital length of stay throughout the years is displayed in Supplemental Figure 2).

Economical Resources

Hospitalization costs consist of procedural and department-associated healthcare expenses. We focus on the latter, since procedural costs are not influenced by earlier discharge in the group of low-risk patients. We present hospital expenses in Group A and Group B (Supplemental Figure 3). Mean hospitalization cost in Group A (n=155) was 2,105.4 euros (95% CI = 1,946.1to 2,345.5) and in Group B (n=102) was 1,557.9 (95% CI = 1,428.5 to 1,946.1), p = 0.016.

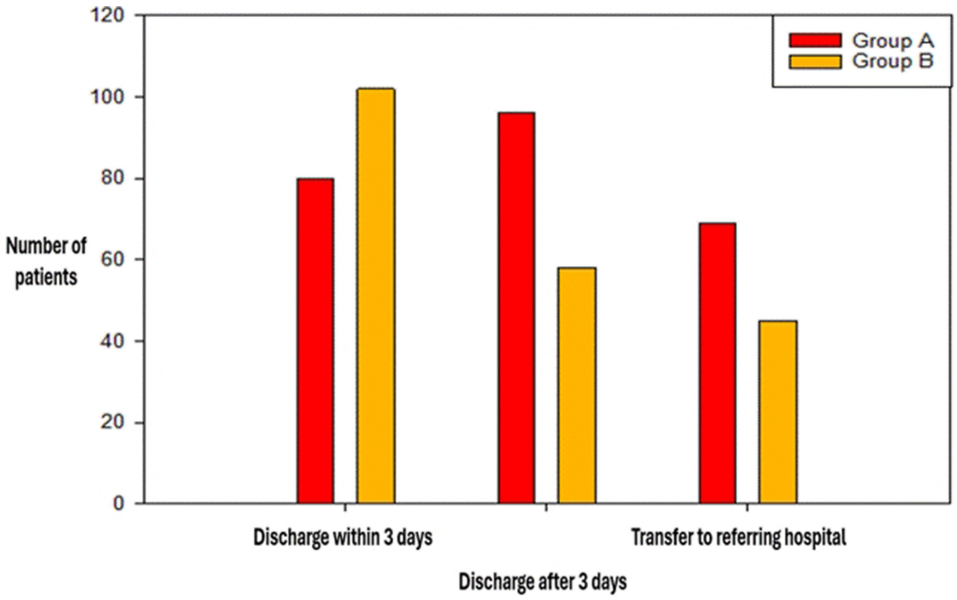

Figure 2 Comparison of low-risk myocardial infarction hospitalization management prior to (Group **A**) and after (Group (**B**) the early discharge protocol implementation.

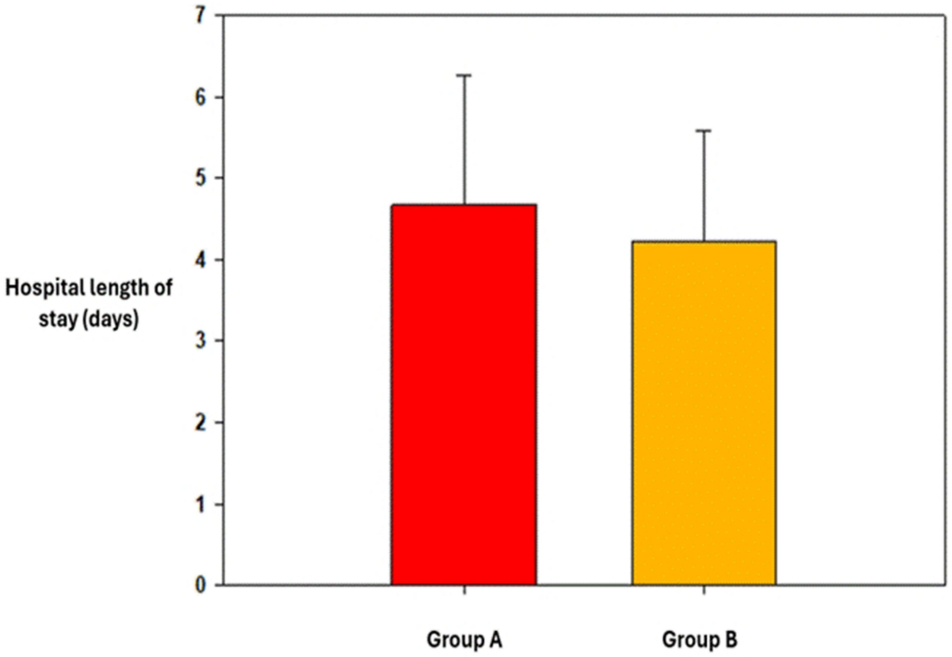

Figure 3 Total hospital length of stay for low-risk MI patients prior to (Group **A**) and after (Group **B**) EDP implementation.

Compliance

In order to assess the impact of individualized education on patient compliance, we compared educated (n = 101) with other non-educated low-risk MI patients prior to discharge (n = 336). We were able to access the prescription history in the majority of both, 92.1% educated (n = 93) and 91.7% not educated (n = 308) patients. Out of these, prescriptions were collected on a regular basis by 95.7% (n = 89) educated and 92.5% (n = 285) non-educated patients. There was no statistical difference regarding pharmacological prescription collection based on individualized education prior to discharge, p = 0.777.

Discussion

Implementing a validated protocol for selecting low-risk patients with MI treated by PCI shows the following:

1. A universal protocol for selecting low-risk patients is sufficient for both types of MI (STEMI and NSTEMI)
2. Early discharge of low-risk patients with MI is feasible and safe across all age groups
3. Systematic selection of low-risk MI patients decreases hospitalization time and reduces healthcare expenses
4. Low-risk MI patients have high medical adherence regardless of in-hospital education.

Risk stratification of MI patients requires a complex evaluation and individual consideration. Stratification models emerged during the thrombolytic era. Routine PCI and progress in therapeutic standards have subsequently contributed to the evolution of stratification models.[15] Although a wide range of scoring systems are available, only a limited number meet the criteria for daily clinical use.

De Luca introduced a useful risk assessment tool in 2004. A Zwolle risk score has been developed to select low-risk STEMI patients eligible for earlier discharge. Original data documented a 0.5% mortality at 30 days (1.2% in patients with a score of 3).[4] Subsequently Zwolle risk score has been validated by numerous studies with very consistent results.[16–18] A universal CADILLAC risk score can be applied for both MI types. Several variables weighted proportionally well describe both clinical and complementary findings, with a mortality rate of 0.1% at 30 days.[3] Currently, the American College of Cardiology recommends the use of the Zwolle risk score for the detection of low-risk STEMI patients, feasible for earlier discharge (within 3 days). Regarding less-studied NSTEMI, there is no specific stratification model recommended. However, same-day discharge after PCI may be considered in patients without troponin elevation (unstable angina pectoris). European guidelines support a similar approach. Low-risk ACS patient selection and earlier discharge (within 48–72 hours) is a feasible option, as pointed out by Zwolle, PAMI and another smaller Czech trial. Additionally, the well-known GRACE scoring system may be utilized for risk stratification and timing of intervention in NSTE-ACS patients.[6] Both guidelines highlight the need for early rehabilitation and adequate follow-up.[8,9]

Recently, Rathod et al presented 12-month clinical outcomes of 1500 STEMI patients treated by PCI, discharged within 48 hours. Criteria are similar to those used by our study group: Left ventricular ejection fraction ≥40%; Successful primary PCI (achieved Thrombolysis In Myocardial Infarction [TIMI] flow grade 3); Absence of bystander disease requiring inpatient revascularization; No recurrence of ischemic symptoms; Absence of heart failure or hemodynamic instability (ie, Killip class 1); No significant arrhythmias (ventricular fibrillation, ventricular tachycardia, or atrial fibrillation/flutter requiring prolongation of stay for ventricular rate control) after the procedure; Mobility, with suitable social circumstances for discharge. The most prominent difference is a lower ejection fraction threshold and no age limit. The mean hospital stay was 24.9 hours. MACE occurred in 3.1% with a 0.6% mortality rate. However, data regarding the time from hospital discharge to death were not presented.[19,20]

The EDP proposed by our study group shows several advantages. First, a simple binary model without a need for a dedicated calculator or weighted variables allows its bedside utilization. It identifies simple clinical, echocardiographic, angiographic, and laboratory findings. Another undisputed advantage of EDP is its application for both MI types (STEMI and NSTEMI). We developed this stratification model based on a single-center retrospective ACS analysis with very promising results.[11] However, there was a lower percentage of selected low-risk MI patients in the prospective validation than expected. Generally, there are a few potential reasons for prolonged hospitalization: a staged coronary procedure or need for cardiac monitoring in an intermediate care unit or titration of medication. Our main limitation was that the subset of low-risk patients were transferred to the referring hospital. A similar decrease in prospective validation by other risk scores reflects clinical practice. An external validation of the Zwolle risk score identified 70% of patients as low-risk; however, only 28% were discharged within 72 hours (median hospitalization stay of all low-risk patients was 4.0 days), with 0.6% mortality at 30 days.[21] In European countries, it is estimated that about 26–28% of potential eligible patients have an early discharge.[22] Another frequently addressed reason for these discrepancies is weekends and public holidays. The "weekend effect" also prolongs hospitalization time when patients' admission is on Friday or during the weekend.[23]

Second, the safety of EDP is documented by an excellent 100% survival rate at 30 days. Such an exceptional outcome in prospective validation was presented only recently by Rathod et al[19] Although we present a lower number of early discharged patients, the excellent mid-term safety with a single death in an average follow-up of 1.9 years is, to the best of our knowledge, the lowest mid-term mortality ever presented in MI patients.[3,4,19,20,24–26] The age limit in our protocol is less strict compared to similar risk stratification models. In our low-risk MI cohort, there are 25 patients (24.3%) over 65 years of age. Increased age in all aforementioned risk scores is associated with higher mortality risk (gradual in GRACE, ≥60 years in ZWOLLE, and >65 in CADILLAC). When applying the same scoring model to our cohort of 25 patients, the average GRACE is 112.1 (± 14.8), which would shift these patients from low to intermediate risk group with an average 6-month mortality of 6.7% (±3.2). The recently proposed protocol for STEMI patients does not include an age threshold.[19] Nevertheless, the average age is very similar between our groups (59.4 ± 8.5 years vs. 58.2 ± 10.3 years). This highlights an important finding: The course of myocardial infarction with contemporary treatment can be mild with excellent outcome despite older age.

Low-risk MI patient selection differs based on the stratification model. Our EDP selected 101 MI patients; however, other scoring models would have excluded some patients. According to the GRACE risk score, 16 (15.8%) patients would be re-classified as intermediate risk with an average score of 123 (± 7.1) and an estimated 6-month mortality of 8.9% (± 2.2%). Additionally, based on the CADILLAC risk score, there would be 3 patients with intermediate and 1 patient with a high-risk score, reaching 1.9% and 8.1% estimated mortality risk at 30 days, respectively. All STEMI-selected patients by our protocol would meet ZWOLLE criteria for low risk, with an average score of 1.3 (± 1.0).

Third, the reduction of the hospital length of stay has several advantages. Earlier discharge of MI patients treated by PCI has been documented as cost-effective. De Luca et al documented this advantage two decades ago.[4] The second Primary Angioplasty in Myocardial Infarction (PAMI-II) study calculated healthcare cost reduction of 16.7% by earlier discharge.[5] Our average hospitalization cost reduction was 22.7%. However, our analysis focused on department-associated costs, so direct comparison would be inaccurate. To emphasize the impact of EDP, our cost-effectiveness analysis was limited to low-risk MI patients prior to (Group A) and after (Group B) EDP implementation. These rather explanatory results may indicate the positive economic impact of earlier discharge. Another important aspect of a reduced hospital length of stay is the decreased risk of healthcare-associated infections (HAI). One study showed that each hospitalization day increases the risk of HAI by 1.37% and conversely, the onset of HAI increases hospital length of stay by almost 10 days.[27] Furthermore, increased bed availability has the potential to lower waiting times for elective procedures with, to some degree, mortality consequences.[28]

Fourth, the education of MI patients plays an important role. Properly educated patients have higher therapy adherence.[29] Similarly, early follow-up after hospitalization for MI is associated with better compliance and a higher rate of guideline-recommended treatment.[30] Several factors influence adherence to medical therapy after MI, including age. Adherence level decreases proportionally after hospital discharge. At 1 year, patients' compliance for guideline-recommended medical therapy, including P2Y12 inhibitors, is surprisingly low.[31,32] Discontinuation of DAPT for at least a month is documented to be 6.8% after only 30 days following discharge and increases to almost 50% in the following year.[33] We report a high percentage of regularly collected pharmacological prescriptions as a surrogate indicator for medical adherence, irrespective of in-hospital education. Interestingly, the compliance of non-educated low-risk MI patients reached 92.5%. Although individualized education did increase compliance to 95.7%, we have to take into account the different average follow-up periods in both groups that could also influence the results. It is, however, an important indicator of advanced-level healthcare and potential secondary prevention benefits.

Limitations

Our study has several limitations. First, the single-center protocol validation included only a limited number of patients. This is pronounced by the fact that part of the low-risk MI patients (22.0%) were transferred to a local hospital prior to discharge. Subsequent follow-up of such patients is lacking. Second, since follow-up of discharged patients has been done by telephone, some clinical data may have been missed. We focused on the mortality endpoint, which was confirmed by the Institute of Health Information and Statistics of the Czech Republic; however, other clinical data are missing. A post-hoc comparison of different risk scores is underpowered, and EDP may identify different risk subsets.

Third, cost-effectiveness for both time periods was calculated based on public health insurance coverage from the same year (2022). We were able to retrospectively obtain all cost-associated data from a limited number of low-risk MI patients (57%). Therefore, the cost analysis could be biased. Fourth, patients' compliance with treatment after discharge was assessed retrospectively by use of the national electronic prescription system. These data were not accessible in 8.2%; therefore, some patients could have a missing record regardless of compliance. Moreover, prescription collection is only a surrogate indicator of compliance and does not ensure patient compliance. The absence of a demonstrable effect of individualized education may therefore reflect methodological limitations rather than a lack of clinical impact. Finally, practice patterns, nursing support, rehabilitation pathways, and social circumstances may differ substantially across centres and healthcare systems. Therefore, a larger multi-center validation with extended follow-up is warranted to confirm our encouraging results.

Conclusion

Implementation of a simple, universal protocol for selecting low-risk MI patients is feasible and safe. We report an average hospitalization time of 2.5 days with excellent 100% survival at 30 days. The average follow-up of 1.9 years confirms mid-term safety of EDP, with a single death occurring 1.7 years after discharge. Systematic selection and earlier discharge of low-risk MI may decrease the length of hospitalization and its costs.

Data Sharing Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Ethics Approval

An acute coronary syndrome registry has been approved by the Faculty Hospital Královské Vinohrady and the Third Faculty of Medicine Charles University ethics committee (No. EK-R/01/0/2017, part of "Interventional treatment of life-threatening cardiovascular diseases" within the framework of the grant call OP VVV No.0216026 "Long-term inter-sectoral cooperation") and was conducted in accordance with the ethical principles of the Declaration of Helsinki. Due to the nature of the study, following current ESC guidelines, the requirement for informed consent was waived by the ethics committee. Despite the prospective nature of the study, all data were fully anonymized before analysis, ensuring that no identifiable information was available to the investigators. The study posed minimal risk to participants, and strict confidentiality of patient data was maintained in compliance with relevant data protection legislation.

Acknowledgment

This manuscript is based on the first author's doctoral thesis "Risk stratification of acute coronary syndrome treated by percutaneous coronary intervention" (Third Faculty of Medicine, Charles University, 2026).[34]

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This research was funded by the Charles University Research programs: University Research Centers (UNCE 204010) and "Cooperatio – Cardiovascular Science".

Disclosure

P. Tousek reports consultant contract and lecture fees from Medtronic. V. Kocka reports consultant contract, lectures and advisory board contract from Medtronic and Phillips; lecture fees from Edwards LifeSciences; personal fees from B Braun, personal fees from Terumo, during the conduct of the study. Other authors do not declare any potential conflicts of interest.

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