Outcomes of Myocardial Infarction in Hospitals With Percutaneous Coronary Intervention Facilities

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Background: Despite evidence on the efficacy and safety of percutaneous coronary intervention (PCI) for patients with acute myocardial infarction, it is unclear whether patients admitted to hospitals with on-site PCI facilities (hereinafter, PCI hospitals) have improved outcomes in routine practice.

Methods: We compared processes of care, hospital outcomes, and 1-year mortality rate for 1176 consecutive patients admitted to 126 PCI hospitals and 738 patients admitted to 190 non-PCI hospitals in France from November 1 to November 30, 2000.

Results: Patients admitted to PCI hospitals were more likely to receive evidence-based acute (within 48 hours of admission) and discharge medications and to undergo PCI within 48 hours of admission than those admitted to non-PCI hospitals (54% vs 6.2%; P < .001). Despite comparable rates of in-hospital stroke (0.9% vs 1.1%; P = .75) and reinfarction (1.7% vs 2.5%; P = .25), patients admitted to PCI vs non-PCI hospitals had lower in-hospital (7.5% vs 12%; P = .001) and 1-year (13% vs 20%; P < .001) mortality rates. Admission to PCI hospitals was associated with decreased hazard ratios of mortality after adjusting for baseline characteristics (0.75; 95% confidence interval, 0.57-0.98) or propensity score (0.76; 95% confidence interval, 0.59-0.97). Most of the survival benefit of admission to a PCI hospital was explained by the use of PCI and evidence-based discharge medications.

Conclusions: In this prospective observational study, admission of patients with acute myocardial infarction to PCI hospitals was associated with greater use of PCI and evidence-based medications and with improved 1-year survival. Although we cannot exclude the possibility that some unmeasured confounding factors might explain the survival benefit of admission to PCI hospitals, our findings support routine use of PCI and evidence-based medications for these patients.

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Percutaneous coronary intervention (PCI) is a proven therapeutic approach for patients with acute ST-segment elevation myocardial infarction. Meta-analyses of randomized controlled trials have shown that primary PCI is associated with improved outcomes compared with thrombolysis, even if the patient’s transfer to a hospital with PCI facilities (hereinafter, PCI hospital) is needed. There is also evidence supporting routine PCI within 24 hours of thrombolysis and rescue angioplasty after failed thrombolysis.

Although promising, the results of these randomized trials have limited generalizability because of the investigators’ reluctance to enroll high-risk patients, performance of PCI at tertiary care centers with a high annual volume of procedures, and time delays that were much shorter than in the real world. In addition, observational studies failed to document any differences in mortality rates for patients presenting at hospitals with vs without on-site catheterization facilities, despite higher rates of PCI use for patients first admitted to hospitals with catheterization facilities.

The aim of this study was to compare processes of care, hospital outcomes, and 1-year mortality rates for patients with acute myocardial infarction who were first admitted to PCI vs non-PCI hospitals.

Methods

Study Design

The Unite´ de Soins Intensifs Coronaires (USIC) 2000 study is a prospective cohort study designed to collect complete and representative data on processes of care and clinical outcomes for patients with acute myocardial in-
Categorical variables were expressed as frequency and percentage and continuous variables as median and interquartile range (IQR). Differences in characteristics for patients first admitted to PCI vs non-PCI hospitals were compared using the \( \chi^2 \) or Fisher exact tests for categorical variables and the Wilcoxon rank sum test for continuous variables.

Hospital mortality was compared for patients first admitted to PCI vs non-PCI hospitals, using univariable and multivariable logistic regression. Multivariable analysis was adjusted for the patient baseline characteristics listed in Table 2. The confounding effect of age was adjusted using a linear spline with knots at 45, 55, 65, 75, and 85 years. Because of the high correlation between on-site PCI availability at the admitting hospital and the use of PCI, the latter variable was not included in the model. All first-order interactions involving on-site PCI availability at the admitting hospital were systematically assessed. The final logistic regression model yielded a C statistic of 0.86, and the corresponding Hosmer-Lemeshow goodness-of-fit \( \chi^2 \) was 5.26 (\( P = .72 \)).

We also performed a propensity score analysis to adjust for imbalances in measured covariates between patients first admitted to PCI vs non-PCI hospitals. Our propensity score analysis attempted to compare outcomes for patients first admitted to PCI vs non-PCI hospitals who had a similar distribution of measured covariates, and in this way approximated the conditions of random site of admission assignment. For this purpose, we first developed a full, nonparsimonious logistic regression model to derive a propensity score for admission to PCI hospitals that included the patient baseline characteristics listed in Table 2. Each patient was assigned a propensity score using the logistic regression model. This score ranged from 0.13 to 0.92 and reflected the probability that a patient would be admitted to a PCI hospital. Our propensity score model yielded a C statistic of 0.67, and the corresponding Hosmer-Lemeshow goodness-of-fit \( \chi^2 \) was 7.76 (\( P = .46 \)). Patients were stratified by quintile of increasing propensity score. We found adequate overlap in propensity score within each quintile and no residual imbalances in covariates for patients admitted to PCI vs non-PCI hospitals after adjusting for quintile. We then used a logistic regression model to estimate the odds ratio for hospital mortality associated with admission to PCI hospitals after adjusting for the quintile of propensity score. Because of the low number of events within comparison groups, adjusted odds ratios for in-hospital stroke and reinfarction could not be estimated in multivariable or propensity analysis.

Hazard ratios for 1-year mortality associated with PCI hospital admission were estimated using Cox proportional hazard models adjusting for baseline characteristics and quintile of propensity score. To determine the role of discharge medications and PCI use within 48 hours of admission in the protective effect of admission to PCI hospitals, these variables were included in separate analyses limited to patients who were discharged alive. The proportional hazard assumption was confirmed by inspection of log(-log [survival]) curves and by examination of Schoenfeld residuals.

Fifty-seven patients (4.8%) admitted to PCI hospitals and 38 patients (5.1%) admitted to non-PCI hospitals had missing data for 1 or more covariates. Exclusion of these patients from the analyses did not modify the estimates of mortality rates or the hazard ratios of mortality associated with admission to PCI hospitals. For all analyses, we used robust estimates of vari-
Of the 2320 patients enrolled in the USIC 2000 study, 1922 had ST-segment elevation, or a presumed new Q-wave or left bundle-branch block. Of these, 8 patients were excluded because of missing information about the hospitals that had first admitted them. Our analytical sample consisted of 1914 patients, with a median number of 4 patients (IQR, 2-8) enrolled per hospital (Table 1). A total of 1176 patients (61%) were first admitted to PCI hospitals and 738 patients (39%) to non-PCI hospitals.

The median age for all patients was 67 years (IQR, 53-76 years), 1393 (73%) were men, 395 (21%) had diabetes mellitus, and 299 (16%) had a prior myocardial infarction. At presentation, 745 patients (39%) had anterior infarct location, and 426 (22%) presented with a Killip class of II or higher. Patients admitted to PCI hospitals were more likely to be current smokers, to have undergone prior PCI, and to be transported by mobile ICU (Table 2). In contrast, patients admitted to non-PCI hospitals were older and more likely to have hypertension and to present with a Killip class of II or higher.

Patients first admitted to PCI hospitals were more likely to undergo PCI (either primary PCI, within 48 hours of admission, or at anytime during hospital stay) and treatment with an intra-aortic balloon pump, whereas those admitted to non-PCI hospitals were more likely to undergo coronary artery bypass graft surgery and to receive thrombolysis (Table 3). Of patients who were admitted to PCI vs non-PCI hospitals, 58% and 40%, respectively, received reperfusion therapy (ie, thrombolysis [22% and 39%, respectively] or primary PCI [36% and 1%, respectively]). Of the 940 patients who did not receive any reperfusion therapy, 424 (45%) were admitted more than 12 hours after symptom onset, with no difference between PCI and non-PCI hospitals. The median time to intravenous administration of thrombolysis was not different for patients who were admitted to PCI (2 hours; IQR, 2-3 hours) vs non-PCI hospitals (2 hours; IQR, 1-3.3 hours) (P=.33), whereas patients admitted to PCI hospitals had a shorter time to PCI (median, 4.2 hours vs 14 hours; P<.01). Although patients who underwent PCI were healthier than those who did not, the baseline characteristics that were associated with the performance of PCI were similar for both patients admitted to PCI hospitals and those admitted to non-PCI hospitals (data not shown). Compared with those patients admitted to non-PCI hospitals, those admitted to PCI hospitals had shorter lengths of stay and were more likely to receive evidence-based acute (within 48 hours of admission) and discharge medications, including low-molecular-weight heparin within 48 hours of admission, and antiplatelet agents, β-blockers, and statins within 48 hours of admission and at discharge (Table 3 and Table 4).

Although the rates of in-hospital stroke and reinfarction were similar for both groups, patients admitted to PCI hospitals had lower hospital mortality and a non-significant trend toward a decreased odds ratio of hos-
table 3. in-hospital procedures, medical treatments, and course for 1914 patients who were first admitted to hospitals with and without on-site PCI facilities*  

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Patients Admitted to Hospitals</th>
<th>P</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With On-site PCI Facilities (n = 1176)</td>
<td>Without On-site PCI Facilities (n = 738)</td>
<td></td>
</tr>
<tr>
<td>Procedures†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary PCI</td>
<td>421 (36)</td>
<td>9 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>PCI within 48 h of admission</td>
<td>631 (54)</td>
<td>46 (6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>PCI at any time</td>
<td>864 (73)</td>
<td>289 (39)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coronary artery bypass graft surgery</td>
<td>25 (2)</td>
<td>27 (4)</td>
<td>.04</td>
</tr>
<tr>
<td>Intra-aortic balloon pump</td>
<td>43 (4)</td>
<td>11 (1)</td>
<td>.005</td>
</tr>
<tr>
<td>Medications used within 48 h of admission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrombolysis</td>
<td>255 (22)</td>
<td>289 (39)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Unfractionated heparin</td>
<td>916 (78)</td>
<td>585 (79)</td>
<td>.48</td>
</tr>
<tr>
<td>Low-molecular-weight heparin</td>
<td>372 (32)</td>
<td>166 (22)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Glycoprotein IIb/IIIa inhibitors</td>
<td>318 (27)</td>
<td>35 (5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Antiplatelet agents</td>
<td>1144 (97)</td>
<td>674 (91)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>878 (75)</td>
<td>489 (66)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Statins</td>
<td>579 (49)</td>
<td>282 (38)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Left ventricular ejection fraction &lt;35%‡</td>
<td>144 (12)</td>
<td>93 (13)</td>
<td>.82</td>
</tr>
<tr>
<td>Length of stay, median (IQR), d§</td>
<td>9 (7-12)</td>
<td>11 (9-15)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range; PCI, percutaneous coronary intervention.  
*Data are given as number (percentage) except where noted.   
†Values for in-hospital procedures were missing for PCI at any time in 53 patients, coronary artery bypass graft surgery in 24 patients, and intra-aortic balloon pump in 35 patients.  
‡Left ventricular ejection fraction was unspecified for 204 patients.  
§Length of stay was missing for 3 patients known to be alive at discharge.

In this nationwide prospective cohort study of patients with acute myocardial infarction, admission to a PCI hospital was associated with better processes of care and lower 1-year mortality rates than admission to a non-PCI hospital. In addition, this study showed that most of the survival benefit of admission to a PCI hospital was explained by a more frequent use of PCI and evidence-based discharge medications.

These findings are supported by randomized controlled trials that demonstrated the efficacy and safety of primary PCI as well as routine and rescue PCI after thrombolysis for patients with ST-segment elevation myocardial infarction. They are also consistent with the findings of other observational studies. In a prospective cohort study of 14,947 patients with acute myocardial infarction, primary PCI was associated with shorter length of hospital stay, less frequent readmission and reinfarction, and lower mortality rate than thrombolysis.13 In the Canadian-American Global Use of Strategies to Open Occluded Coronary Arteries Ilb/14 and the Myocardial Infarction and Triage Intervention15 studies, the presence of on-site catheterization facilities at the admitting hospital was associated with greater use of PCI and lower 1- and 3-year mortality rates for patients with ST-segment elevation myocardial infarction. In contrast, Krumholz et al16 reported comparable short- and long-term mortality rates for Medicare patients who were admitted to hospitals with and without catheterization facilities. However, in this study, patients originally admitted to hospitals with vs without such facilities had comparable rates of coronary revascularization procedures during the index episode of care (19.5% vs 20.5%).17 The European Network for Acute Coronary Treatment study17 found a more frequent use of PCI in patients with ST-segment elevation myocardial infarction who were admitted to hospitals with on-site catheterization facilities but with no discernible effect on in-hospital mortality. This latter study was underpowered to detect a moderate difference in mortality rates, and a longer follow-up would have been required to demonstrate any survival benefit for patients admitted to hospitals with catheterization facilities. The Global Registry of Acute Coronary Events showed that patients admitted to hospitals with catheterization facilities had no survival benefit by 6 months and an increased risk for major bleeding,18 although there was a potential for overadjustment in this
Table 5. Comparison of Outcomes for Patients Who Were First Admitted to Hospitals With and Without On-site PCI Facilities

<table>
<thead>
<tr>
<th>Outcome</th>
<th>With On-site PCI Facilities</th>
<th>Without On-site PCI Facilities</th>
<th>OR or HR† (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital stroke§</td>
<td>11/1172 (1)</td>
<td>8/734 (1)</td>
<td>0.86 (0.33-2.22)</td>
<td>.75</td>
</tr>
<tr>
<td>In-hospital reinfarction‡</td>
<td>20/1174 (2)</td>
<td>18/733 (2)</td>
<td>0.69 (0.36-1.30)</td>
<td>.25</td>
</tr>
<tr>
<td>In-hospital mortality rate</td>
<td>Unadjusted</td>
<td>88/1176 (7)</td>
<td>0.57 (0.41-0.80)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>Adjusted for baseline characteristics, %§</td>
<td>3.6 (5.2)</td>
<td>0.69 (0.45-1.06)</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Adjusted for quintile of propensity score, %§</td>
<td>7.2 (9.8)</td>
<td>0.72 (0.51-1.02)</td>
<td>.06</td>
</tr>
<tr>
<td>1-y mortality rate</td>
<td>Unadjusted</td>
<td>147/1176 (13)</td>
<td>0.60 (0.47-0.75)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Adjusted for baseline characteristics§</td>
<td>13 (16)</td>
<td>0.75 (0.57-0.98)</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Adjusted for quintile of propensity score§</td>
<td>13 (16)</td>
<td>0.76 (0.59-0.97)</td>
<td>.03</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; HR, hazard ratio; OR, odds ratio; PCI, percutaneous coronary intervention.
*Data are given as number/total (percentage) except where noted.
†We estimated ORs for in-hospital events and HRs for 1-year mortality rate.
‡Values were missing for stroke in 8 patients and reinfarction in 7 patients; ORs for stroke and reinfarction were unadjusted because of the low number of events.
§Ninety-five patients were excluded from multivariable and propensity analyses because of missing values. Percentages were estimates of adjusted mortality in multivariable models.
¶Unique estimates of adjusted 1-year mortality rate could not be calculated for patients admitted to hospitals with vs without PCI facilities because the Cox multivariable model was stratified by smoking status, time to admission, and hypertension to account for time interaction.

Indeed, the survival benefit associated with patient admission to catheterization facilities may have disappeared after adjusting for PCI as a result of the high correlation between these 2 variables. Actually, our data show that it is the more frequent use of PCI that explains most of the survival benefit of admission to a PCI hospital and not the fact that the hospital is a PCI hospital per se that improves outcomes. Another important finding of our study was the greater use of guidelines-recommended medications for patients who were admitted to PCI hospitals. The Intravenous nPA for Treatment of Infarcting Myocardium Early II study19 reported concordant results with a more common use of β-blockers for patients admitted to hospitals with 24-hour PCI facilities. Our findings are also supported by previous studies20,21 showing that patients undergoing PCI were more likely to receive guidelines-recommended therapies. Secondary prevention therapy with antiplatelet agents, β-blockers, and statins has been shown to be associated with a decreased 1-year mortality rate in patients with acute myocardial infarction.22,23 Although not recommended as an ancillary therapy to PCI, low-molecular-weight heparin was used more frequently within 48 hours of admission in patients admitted to PCI hospitals in our study. A potential explanation for this discrepancy may be that low-molecular-weight heparin was used for the prevention of venous thromboembolism,24 as suggested by the overlap of unfractionated and low-molecular-weight heparin use within 48 hours of admission.

Only 40% of the patients who were admitted to non-PCI hospitals received reperfusion therapy (ie, thrombolysis [39%] or primary PCI [1.2%]). Although 45% of the patients who did not receive any reperfusion therapy were admitted more than 12 hours after symptom onset, the lack of cardiac catheterization facilities was probably a key determinant for nonperformance of PCI for the remaining 55% of patients.25 Regional initiatives have been launched to improve processes of care for patients with ST-segment elevation myocardial infarction since the USIC 2000 study was conducted. These initiatives include dissemination of evidence-based guidelines, use of an algorithm for guiding the initial reperfusion therapy decision (ie, thrombolysis performed before hospital admission, direct transport to a facility capable of primary PCI, or conservative treatment), and transferring patients from hospitals without PCI capability to specialized regional primary PCI hospitals. A recent study26 showed that regionalization of care for acute myocardial infarction in the Alps area in France was followed by an increasing use of thrombolysis performed before hospital admission for patients transported by mobile ICUs (49%, 67%, and 68% in 2002, 2003, and 2004, respectively) and PCI (either primary or routine/rescue PCI within 24 hours of thrombolysis) for patients who pre-
sent to non-PCI hospitals (48%, 59%, and 72% in 2002, 2003, and 2004, respectively).

The limitations of our study should be acknowledged. First, admission to PCI hospitals was not based on random assignment, and therefore our results may be confounded by other factors. Although we performed multivariable and propensity score analyses to adjust for imbalances in measured covariates, unmeasured covariates that we did not account for may exist and could explain the survival benefit of admission to PCI hospitals. For the same reason, comparisons of mortality rates for patients who had or did not have PCI should be interpreted with caution because some patients might have died before undergoing this procedure. However, our observational study addresses an important question that is unlikely to be studied by large randomized controlled trials because the initial site of admission for patients with acute myocardial infarction depends on many factors, including distance to PCI facilities and patient preferences. Second, we cannot exclude the possibility that some mobile ICUs might have used protocols for guiding the initial site of admission decision at the time that the USIC 2000 study was conducted. However, baseline characteristics associated with admission to PCI hospitals were not different for patients who were transported by mobile ICU and those who were not (data not shown). Moreover, we did not find a significant interaction between transport by mobile ICU and admission to PCI hospital for the hazard ratio of mortality. Third, the 5-year difference in median age between the 2 groups of patients was unexpected, although this finding was consistent with other studies showing that patients admitted to hospitals without catheterization facilities were significantly older than those admitted to hospitals with on-site catheterization facilities. To adjust for imbalances in age for patients admitted to PCI vs non-PCI hospitals, we used a linear spline in multivariable and propensity score analyses. Fourth, physicians were not asked for their reasons for conservative treatment of the 267 patients who did not receive any reperfusion therapy despite admission to PCI hospital less than 12 hours after symptom onset. Fifth, our study was conducted in France, and our findings may not extend to patients treated in other geographic locations because processes of care for patients with acute coronary syndrome have been shown to vary across countries. Sixth, the potential for a selection bias was real because participation in the USIC 2000 study was voluntary. However, 83% of the French ICUs that treated patients with acute myocardial infarction participated in the USIC 2000 study independently of the region and teaching or private status.

In conclusion, admission of patients with acute myocardial infarction to PCI hospitals was associated with greater use of PCI and evidenced-based therapies and with lower 1-year mortality rate in this observational study. These findings provide additional support for recommending PCI, either primary PCI or after failed thrombolysis, and secondary prevention with evidence-based therapies for these patients.

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Table 6. Hazard Ratios (HRs) of Death Within the First Year of Index Admission for 1735 Patients Who Were Discharged Alive From Hospital

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unadjusted HR (95% CI)</th>
<th>P Value</th>
<th>Adjusted* HR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admission to hospitals with on-site PCI facilities</td>
<td>0.60 (0.41-0.88)</td>
<td>.01</td>
<td>1.07 (0.72-1.59)</td>
<td>.73</td>
</tr>
<tr>
<td>PCI within 48 h of admission</td>
<td>0.38 (0.24-0.61)</td>
<td>&lt;.001</td>
<td>0.53 (0.30-0.94)</td>
<td>.03</td>
</tr>
<tr>
<td>Discharge medications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antiplatelet agents</td>
<td>0.32 (0.19-0.54)</td>
<td>&lt;.001</td>
<td>0.98 (0.51-1.87)</td>
<td>.95</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>0.17 (0.11-0.26)</td>
<td>&lt;.001</td>
<td>0.30 (0.19-0.47)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Statins</td>
<td>0.38 (0.26-0.55)</td>
<td>&lt;.001</td>
<td>0.63 (0.42-0.96)</td>
<td>.03</td>
</tr>
<tr>
<td>Left ventricular ejection fraction, %†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;50</td>
<td>1 [Reference]</td>
<td></td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>36-50</td>
<td>2.60 (1.57-4.30)</td>
<td>&lt;.001</td>
<td>2.24 (1.32-3.82)</td>
<td>.003</td>
</tr>
<tr>
<td>21-35</td>
<td>9.44 (5.65-15.76)</td>
<td>&lt;.001</td>
<td>6.34 (3.71-10.83)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>≤20</td>
<td>20.27 (8.85-46.42)</td>
<td>&lt;.001</td>
<td>8.64 (3.20-23.36)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Unspecified</td>
<td>4.69 (2.51-8.75)</td>
<td>&lt;.001</td>
<td>2.81 (1.44-5.49)</td>
<td>.002</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; PCI, percutaneous coronary intervention.
* Covariates included in multivariable Cox proportional hazard model were admission to hospitals with on-site PCI facilities, PCI within 48 hours of admission, antiplatelet agents, β-blockers, statins, left ventricular ejection fraction, and quintile of propensity score. Eighty patients were excluded from multivariable analysis because of missing values.
† Left ventricular ejection fraction was unspecified for 144 patients.
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