Length of Hospital Stay After Acute Myocardial Infarction in the Myocardial Infarction Triage and Intervention (MITI) Project Registry

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Objectives. This study sought to identify current trends in length of stay in patients with an acute myocardial infarction and to evaluate which demographic, clinical, procedural and hospital-related factors explain the variation and reduction in length of stay observed during the study period.

Background. Hospital length of stay is an important contribution to cost of care. Previous studies of length of stay after acute myocardial infarction have been performed largely on administrative data bases and do not reflect current practice patterns.

Methods. We used univariate and multivariate models to evaluate which demographic, clinical and administrative factors influenced length of stay in 11,932 patients with acute myocardial infarction admitted to 19 Seattle-area hospitals between 1988 and 1994.

Results. Length of hospital stay decreased from (mean ± SD) 8.5 ± 8.2 to 6.0 ± 5.8 days during the study period. Demographic

During the past three decades, hospital length of stay has been the most important determinant of the total cost of care (1). In acute myocardial infarction, as in many medical and surgical conditions, the mean length of stay has been dramatically reduced. The earliest clinical guidelines recommended a 3-week length of stay to reduce the risk of myocardial rupture (2). In the late 1970s, based partially on a series of observational studies and controlled trials, mean length of stay was reduced to 7 to 10 days in low risk patients (3-5). Most recently, length of hospital stay has been further reduced to ≤6 days in patients with no complications (6). This most recent reduction in length of stay may be a result of changing

demographic or clinical characteristics of patients or advances in the treatment of acute myocardial infarction, such as thrombolytic therapy (7) or primary angioplasty (8). However, underlying economic pressures may also influence practice styles independent of patient and treatment characteristics.

Previous studies (9-14) have used large administrative data bases to show that age, gender and race as well as institutional and insurance-related factors influence length of stay. However, nearly all the studies on this topic, have been limited by lack of clinical detail or have examined older practice patterns predating recent clinical and health care system changes.

The Myocardial Infarction Triage and Intervention (MITI) Project registry, a community-wide chart-based data base, was established in 1988 to study community patterns of care for all Seattle-area patients with an acute myocardial infarction. This registry provides important data about trends in patterns of care during a period of significant advances in the treatment of acute infarction. The purpose of the present study was to identify clinical and nonclinical factors that influence hospital length of stay and to analyze which factors were associated with any observed reduction in length of stay during the 7-year observation period.

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Methods

Patients. The subjects of the present study were 11,932 patients admitted with an acute myocardial infarction to 1 of the 19 hospitals participating in the MITI Project. Characteristics of the registry, data-gathering procedures and reliability have been previously described (15). Briefly, the MITI project is a collaborative effort to evaluate new treatment strategies for patients with an acute myocardial infarction and includes a registry of all patients admitted for suspected myocardial infarction in the Seattle metropolitan area. The registry contains detailed data about all patients who had an acute myocardial infarction at discharge or death, as confirmed by medical records. For patients transferred to a different institution during the index hospital stay, charts were abstracted at the receiving facility such that each patient had a continuous care record. The study was approved by the University of Washington Human Subjects Review Committee.

The present analysis included consecutive patients admitted with an acute myocardial infarction between January 1988 and April 1994. Patients with an acute infarction admitted after resuscitation from cardiac arrest as well as those diagnosed with an acute infarction after admission for another condition (e.g., orthopedic surgery) were excluded from the analysis. Hospitals participating in the MITI registry include 2 university hospitals, 2 staff-model health maintenance organization (HMO) hospitals, 1 Veterans Affairs (VA) hospital and 14 community hospitals that served predominantly fee-for-service patients (managed-care market share in these hospitals was 5% during the majority of the study period). During most of the study period, 11 (57%) of the participating hospitals had on-site catheterization laboratories, and 2 (10%) routinely performed primary angioplasty in eligible patients.

Data collected. Trained abstractors collected detailed data from patient records within 3 months after discharge or death. Demographic variables included age, gender and race (coded as white or nonwhite). Prehospital and emergency department variables included type of transport to the hospital (911 call or other), duration of cardiac symptoms before emergency department evaluation, electrocardiographic (ECG) location of the infarction, vital signs on admission and new evidence of congestive heart failure. Information from the cardiac history included prior myocardial infarction, heart failure, angina, hypertension, percutaneous coronary angioplasty or bypass surgery. Data on hospital course included the presence of cardiogenic shock, infarct extension, recurrent chest pain, left ventricular ejection fraction for those who underwent either cardiac catheterization, coronary angioplasty or bypass surgery. Data on hospital course included the presence of cardiogenic shock, infarct extension, recurrent chest pain, left ventricular ejection fraction for those who underwent either cardiac catheterization, coronary angioplasty or bypass surgery. Coronary angioplasty was defined as either primary, performed <6 h after admission without the concomitant use of thrombolytic therapy, or salvage, all other angioplasty in the setting of acute infarction. Coronary angioplasty was defined as early when the procedure was performed <24 h after admission and was not in the setting of primary angioplasty.

Postdischarge readmission data were obtained by linking the MITI registry to the Washington State Comprehensive Hospital Abstract Reporting system (CHARS). The CHARs database includes hospital period data, vital status and hospital charge data for every hospital admission in the state of Washington. Socioeconomic status data were obtained by linking MITI registry patient address to population-based geocodes. In this methodology, patients in the MITI registry are assigned mean and median income and educational status on the basis of census data from the linked geocode.

Statistical methods. Length of stay was calculated from the date of hospital admission to the date of discharge, including any hospital transfers that occurred. Because length of stay was not normally distributed, we used the natural logarithmic transformation of length of stay as the dependent variable in this model. First univariate comparisons were made using one-way analysis of variance to explore the influence of demographic, institutional and clinical variables on length of stay (e.g., comparing length of stay in all female vs. male patients).

To study trends and factors that independently influenced hospital length of stay, we used a series of linear regression models with the natural logarithmic transformation of length of stay as the dependent variable. Patients who died in the hospital were excluded from the primary linear regression models. To evaluate possible bias from the exclusion of these cases, a separate model was evaluated that included patients who died in the hospital. Factors significantly associated with length of stay in univariate comparisons (p < 0.05) entered stepwise as independent variables into the model. Adjusted length of stay was calculated by multiplying the mean length of stay by the beta coefficient. An initial model included only demographic, historical and comorbidity variables available on admission. The second model included all variables in the first model as well as hospital complications, such as heart failure or stroke. The third model included all previous variables as well as process of care variables, such as the use of cardiac procedures or admission to an HMO hospital.

We adjusted for case severity using clinical variables collected in the MITI data base, such as prior heart failure or myocardial infarction, and then, for comorbid conditions, using a separate severity adjustment that summed a count of the number of secondary discharge diagnoses (five additional discharge diagnoses were collected by abstractors). In this method, patients with multiple comorbid conditions (e.g., diabetes or obstructive pulmonary disease) would have a higher comorbidity score. This method of severity adjustment has recently been evaluated and compared favorably with other more complicated severity adjustment methods (16).

To explore factors that may have influenced the observed reduction in length of stay between 1988 and 1994, a regression model was used that included all significant variables from the full model with the addition of multiple interaction terms. Interaction terms included cohort year with the variable of interest. For example, an interaction term was added that included cohort year and patient age to evaluate whether
increasing patient age had a more important association with length of stay in 1988 than in 1994. Additional interaction terms included year with gender, previous cardiac history, the use of coronary angiography, angioplasty and bypass surgery as well as hospital type.

Results

Baseline characteristics. There were 11,932 patients admitted to the 19 hospitals participating in the MITI registry. They were predominantly male (65.5%) and white (88%), with a mean age of 66.1 years. Overall, 57% of patients underwent coronary angiography, 23% underwent coronary angioplasty (this includes 7.3% who underwent primary angioplasty), and 11.4% had bypass surgery during the initial hospital period. The mean (±SD) length of stay was 7.45 ± 5.1 days (median 7). Hospital length of stay varied considerably between Seattle area hospitals (Fig. 1).

Univariate analysis. In the univariate analyses, patient factors that were associated with a longer length of stay included female gender, previous myocardial infarction or heart failure; recurrent infarction after admission, and heart failure or stroke during the hospital period (Table 1). With each decade of life, there was an approximate half-day increase in length of stay until the seventh decade, where length of stay remained nearly constant. Length of stay was reduced 29%, from nearly 8.5 days in 1988 to 6.0 days in 1994 (Fig. 2). Comorbid conditions appeared to influence length of stay. Patients with no secondary discharge diagnoses had a mean length of stay of 5.2 days versus 5.6, 6.2 and 8.5 days for patients with two, three and four secondary discharge diagnoses, respectively (p = 0.0001).

Because bypass surgery had a strong association with length of stay, the remaining univariate analyses were stratified by the use of bypass surgery. Hospital and treatment factors resulting in a longer length of stay included the absence of on-site angiography at the admitting hospital, the use of coronary angiography and the use of bypass surgery (Table 2). Although the use of salvage angioplasty was associated with a longer length of stay, the use of primary angioplasty was associated with a shorter length of stay. The type of admitting hospital also had an effect on length of stay. Patients admitted to VA hospitals had a much longer stay (9.8 days); HMO and university hospitals intermediate (8.4 days) and fee-for-service hospitals the shortest (7.5 days) (Table 3). For each type of hospital, there was a nearly equivalent relative reduction in length of stay between 1988 and 1994: fee-for-service (7.8 to 5.5 days), HMO (8.8 to 6 days), VA (9.4 to 7.9 days) and university hospitals (8.3 to 6.6 days).

To test the hypothesis that diagnostic and therapeutic procedure use (e.g., advances in technology) was associated with the 29% reduction in length of stay observed during the study period, the percent reduction in length of stay between 1988 and 1994 was calculated and compared in patients with and without specific procedures (Table 4). Overall, the reduction in length of stay in patients undergoing cardiac procedures was nearly identical to that in patients managed without cardiac procedures.

Multivariate analysis. To evaluate which demographic, clinical and hospital-related factors independently influenced length of stay, we constructed a series of linear regression models. In the first model, factors known at admission (e.g.,

Table 1. Univariate Results: Mean and Median Length of Stay, Patient Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>With Variable [mean (median)]</th>
<th>Without Variable [mean (median)]</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>White race</td>
<td>7.7 (6.0)</td>
<td>7.8 (7.0)</td>
<td>0.89</td>
</tr>
<tr>
<td>Female gender</td>
<td>8.1 (7.0)</td>
<td>7.5 (6.0)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Prior infarction</td>
<td>7.8 (7.0)</td>
<td>7.4 (7.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>Prior heart failure</td>
<td>8.3 (7.0)</td>
<td>7.3 (7.0)</td>
<td>0.004</td>
</tr>
<tr>
<td>Recurrent infarction at hospital admission</td>
<td>10.2 (8.0)</td>
<td>7.7 (7.0)</td>
<td>0.009</td>
</tr>
<tr>
<td>CHF at hospital admission</td>
<td>9.6 (8.0)</td>
<td>6.9 (6.0)</td>
<td>0.04</td>
</tr>
<tr>
<td>Stroke at hospital admission</td>
<td>16.2 (13.0)</td>
<td>7.9 (7.0)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

CHF = congestive heart failure.

Figure 2. Median, mean and 25th and 75th percentiles for length of stay by year of admission. Between 1988 and 1994, there was a 2.5-day decrease in mean length of stay. Format as in Figure 1.
Table 2. Univariate Results: Mean Length of Stay, Hospital and Treatment Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Length of Stay: All Patients</th>
<th>Length of Stay: Patients Without CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Variable</td>
<td>Without Variable</td>
</tr>
<tr>
<td>On-site angiography</td>
<td>7.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Use of angiography</td>
<td>7.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Use of PTCA</td>
<td>7.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Use of CABG</td>
<td>13.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Use of thrombolysis</td>
<td>7.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Primary PTCA</td>
<td>7.0</td>
<td>7.8</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass graft surgery; PTCA = percutaneous transluminal coronary angioplasty.

demographics, patient history, presenting signs and symptoms and comorbidity) were entered. Demographic factors that predicted a longer adjusted length of stay included increasing age (0.6 day increase for each decade) (Fig. 3). Neither nonwhite race nor female gender was significantly associated with length of stay in this limited model. Clinical characteristics that predicted a longer length of stay included a history of heart failure (mean 7.5 days, 95% confidence interval [CI] 7.3 to 7.9, vs. mean 7.0 days), angina (7.3 days, 95% CI 7.2 to 7.5) or hypertension (7.3 days, 95% CI 7.2 to 7.5). Each additional comorbid diagnosis resulted in a 0.7-day (95% CI 0.6 to 1.0) increase in length of stay (p = 0.0001). Neither histories of myocardial infarction nor bypass surgery were predictive of a longer length of stay. Patients with admission systolic blood pressure <90 mm Hg (7.7 days, 95% CI 7.5 to 7.8), as well as patients with either anterior or multiple infarct locations, had a longer length of stay (7.7 days, 95% CI 7.5 to 8.2, and 7.6 days 95% CI 7.5 to 7.8, respectively), whereas admission heart rate >90 beats/min was not associated with length of stay. The only factor that predicted a shorter length of stay was a history of angioplasty (6.4 days, 95% CI = 6.1 to 6.8). In this model, which included factors known at the time of admission, very little variation in length of stay was predicted (R² = 5.8%).

In the next model, clinical events and complications that occurred during the hospital period were added. In-hospital complications, including infarct extension (8.2 days, 95% CI 7.8 to 8.7) (Fig. 4), heart failure (9.0 days, 95% CI 8.8 to 9.2), recurrent chest pain (8.4 days, 95% CI 8.2 to 8.6), cardiogenic shock (8.8 days, 95% CI 7.9 to 9.7) and stroke (13.5 days, 95% CI 12.1 to 14.7) were predictive of a longer length of stay. This entire model, including all the demographic and historical variables entered in the first model, accounted for 14% of the variation in length of stay.

In the full model that included hospital and process of care variables (Fig. 5), the use of early diagnostic coronary angiography (6.2 days, 95% CI 6.0 to 6.5), the use of primary angioplasty (length of stay 6.8 days, 95% CI 6.5 to 7.1), the availability of on-site angiography (6.7 days, 95% CI 6.6 to 6.95) and later years of hospital admission (0.3-day decrease in length of stay/year, 95% CI 0.2 to 0.4) each independently predicted a shorter length of stay. The use of thrombolytic therapy (8.2 days, 95% CI 8.0 to 8.3), any coronary angiography (8.2 days, 95% CI 8.1 to 8.4), salvage angioplasty (7.6 days, 95% CI 7.3 to 7.9), as well as bypass surgery (12.7 days, 95% CI 12.2 to 13.2) predicted a longer length of stay.

Compared with fee-for-service hospitals, patients admitted to VA hospitals had a much longer adjusted length of stay (9.5 days, 95% CI 8.9 to 10.1), whereas length of stay at HMO and university facilities was intermediate but still significantly longer than the fee-for-service system (7.8 days, 95% CI 7.5 to 8.1, and 7.5 days, 95% CI 7.2 to 7.8, respectively) (Fig. 4). This final model, which included demographic, clinical and process of care variables, explained 33% of the variation in hospital length of stay (R² = 0.33). There were no important differences in this model when we included patients who died in the hospital.

To evaluate which factors were associated with the 29%...
reduction in length of stay between 1988 and 1994, a series of interaction terms were entered into the final regression model. Each interaction term included the year of the cohort with one of the variables of interest. In this model, none of the interaction terms (year by age, gender, race, cardiac history, clinical complications, comorbidity, procedure use or hospital type) was significantly associated with length of stay. Thus, it is unlikely that any of the measured factors in the present study can explain the decrease in length of stay observed during the study period.

**Discussion**

Length of hospital stay is an important determinant of the cost of medical care (1). For conditions that nearly always require hospital admission, such as acute myocardial infarction, limiting hospital length of stay is an obvious component of cost containment. Hospital length of stay has been decreasing for nearly all medical and surgical conditions, and the treatment for acute myocardial infarction has been no exception.

The reasons for this reduction in length of stay are multifactorial. In acute myocardial infarction, clinical innovations such as reperfusion therapy (5,7) may have contributed to a reduction in length of stay; however, economic pressures to increase efficiency and eliminate unnecessary care may also be important factors.

**Variation in length of stay.** In the present study, we used a large clinical data base that included extensive demographic, clinical and institutional data from nearly 12,000 patients with an acute infarction to document trends in length of stay and to identify many of the factors that influence length of stay. Factors known at admission explained only 6% of the variation in length of stay. Older age, a history of heart failure, angina or hypertension as well as an increased number of comorbid conditions predicted a longer length of stay, whereas a history of myocardial infarction or bypass surgery were not associated with differences in length of stay. Infarct-related complications accounted for an additional 10% of variation in length of stay, and factors that were associated with a longer length of stay included recurrent myocardial infarction, heart failure or stroke during the hospital period.

Factors reflecting the process of care, such as the use of cardiac procedures, were even more important in understanding length of stay in this population and explained an additional 17% of variation. Patients who underwent salvage angioplasty or bypass surgery had a longer length of stay than those without these procedures. In contrast, the length of stay was ~1 day shorter in patients who underwent early diagnostic coronary angiography and ~0.5 day shorter in those who underwent primary angioplasty.

Although previous studies of this population suggested that those patients admitted to hospitals with on-site angiography facilities were more likely to undergo angiography (17), the present analysis showed that patients admitted to these hospitals had a length of stay that was one-third of a day shorter than patients admitted to hospitals without these facilities. We
suspect that this finding resulted from the requirement for hospital transfer when procedures were required in patients admitted to hospitals without catheterization facilities. Based solely on this finding, it is impossible to determine whether this shorter length of stay offsets higher costs associated with the greater use of cardiac procedures.

The type of admitting hospital also had a significant influence on length of stay. Patients admitted to the single VA medical center included in this study had a length of stay that was nearly 3 days longer than patients admitted to fee-for-service hospitals despite the exclusion of patients transferred to the VA medical center from other out-of-region VA hospitals. Patients admitted to staff model HMO or university hospitals had a >0.5-day longer length of stay than patients at the fee-for-service hospitals. Although some have argued that university hospitals attract “sicker” patients, the increased length of stay persisted after adjustment for both infarct-related complications and comorbid conditions.

**Decrease in length of stay.** Overall, the 29% reduction in length of stay observed during the study period was impressive. Unfortunately, none of the measured variables could explain this decrease. For example, neither changing demographics nor patient clinical characteristics were associated with the decrease. More surprising, however, is that procedure utilization was not associated with the reduction in length of stay. That is, although patients undergoing primary angioplasty or early diagnostic catheterization had a shorter length of stay than those who did not, the proportionate reduction in length of stay during the study period was not different between these patients and those treated more conservatively.

Because none of the numerous measured variables could explain the observed reduction in length of stay, we tested several other nonclinical factors that might help to explain the reduction: 1) To evaluate whether higher readmission rates explained the results, we compared readmission rates at 1 year between patients admitted in 1989 and 1993 and found higher readmissions for the 1989 cohort. Thus, it is unlikely that earlier patient discharge with a higher rate of subsequent readmissions was associated with the decreased length of stay. 2) We found no substantial differences in education or adjusted income between the 1989 and 1993 cohorts. Thus, it is unlikely that changes in socioeconomic status were responsible for the decrease in length of stay. We also compared discharge medications in the 1989 and 1993 cohorts and found that a significantly higher proportion of patients in 1993 were discharged with either aspirin or beta-adrenergic blocking agents, or both. This may be a marker for improvements in general medical care during the study period that might have influenced length of stay. In the final analysis, however, we must speculate that unmeasured variables, such as insurance-related factors, hospital administrative pressures or changes in physician practice styles, were an important influence in the observed reduction in length of stay.

**Previous studies.** Previous studies evaluating a variety of conditions have identified several factors that help to explain variation in length of stay. These include chronologic age, admission diagnosis, surgery status (elective versus emergent), hospital characteristics (9), type of insurance payment (10), physician ratings of severity of illness (11) as well as various severity indexes (13,14,18,19). The effect of teaching hospitals on length of stay has been controversial, with one study showing a longer length of stay in teaching hospitals (12) and one a shorter length of stay (10,20).

Several studies have been performed examining length of stay in patients with an acute myocardial infarction. Using a 1987 administrative data set of 4,033 patients diagnosed with an acute infarction, Young and Cohen (21) found that an increased length of stay was associated with advancing age, female gender, a larger number of chronic diseases and admission to a teaching hospital. In contrast to the present study, hospitals with on-site catheterization facilities were associated with an increased length of stay. However, this analysis did not adjust for the use of procedures resulting from the angiogram, thereby underestimating the potential impact of a diagnostic angiogram on length of stay. Other older analyses have associated creatine kinase isoenzyme peak, presence of an anterior infarction and the use of either predischarge stress testing or 24-h ambulatory monitoring with increased length of stay (22,23).

In a study that is most comparable to the present analysis, Chen and Naylor (24) evaluated factors that predicted length of stay in 11,411 patients using administrative data collected between 1990 and 1991. The mean length of stay was 9.9 days versus 7.4 days in the present American study. Older age, female gender, infarct-related complications and comorbidity were associated with a longer length of stay. Similar to the present study, patients who underwent angiography had a longer length of stay, and there was a trend toward a shorter length of stay in patients admitted to hospitals with on-site angiography. However, only 12% of variation in length of stay was explained by the Canadian study compared with 33% in the present analysis. This difference illustrates the better predictive power of a clinical than an administrative data base.

The present study has several other advantages over previous work: 1) The MITI registry is a more contemporary data base, reflecting the most recent changes in health care delivery; 2) we were able to examine the effects of the most recent advances in the management of myocardial infarction, such as the use of primary angioplasty or thrombolytic therapy; and 3) none of the reported studies, to our knowledge, evaluated whether technologic advances in the treatment of acute infarction were associated with the profound decrease in length of stay that has been observed in patients with acute infarction.

**Study limitations.** There are important limitations to the present study: 1) Data were collected in only one city; thus, these data must be interpreted cautiously in a setting with different practice styles or a rural setting. 2) We were also limited by the presence of a single, large, staff-model HMO and a single VA medical center. 3) Despite a major improvement in understanding length of stay variation in the management of myocardial infarction, nearly 67% of variation remains unexplained. 4) We were unable to explain the observed
decrease in length of stay. Clearly, there were unmeasured variables that may have contributed to our understanding of length of stay in this setting. The addition of more detailed insurance-related data, such as the use of economic or administrative incentives or physician profiling, as well as more details about the individual physicians such as age and education, might have been an important addition to the measured variables.

Conclusions. There has been a substantial decrease in the length of stay in postinfarction patients in the Seattle area over the past 6 years. Although demographic characteristics, past clinical history, procedure utilization, hospital complications and hospital characteristics are important factors in explaining variation in length of stay, none of the measured factors explains the reduction in length of stay observed during the study period. Future research should evaluate other nonclinical factors, such as administrative incentives or the use of practice guidelines, to better understand unique influences on hospital length of stay.

References