Outcomes of Pancreaticoduodenectomy
Where Should We Focus Our Efforts on Improving Outcomes?

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IMPORTANCE Changes in health care reimbursement policy have led to an era in which hospitals are motivated to improve quality of care while simultaneously reducing costs. Research demonstrating the most efficient means to target costs may have a positive effect on patient quality of life and the overburdened health care system.

OBJECTIVE To evaluate the effect of hospital length of stay (LOS) and the occurrence of postoperative complications on total charges in patients undergoing elective pancreaticoduodenectomy.

DESIGN, SETTING, AND PATIENTS We performed a retrospective review of 89 cases identified in an institutional database of patients who underwent elective pancreaticoduodenectomy at an academic tertiary care center from December 1, 2007, through May 31, 2012.

MAIN OUTCOMES AND MEASURES Occurrence of postoperative and inpatient complications, LOS, incidence of readmission within 60 days of discharge, and hospital charges from initial postoperative hospitalization. Linear regression analysis was performed comparing LOS with hospital charges.

RESULTS Thirty-four of 89 patients (38%) developed postoperative complications. Mean and median LOSs were 12 and 8 days, respectively. The LOS was significantly related to postoperative complications. Of the 34 patients who developed complications, the mean LOS was 19 days compared with 7 days for those patients not developing complications (P < .001). Only 2 of 55 patients (4%) without complications were readmitted to the hospital, whereas 13 of 34 patients (38%) with complications required readmission. Perioperative hospital charges were significantly related to LOS (R² = 0.840, R = 0.917). For those patients without complications, linear regression demonstrated a daily hospital charge of $11,612 (R² = 0.923, R = 0.961). However, for those patients with complications, the optimal relationship between LOS and hospital charges was exponential (R² = 0.832).

CONCLUSIONS AND RELEVANCE Prolonged LOS is associated with increased total charges, but given the exponential increase in charges, the complication itself has an effect on increased charges above and beyond that of a prolonged hospitalization. The drive to reduce LOS after pancreaticoduodenectomy has minimal effect on overall charges to the patient. Efforts should be directed instead at reducing complications because this has a much more significant effect on financial outcomes.
n ongoing efforts to improve the value of health care, evaluation of patient outcomes and the cost of health care provision are being scrutinized by various stakeholders for areas of improvement. Complex operations with high rates of morbidity and mortality have been a major setting for quality improvement in the surgical fields. Pancreatectoduodenectomy (PD) has high morbidity rates and often poor long-term survival; therefore, it is a commonly selected procedure for investigation to improve outcomes. Many health care policymakers anticipate that efforts to improve outcomes will have effects on reduction of costs and therefore achieve additive effects on the value of provided health care. Initial efforts to improve outcomes from complex surgical procedures, including PD, have primarily focused on the process of surgical care provision surrounding the volume-outcome relationship. Numerous studies1-7 have reported decreased complication rates and lower mortality when performed at high-volume centers. Although no standard definition of high volume has been determined, it is generally recommended that low-volume centers refer patients to tertiary care centers for such procedures. Despite this transition, morbidity rates for PD remain high, and regionalization of surgical therapy for pancreatic diseases has been poorly implemented.8

An additional focus to improve quality has been through the implementation of clinical care pathways as a means to reduce costs through elimination of redundant or excess resource use and shortening the hospital length of stay (LOS). Hospital administrators and health insurance coordinators have favored this approach as a primary mechanism to reduce hospitalization costs. These efforts, however, have demonstrated only some success in lowering perioperative hospital costs associated with complex operative procedures because they minimally affect the value of health care provision. Despite decreases in LOS, complication rates have not decreased as a consequence of the implementation of clinical care pathways.9 One concern is that the drive to discharge patients in a shorter time frame may inadvertently increase total cost of disease-based care because of the increased recognition of operative complications in the outpatient setting and possible associated increase in hospital readmission rates. This concern is critical for operations with high rates of morbidity because up to 32% of postoperative complications are identified in the outpatient setting after discharge.10

The current study aims to evaluate the effect of hospital LOS and the occurrence of postoperative complications on total cost in patients undergoing elective PD. Secondary outcomes include examining rates of readmission and the potential effect of readmission and complications on LOS. We hypothesize that the effect of complications on hospital charges is more significant than the effect on LOS alone. Although such events may result in increased LOS, we predict that the complication itself has an effect on increased cost above and beyond that of a prolonged hospitalization.

Methods

The current study is a retrospective review of an institutional database at the University of California Davis Comprehensive Medical Center maintained under approval of the institutional review board. The database includes all patients who underwent PD at the University of California Davis Comprehensive Medical Center, an academic tertiary care center, from December 1, 2007, through May 31, 2012. After review of the database, we identified 89 patients who underwent elective PD for any diagnosis at our institution and had complete data available for review, including documentation of all clinical care within 60 days of surgery. Informed consent was not required per institutional review board–approved protocol. All operations were a standard PD by 1 of 3 surgeons (A.Y., R.J.C., or R.J.B.).

Main outcome measures were occurrence of postoperative and inpatient complications, LOS, incidence of readmission within 60 days of discharge, and total charges from initial postoperative hospitalization. Patient medical records were reviewed for the occurrence of any postoperative complication and incidence of any readmission within 60 days of surgery. All complications were maintained as separate categories with the exception of wound infection, which included both superficial and deep space infection. Infections were classified using standard National Surgical Quality Improvement Program definitions.11,12 Pancreatic leak and delayed gastric emptying were defined in accordance with the International Study Group of Pancreatic Surgery.13,14 Mortality within 30 days of surgery was included as a complication, but these patients were excluded from charge analysis. Patients with more than one complication were also analyzed.

Statistical analysis was performed with univariate analysis using the χ² test and t test. P < .05 was considered significant. Regression analysis was performed comparing LOS with hospital charges for the entire cohort, those without complications, and those with complications. R² values were calculated to determine the strength of the linear relationship between charges and LOS. Both linear and exponential regression models were tested with the optimal model selected based on the best fit (R² value).

Results

We identified 89 patients who underwent elective PD by 1 of 3 different surgeons from December 1, 2007, through May 31, 2012 (Table 1). The mean age of the patients was 65 years. Fifty-eight (65%) were male and 31 (35%) were female. All patients underwent a standard PD procedure, and the most common indication was for malignant disease (76 [85%]). The mean and median LOSs for the entire group were 12 and 8 days, respectively. Three patients died within 30 days of surgery, for a mortality of 3%; they were excluded from further charge analysis. Thirty-four patients developed postoperative complications, for a morbidity of 38%.

The most common complications were pancreatic leak in 7 patients (21%), infection (superficial or deep) in 9 patients (26%), and delayed gastric emptying in 13 patients (38%) (Table 2). Other complications included additional operation, arterial pseudoaneurysm, bacteremia, pneumonia, new-onset atrial fibrillation, myocardial infarction, and stroke. Thirteen of the 34 patients (38%) had more than one complica-
When examining rates of readmission, only 2 of 55 patients (4%) without an initial postoperative complication required re-admission, whereas 13 of 34 patients (38%) with a complication required readmission ($P < .001$) (Table 1). When examining reasons for readmission, 100% were readmitted for care of a postoperative complication (Table 2).

In 8 of the 15 readmitted patients (53%), the reason for admission was for treatment of a wound infection. In addition, the 3 most common complications (wound infection, pancreatic leak, and delayed gastric emptying) accounted for readmission in 14 of the 15 patients (93%). The reasons for admission in those 2 patients without complications were lower extremity edema and dehydration secondary to gastroenteritis.

When examining the time to discharge for patients without complications compared with those with infection, delayed gastric emptying, or pancreatic leak, the proportion of patients with prolonged LOS was markedly increased in patients with pancreatic leak. The plots comparing the proportion of patients remaining hospitalized for each group demonstrate similar time to discharge for patients without complications and those with infection or delayed gastric emptying, whereas the curve for patients with pancreatic leak shows a much longer time to discharge (Figure 1).

Linear regression analysis was performed to determine the association between hospital charges and LOS. As expected, hospital charges for all patients were significantly related to LOS ($R^2 = 0.840, R = 0.917$) (Figure 2). When the analysis was performed separately for those with complications and those without, the associations were improved. A superior linear regression was observed for those patients without complications with a rate of $11,612$ per day ($R^2 = 0.923, R = 0.961$) (Figure 3A). The optimal association between LOS and hospital charges for those patients with complications was exponential ($R^2 = 0.832$) (Figure 3B). We then examined the interaction of postoperative complications, LOS, and charges. The LOS was significantly related to postoperative complications; of the 34 patients developing a complication, the mean LOS was 19 days compared with 7 days for those patients not developing a complication ($P < .001$). In addition, of the 13 patients with more than one complication, the mean LOS was 30 days, which was significantly longer than the mean LOS of 12 days for those with only 1 complication ($P = .003$).

Using the linear regression model for patients without complications, we then calculated the total postoperative charge for patients with the 3 most common complications (delayed gastric emptying, infection, and pancreatic leak) based solely on LOS using a per day rate from those without complica-

### Table 1. Demographic Characteristics of 89 Patients Who Underwent Elective PD

<table>
<thead>
<tr>
<th>Demographic Characteristic</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male 58 (65) Female 31 (35)</td>
</tr>
<tr>
<td>Age, mean (range), y</td>
<td>65 (35-90)</td>
</tr>
<tr>
<td>Indication for surgery</td>
<td>Malignant neoplasm 76 (85) Benign neoplasm 6 (7) Chronic pancreatitis 5 (6) Other 2 (2)</td>
</tr>
<tr>
<td>Complications</td>
<td>34 (38)</td>
</tr>
<tr>
<td>Readmission (within 60 d)</td>
<td>15 (17)</td>
</tr>
<tr>
<td>No complications</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Complications</td>
<td>13 (34)</td>
</tr>
<tr>
<td>Mortality (within 30 d)</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Mean length of stay, d</td>
<td>Entire group 12 No complications 7 Complications 19 1 12 &gt;1 30</td>
</tr>
</tbody>
</table>

Abbreviation: PD, pancreaticoduodenectomy.

* Data are presented as number (percentage) of patients unless otherwise indicated.

### Table 2. Complications and Associated Incidence of Readmission and Mean Length of Stay

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of Complications</th>
<th>No. of Readmissions</th>
<th>Mean Length of Stay, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wound infection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial</td>
<td>4</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Deep</td>
<td>5</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Pancreatic leak</td>
<td>7</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Delayed gastric emptying</td>
<td>13</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Additional operation</td>
<td>3</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
<td>1</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>6</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Bacteremia</td>
<td>3</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>2</td>
<td>0</td>
<td>48</td>
</tr>
<tr>
<td>CVA</td>
<td>2</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>MI</td>
<td>1</td>
<td>0</td>
<td>66</td>
</tr>
<tr>
<td>&gt;1 Complication</td>
<td>13</td>
<td>6</td>
<td>28</td>
</tr>
</tbody>
</table>

Abbreviations: CVA, cardiovascular accident; MI, myocardial infarction.
tions (Table 3). These charges were estimated to be $273,318, $319,766, and $575,230 for delayed gastric emptying, infection, and pancreatic leak, respectively. We then compared these values with the actual mean hospital charges for patients experiencing these complications. For patients with delayed gastric emptying, the additional LOS due to this complication generated lower charges than had a complication not developed, by a difference of −$18,367. Wound infections resulted in an increase in charges of $36,165. The most drastic increase was seen in patients with a postoperative pancreatic leak. These patients accumulated close to 35% additional charges beyond those estimated purely based on increased LOS. However, a limitation of this analysis is that the model used “average” charge per day to calculate the effect of prolonged LOS for patients with complications. This average charge is across all hospital locations of varying acuities during a patient’s hospitalization and may not accurately reflect the charges incurred during management of a complication. For example, although patients with delayed gastric emptying had longer LOS, their total charges did not necessarily reflect a prolonged hospitalization, likely because of the minimal medical services required for the management of the complication.

### Discussion

Although others have previously established relationships between complications with both prolonged LOS and increased hospital costs, the exponential relationship between LOS and charges for patients with complications (compared with the linear relationship for patients without) demonstrates that the complication itself has an effect on increased...
The linear relationship between charges and LOS in those patients without complications demonstrates that strategies focused on decreasing LOS will decrease hospital charges; however, these strategies are unlikely to produce major cost savings. The relationship of charges to LOS in those patients with complications is exponential, which suggests that efforts to decrease complication rates will not only decrease LOS but will also have the potential to exponentially decrease hospital charges. In addition, this study highlights that certain complications will have a larger effect on increased charges than others. Patients with delayed gastric emptying actually generated lower charges than had a complication not developed, which is likely related to the decreasing acuity of care and intensity of medical therapy of the complication beyond immediate and early postoperative care. Conversely, patients with pancreatic leak incurred drastically increased charges compared with those without complications. This finding demonstrates the significant consequence of the management of this postoperative complication on the total postoperative hospital charges of patients undergoing PD.

Research on the financial consequence of operative complications after PD has found a similar relationship between complications and increased costs. Holbrook et al\textsuperscript{15} demonstrated that the cost of PD is significantly higher in patients experiencing a postoperative complication. This analysis attributed the increase largely to a prolonged LOS. Enestvedt et al\textsuperscript{16} similarly found that complications after PD nearly doubled hospital costs. On the basis of the results of our study, we estimated the financial effect of complications to be up to $300,000 of additional hospital charges beyond actual LOS. Direct costs are difficult to ascertain because they relate to the volume and intensity of resources used. In addition, hospital charges may be a more accurate reflection of the financial consequence to patients and insurance carriers. We believe that these figures are conservative and significantly underestimate the actual burden of complications because we did not include additional outpatient charges or charges associated with readmission. Furthermore, the complication and mortality rates observed are within those expected from a high-volume PD center. We would suggest that low-volume surgeons and centers would sustain significantly greater financial consequences due to the higher incidence of complications. Although without evidence, low-volume centers may also have higher charges per complication given unfamiliarity with optimal management.

The readmission rate after surgery is an additional focus of quality metrics that has become increasingly important and is associated with both higher patient morbidity and higher hospital costs. The financial burden of readmission is undeniable. Several studies\textsuperscript{17,18} estimated the annual cost of unplanned readmissions among Medicare patients to be more than $17 billion, and with a readmission rate of 11% among general surgery patients, this represents a major source of cost in health care provision. When readmission after pancreatectomy is specifically examined, the estimated average cost associated with readmission is $16,000, and more than half of these readmissions have been attributed to gastrointestinal complications or wound infections.\textsuperscript{17,19} Although the numbers in our study are small, wound infection was one of the most common postoperative complications in our patients with PD and 6 of the 9 patients with wound infections required readmission. Therefore, it is reasonable to assume that the estimated financial effect of $36,165 in our study grossly underestimates the actual financial burden of this complication because it does not include the costs associated with these readmissions.

Clinical care pathways, also known as fast-tracking protocols, have become a new focus for efforts by hospital administrators and health insurance carriers to improve value and decrease costs by focusing on reducing LOS and increasing efficiency. Most clinical care pathways have focused on diseases and procedures with highly variable lengths of hospitalization.\textsuperscript{20} However, concerns have arisen that these protocols may inadvertently increase readmission rates. Several studies\textsuperscript{21,22} have reported a decrease in LOS and cost after implementation of care pathways for PD. However, although researchers have evaluated rates of readmission for certain high-risk procedures, including hepatobiliary procedures, the effect of clinical care pathways on readmission is unclear.\textsuperscript{23} Although Kennedy et al\textsuperscript{9} state that implementation of their pathway did not increase their readmission rate, more investigation is needed to determine whether this is universally true. The current study found that those experiencing postoperative complications are at a significantly higher risk for readmission within 60 days of discharge. Therefore, it stands to reason that specific measures to target reducing complication rates will also reduce readmission rates. The same cannot be said for measures targeting only LOS.

Conclusions

The current study investigates the effect of LOS on hospital charges and postoperative complications. The exponential relationship between LOS and cost among those with complications compared with the linear relationship in patients without complications highlights an underrecognized factor in valuation of care. Patients without complications tended to have shorter hospitalizations, exponentially lower hospital charges associated with the initial hospitalization, and lower rates of readmission. Therefore, strategies focused on both reducing complications and more effectively diagnosing and treating complications are likely to be a more effective and efficient means of improving value of care. With clinical care pathways becoming an increasingly popular method to improve quality, addressing complications should be a critical component of such pathways.
responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Brown, Bold. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: Brown. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Brown, Bold. Administrative, technical, or material support: Yang, Bold. Study supervision: Bold.

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REFERENCES


