Estimation of Surgical Costs Using a Prediction Scoring System

Estimation of Physiologic Ability and Surgical Stress

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Hypothesis: Our predictive scoring system, Estimation of Physiologic Ability and Surgical Stress, can estimate surgical costs.

Design: Multicenter cohort study for 1 year.

Setting: Six national hospitals in Japan.

Patients: A consecutive series of 929 patients who underwent elective gastrointestinal operations.

Main Outcome Measures: The preoperative and the comprehensive risk scores of the Estimation of Physiologic Ability and Surgical Stress were determined preoperatively and immediately after the operation, respectively. Estimated costs were computed using the following equation: costs = US $10160 + (US $13470 / comprehensive risk score). Data on length of stay, costs for surgical admission, and severity of postoperative complications were collected at hospital discharge.

Results: The comprehensive risk score significantly correlated with the severity of the postoperative complications (Spearman rank correlation = 0.54, P < .001), the length of stay (Spearman rank correlation = 0.69, P < .001), and the costs (Spearman rank correlation = 0.72, P < .001). The ratio of real to estimated costs varied from 0.82 to 1.17 at the various ranges of the comprehensive risk score, resulting in 0.93 in the total 929 patients. This ratio varied from 0.71 to 1.12 among the hospitals, the smallest of which was attributed to the hospital that primarily used the clinical pathways. A significant increase in the costs was observed according to the preoperative risk score for open colectomy (P = .009) and distal gastrectomy (P = .002). When we simulated the hospital revenue where different payment rates were set according to the preoperative risk score, the revenue seemed to improve in the hospitals that treated more high-risk patients, compared with the fixed payment system.

Conclusion: The Estimation of Physiologic Ability and Surgical Stress scoring system may be useful for estimating surgical costs, making a benchmark analysis, and determining the rate in a risk-based payment system.

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CONTROL OF inflated medical expenditures is an emerging problem in developed countries. The United States introduced a fixed payment system, called the diagnosis-related group/prospective payment system, in the 1980s. Under this system, hospitals must thoroughly lower individual costs to gain a profit. For this purpose, clinical pathways, which show a time table and an outcome to patients and medical staff, were generated and spread throughout the country. As a result, the average length of stay decreased from 10 to 6.3 days in the United States. The diagnosis-related group/prospective payment system and the subsequent innovation of managed care, characterized by restricting access through utilization review and capitation, have succeeded in controlling health care costs. However, under the diagnosis-related group system, it is conceivable that hospitals tend to avoid operating on patients with severe comorbidities. In addition to this negative aspect of the diagnosis-related group system, demand to open the restricted access to the hospitals has been increased in consumers. Recently, the managed care system has failed politically, and the health care systems are being changed to broaden physician panels, remove restrictions, and revert to fee-for-service payment.1

In contrast, the Japanese government has maintained a health insurance policy for 40 years that forces all people to join one of the public insurance systems, in which...
PATIENTS AND METHODS

This study was approved by the institutional ethics committee of each hospital. The subjects consisted of 929 consecutive patients who underwent elective gastrointestinal operations between April 1, 1999, and March 31, 2000, in 6 national hospitals in Japan. This study excluded patients who underwent emergency operations and those who met the criteria of systemic inflammatory response syndrome before surgery. The male-female ratio was 419:510. The median age of the patients was 65 years (range, 7-96 years). The subjects included patients who underwent transthoracic esophagectomy (n = 12), pancreateoduodenectomy (n = 17), hepatectomy (n = 19), total gastrectomy (n = 53), laparoscopic-assisted distal gastrectomy (n = 12), open distal gastrectomy (n = 114), open cardia-lungectomy (n = 9), laparoscopic wedge resection of the stomach (n = 9), laparoscopic-assisted colon resections (n = 27), open colon resections (n = 113), laparoscopic cholecystectomy (n = 276), open cholecystectomy (n = 46), laparoscopic choledochotomy (n = 11), open choledochotomy (n = 13), rectal resections (n = 87), laparoscopic splenectomy (n = 10), and others. All findings were collected prospectively for the E-PASS scores, surgical procedure, postoperative course, and the costs of the hospital stay. The equations of the E-PASS scoring system are as follows (data from Haga et al):

1. \( PRS = -0.0686 + 0.0034X_1 - 0.323X_2 + 0.205X_3 - 0.153X_4 + 0.148X_5 + 0.0666X_6 \)

where \( X_1 \) is age; \( X_2 \), the presence (1) or absence (0) of severe heart disease; \( X_3 \), the presence (1) or absence (0) of severe pulmonary disease; \( X_4 \), the presence (1) or absence (0) of diabetes mellitus; \( X_5 \), the performance status index (range, 0-4); and \( X_6 \), the American Society of Anesthesiologists' physiological status classification (range, 1-3).

Severe heart disease is defined as heart failure of New York Heart Association class III or IV or severe arrhythmia requiring mechanical support. Severe pulmonary disease is defined as any condition with a percentage vital capacity of less than 60% and/or a percentage forced expiratory volume in 1 second of less than 50%. Diabetes mellitus is defined according to the World Health Organization criteria. Performance status index is defined by the Japanese Society for Cancer Therapy.

2. \( SSS = -0.342 + 0.0139X_1 + 0.0392X_2 - 0.352X_3 \)

where \( X_1 \) is blood loss (in grams) divided by body weight (in kilograms); \( X_2 \), the operating time (in hours); and \( X_3 \), the extent of the skin incision (0 indicates a minor incision for laparoscopic or thoracoscopic surgery, including laparoscopic- or thoracoscopic-assisted surgery; 1, laparotomy or thoracotomy alone; and 2, laparotomy and thoracotomy).

(3) \( CRS = -0.328 + (0.936 \times PRS) + (0.976 \times SSS) \)

The costs for the hospital stay were calculated only for the surgical period. These included the fees for the operation, hospital laboratory tests, and diagnostic imaging; ward costs; and costs for the treatment of the postoperative complications. These excluded the costs unrelated to surgical operations, such as the costs of chemotherapy, radiotherapy, percutaneous transhepatic biliary drainage, and endoscopic removal of stones of the common bile duct.

Postoperative complications were only included when medical or interventional treatment had been performed. The complications included wound infection, wound dehiscence, anastomotic leakage, biloma, intra-abdominal abscess, intrathoracic abscess, ileus, intra-abdominal bleeding, severe atelectasis, anastomatic stenosis requiring dilation, cholangitis, pneumonia, interstitial pneumonitis, atrial fibrillation, bronchial asthma, urinary tract infection, acute pancreatitis, thrombotic phlebitis, bleeding from a duodenal ulcer, severe colitis, heart failure, disseminated intravascular coagulation, acute respiratory distress syndrome, hepatic failure, acute renal failure, and multiple organ failure. Complications developed in 182 patients, and there were 23 in-hospital deaths. The crude morbidity and mortality of the total 929 patients were 19.6% and 2.5%, respectively. The morbidity score was arbitrarily determined as follows: 0, no complications; 1, mild complications that were not life threatening; 2, moderate complications that were potentially life threatening unless adequate treatment was initiated; 3, severe organ dysfunction that usually required mechanical support, being equivalent to stage III in another classification of organ dysfunction, with precise definitions determined in 7 organs; and 4, in-hospital death as a direct result of complications.

A previous study revealed a significant correlation between the CRS and the surgical costs. A regression analysis showed an equation for estimating surgical costs from the CRS: costs = US $10160 + (US $13470 \times CRS). The ratio of real costs to estimated costs was calculated at the various ranges of the CRS and also among hospitals. This ratio was designated the economic index (EI).

Statistical analyses were performed as previously reported. Significance between the values of 3 independent groups was determined by the Kruskal-Wallis test. The correlation between different variables was quantified by the Spearman rank correlation, the significance of which was determined using the Spearman rank sum test. A linear regression analysis between 2 variables was performed using a simple regression method, the significance of which was quantified by an analysis of variance. \( P<.05 \) (2-tailed) was considered statistically significant.

everyone can receive necessary medical care for a small fee. These systems are regulated by the same rules, secure free access to the hospitals, and sustain a traditional fee-for-service system. Almost all surgical costs spent are basically reimbursed according to the clinical course. Although the government has developed several regulations to lessen the hospital stay, the average length of stay in Japan is about twice that in the United States. Clinical path-
have made it difficult to maintain this policy. The Japanese government is searching for a new system to achieve cost-effectiveness and egalitarianism.

A prediction scoring system designated as Estimation of Physiologic Ability and Surgical Stress (E-PASS) was previously generated to estimate the postoperative risk in general surgery. This system comprises the preoperative risk score (PRS), the surgical stress score (SSS), and the comprehensive risk score (CRS) (determined by the PRS and the SSS). A multicenter prospective study revealed that postoperative morbidity and mortality rates increased as the CRS increased. The CRS was significantly correlated with the severity of postoperative complications and the costs of the hospital stay. In this study, we demonstrate the usefulness of the E-PASS to estimate surgical costs and propose a new risk-based payment system (RBPS).

**RESULTS**

The relationship between the CRS and postoperative complications is shown in Figure 1. The incidence of postoperative morbidity linearly increased as the CRS increased. When the CRS was less than 0.3, the postoperative mortality was only 0.15%; however, the mortality increased to 2.3% when the CRS ranged between 0.3 and less than 0.5 and to 9.5% when the CRS ranged between 0.5 and less than 1.0. It reached 26.9% when the CRS exceeded 1.0. The CRS significantly correlated with the morbidity score (Spearman rank correlation = 0.54, P < .001 [n = 929]). It also correlated with the length of stay and the costs of the hospital stay (Figure 2).

Figure 3 shows the EI at the various ranges of the CRS. The EI varied from 0.82 to 1.17. The EI of the total patients was 0.93. Only 2% of the patients exceeded a cost that was twice the estimated cost. When we evaluated this ratio among the hospitals, it varied from 0.71 to 1.12 (Figure 4). Hospital F, which showed the smallest EI, used the clinical pathways for most elective surgical procedures, unlike the other hospitals.

Subsequently, we investigated whether the E-PASS could preoperatively predict surgical costs. Table 1 shows the relationship of the PRS and the surgical costs for open distal gastrectomy for gastric cancer and open colectomy for colon cancer. For both procedures, significantly different costs were observed among the 3 groups at varying ranges of the PRS. Moreover, the PRS significantly correlated with the surgical costs in the total patients (Spearman rank correlation = 0.32, P < .001 [n = 813]).

Then, we considered that different rates could preoperatively be set between the low- and high-risk patients in a prospective payment system. This system was designated as an RBPS, in which the rates for the patients with a PRS of 0.5 or greater and of less than 0.5 were set as $15,320 and $10,550, respectively, which are 95% of the average costs for each. We simulated hospital revenue using the different payment systems, a fixed payment system regardless of the patients’ risk and the RBPS, comparing them with the present Japanese fee-for-service system. For distal gastrectomy for gastric cancer, hospitals B and F, with a lower EI, used the clinical pathways for most elective surgical procedures, unlike the other hospitals.

When the RBPS was adopted, hospital F, where 30% of the patients treated had a PRS of 0.5 or greater, increased the surplus, while hospital B, where 7% of the patients treated had a PRS of 0.5 or greater, decreased the surplus. Similarly, hospitals D and E, treating more
high-risk patients, decreased the deficit, while hospitals A and C, treating fewer high-risk patients, expanded the deficit. Similar results were obtained for open colectomy for colorectal cancer (Table 2).

The E-PASS scoring system was generated based on our hypothesis that surgical stress exceeding the patients’ reserve capacity results in disruption of the homeostasis in internal environments, leading to hypovolemia, renal dysfunction, acute lung injury, decreased tissue repair, decreased immune response, hypercoagulation, and impaired glucose tolerance. These alterations are commonly observed in patients who undergo major surgery, regardless of the type, and cause various postoperative complications that mostly affect the surgical costs. Therefore, the balance between the patients’ reserve capacity and the surgical stress may be a key factor in the development of postoperative complications. The E-PASS scores were computed by a multiple regression analysis and can express the degree of the patients’ reserve capacity and the severity of surgical stress as continuous variables. The relationship between the CRS and the morbidity and mortality rates obtained in the present study was quite similar to those of previous studies. Recently, comparative results were obtained in patients who underwent lung surgery (S. Yamashita, MD, unpublished data, 2001). These findings support the previously described hypothesis.

To our knowledge, no scoring system to predict surgical costs has previously been reported. Because the E-PASS does not require any special examinations, this system can be used in any institution. Because the error of the equation to estimate the surgical costs was only 7% in the research subjects, it may be useful to estimate a hospital- or a nation-level budget. There were marked differences between the EI of the hospitals. Hospital F, which used clinical pathways for most elective surgical procedures, unlike the others, had the lowest EI. This hospital also had the lowest average costs for open distal gastrectomy and colectomy. Therefore, the EI may represent the most cost-effective outcome among the hospitals. The usefulness of the E-PASS for assessing clinical outcome was investigated in a multicenter cohort study. To assess the quality of surgical performance among hospitals, a simple comparison of mortality rates leads to much misunderstanding. Hospitals that treat more high-risk patients would show higher mortality rates. Similarly, hospitals that adopt an extensive lymph node dissection would demonstrate higher mortality rates. Therefore, the standardization of patient populations and surgical severity would be necessary before the surgical performance could be compared. Because the E-PASS expresses the degree of the patients’ reserve capacity and the severity of surgical stress as continuous variables, it may be useful to standardize the patient population and surgical severity. Preliminary findings demonstrated that a risk-adjusted mortality rate using the CRS was significantly related to the volume of operations performed.

![Figure 3](image-url)  
**Figure 3.** The estimation of the surgical costs by the comprehensive risk score (CRS). The surgical costs of the research subjects were estimated using an equation obtained in a previous study. The ratio of real costs to estimated costs (economic index [EI]) was quantified at the various ranges of the CRS.

![Figure 4](image-url)  
**Figure 4.** Comparison of the economic index (EI) among hospitals. The ratio of real costs to estimated costs (EI) was quantified among the 6 hospitals. Hospital F uses the clinical pathways for most of the elective surgical procedures, unlike the other hospitals.

<p>| Table 1. Relationship of the Preoperative Risk Score (PRS) and Surgical Costs |
|---------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>PRS</th>
<th>Open Distal Gastrectomy for Gastric Cancer</th>
<th>No. of Patients</th>
<th>Surgical Costs Spent, US $</th>
<th>P Value</th>
<th>Open Colectomy for Colon Cancer</th>
<th>No. of Patients</th>
<th>Surgical Costs Spent, US $</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.3</td>
<td>33</td>
<td>10 756 ± 4116</td>
<td></td>
<td></td>
<td>27</td>
<td>9861 ± 3065</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3-0.5</td>
<td>50</td>
<td>11 335 ± 3447</td>
<td>.002</td>
<td></td>
<td>42</td>
<td>11 900 ± 4948</td>
<td>.009</td>
<td></td>
</tr>
<tr>
<td>≥0.5</td>
<td>19</td>
<td>16 126 ± 6919</td>
<td></td>
<td></td>
<td>24</td>
<td>13 658 ± 4417</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Data are given as mean ± SD. Surgical costs included the fees for the operation, the hospital stay, and postoperative treatment.
†Using the Kruskal-Wallis test.
Several clinical prediction rules have been generated in some of the clinical settings to predict clinical outcome, especially mortality rates.7-10 The wide dissemination of computers in hospitals has given the opportunity for clinicians to use these indexes. These rules can be important in reducing uncertainty and assisting in medical decision making. Furthermore, adoption of the prediction rules will enable us to assess a quality of care and establish an RBPS.

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### Table 2. Effects of Payment System on Hospital Revenue for 2 Procedures

<table>
<thead>
<tr>
<th>Hospital</th>
<th>No. of Patients*</th>
<th>Average Fee Paid by the Fee-for-Service System, US $†</th>
<th>Balance per Patient, US $ Under a Fixed Payment System‡</th>
<th>Balance per Patient, US $ Under a Risk-Based Payment System§</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open Distal Gastrectomy for Gastric Cancer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>14 (12 + 2)</td>
<td>11,483</td>
<td>-45</td>
<td>-252</td>
</tr>
<tr>
<td>B</td>
<td>14 (13 + 1)</td>
<td>9,995</td>
<td>1,443</td>
<td>895</td>
</tr>
<tr>
<td>C</td>
<td>16 (15 + 1)</td>
<td>12,840</td>
<td>-1,402</td>
<td>-1,992</td>
</tr>
<tr>
<td>D</td>
<td>20 (15 + 5)</td>
<td>13,226</td>
<td>-1,788</td>
<td>-1,484</td>
</tr>
<tr>
<td>E</td>
<td>28 (21 + 7)</td>
<td>13,491</td>
<td>-2,053</td>
<td>-1,748</td>
</tr>
<tr>
<td>F</td>
<td>10 (7 + 3)</td>
<td>7,967</td>
<td>347</td>
<td>401</td>
</tr>
<tr>
<td><strong>Open Colectomy for Colon Cancer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>5 (3 + 2)</td>
<td>12,085</td>
<td>-911</td>
<td>-566</td>
</tr>
<tr>
<td>B</td>
<td>20 (15 + 5)</td>
<td>9,886</td>
<td>1,288</td>
<td>1,268</td>
</tr>
<tr>
<td>C</td>
<td>25 (19 + 6)</td>
<td>13,892</td>
<td>-2,718</td>
<td>-2,762</td>
</tr>
<tr>
<td>D</td>
<td>19 (9 + 10)</td>
<td>14,188</td>
<td>-2,394</td>
<td>-2,283</td>
</tr>
<tr>
<td>E</td>
<td>12 (11 + 1)</td>
<td>9,632</td>
<td>1,542</td>
<td>1,117</td>
</tr>
<tr>
<td>F</td>
<td>12 (12 + 0)</td>
<td>8,730</td>
<td>2,444</td>
<td>1,817</td>
</tr>
</tbody>
</table>

*The numbers with a preoperative risk score of less than 0.5 and of 0.5 or greater, respectively, are given in parentheses.
†The total sum paid by the present Japanese health insurance system. In this system, almost all surgical costs spent are basically reimbursed according to the clinical course after a case review.
‡Estimated balance per patient when US $11,438 (for open distal gastrectomy) and US $11,174 (for open colectomy) are paid for one patient regardless of medical conditions. In this system, 5.0% of cost savings can be achieved in total compared with the present fee-for-service system.
§Estimated balance per patient when US $10,550 (for open distal gastrectomy) and US $10,645 (for open colectomy) are paid for a patient with a preoperative risk score of less than 0.5 and US $15,320 (for open distal gastrectomy) and US $15,322 (for open colectomy) are paid for a patient with a preoperative risk score of 0.5 or greater. In this system, 5.0% of cost savings can be achieved in total compared with the present fee-for-service system.

### References