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Differences in Practice Patterns and Costs between Small Cell and Non-Small Cell Lung Cancer Patients in Japan

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Many reports exist regarding the economic evaluation of evolving chemotherapeutic regimens or diagnostic images for lung cancer (LC) patients. However, it is not clear whether clinical information, such as pathological diagnosis or cancer stage, should be considered as a risk adjustment in lung cancer. This study compared the cost and practice patterns between small cell lung carcinoma (SCLC) and non-small cell lung carcinoma (NSCLC) patients. 6,060 LC patients treated at 58 academic hospitals and 14,507 at 257 community hospitals were analyzed. Study variables included demographic variables, comorbid status, cancer stage, use of imaging and surgical procedures, type of adjuvant therapy (chemotherapy, radiation or chemoradiation), use of ten chemotherapeutic agents, length of stay (LOS), and total charges (TC; US$1 = ¥100) in SCLC and NSCLC patients. The impact of pathological diagnosis on LOS and TC was investigated using multivariate analysis. We identified 3,571 SCLC and 16,996 NSCLC patients. The proportion of demographic and practice-process variables differed significantly between SCLC and NSCLC patients, including diagnostic imaging, adjuvant therapy and surgical procedures. Median LOS and TC were 20 days and US$6,015 for SCLC and 18 days and US$6,993 for NSCLC patients, respectively ($p < 0.001$ for each variable). Regression analysis revealed that pathological diagnosis was not correlated with TC. Physicians should acknowledge that pathological diagnosis dose not accounts for any variation in cost of LC patients but that should remain as an indicator of appropriate care like selection of chemotherapeutic agents.
——— lung cancer; pathological diagnosis; practice pattern; costs; quality of care.
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Lung cancer (LC) is currently the most common types of cancer in Japan. Of the estimated 123,000 cases of LC in Japan in 2006, 70% were 65 years or older, and healthcare expenditures for LC were $US2.63 billion (Ministry of Health, Welfare and Labor, 2006). LC has been attracting attention both clinically and economically, as new chemotherapeutic agents and diagnostic imaging techniques continue to be developed (Dooms et al. 2006; Pimentel et al. 2006; Maniadakis et al. 2007; Ng et al. 2007; Spiro et al. 2008). These advances in medical care have benefited LC patients (Oliver et al. 2001; Conron et al. 2007; Ostgathe et al. 2008).

In developed countries where healthcare expenditures and the aging population are both experiencing rapid growth, a sustainable health care system is necessary. Consequently, a good deal of research in the health service on non-communicable diseases has focused on monitoring the quality and efficiency of medical care, as well as improving the quality of care through the introduction of multidisciplinary practice. When conducting health service research, several factors affecting resource use should be taken into account. Some factors are specific to a particular disease, cancer stage, or pathological diagnosis of a malignant neoplasm. Other variables are common to a wide range of diseases, although the impact of a particular variable may vary dramatically among them.

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Although many LC studies have noted a difference in practice between patients with SCLC and those with NSCLC (Oliver et al. 2001; Dooms et al. 2006; Pimentel et al. 2006; Maniadakis et al. 2007; Ng et al. 2007; Ostgathe et al. 2008), the study population were often limited to either small cell LC (SCLC) patients or non-small cell LC (NSCLC) patients. For effective management of health policy for the entire LC population, it is necessary to understand the effect of LC-related variables and prioritize these variables. In addition, clinical experts involved in health service research need to be reassured of the significance of relevant clinical information. Within that context, it is important to measure the effect of pathological diagnosis or cancer stage on resource use and practice differences. In the current study, we investigated differences in practice between SCLC and NSCLC patients and examined how LC-related severity, such as pathological diagnosis or cancer staging, impacts on costs.

Materials and Methods

We utilized the Japanese administrative database gathered by the Ministry of Health, Labor and Welfare (MHLW) between July 1 and December 31, 2006. This database was created in order to develop Japanese case-mix grouping, refine the payment system, and disclose hospital performance for 731 institutions (80 university hospitals, the National Cancer Center, the National Cardiovascular Center, and 649 community hospitals). These hospitals serve various functions, including the delivery of acute care, advanced medical research, and/or the education of students and trainees. The database contains both discharge summaries and claims data in electronic format, which is useful for profiling detailed practice patterns. In the current study, we analyzed LC cases from hospitals that voluntarily participated in our research project. The study has been approved by the ethics committee of the University of Occupational and Environmental Health.

Definition of variables

The principal diagnosis recorded for the patients evaluated in this study was primary malignant respiratory neoplasm, according to the International Statistical Classification of Diseases, Version 10 (ICD10) (C33, C34 $). As pathological diagnosis was not listed in the ICD10 code, we collected information regarding pathology (SCLC, NSCLC, or unspecified) at admission, as advised by clinical experts. The independent variables analyzed were: use of an ambulance, hospital function, age, gender, diagnostic test, pathological diagnosis (SCLC and NSCLC), cancer stage classification (as an indicator of disease progression status at admission), status of comorbid conditions, procedure type, chemotherapeutic agents, and outcome. Use of an ambulance was used as a surrogate indicator of emergency admission. Patients were divided into two groups: patients < 65 years of age and those ≥ 65 years of age. The Charlson Comorbidity Index (CCI) was used to assess the degree of chronic comorbid conditions (Sundararajana et al. 2004). Although the original CCI included primary respiratory cancer, this was not considered a chronic comorbid condition in the current study. Stage of LC was classified as 0 or 1, 2, 3, or 4, in accordance with the American Joint Committee on Cancer Staging System (Maddaus et al. 2005). Various diagnoses in this database were recorded via ICD10 codes. The types of diagnostic imaging recorded included computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography, scintigraphy, and positron emission tomography (PET). Procedure-related complications were identified to be present if any of the ICD10 codes (T81$ through T87$), were recorded (Zhan et al. 2003). The use of LC-related surgical procedures including resection (partial or wedge) or lobectomy for one lobe (referred to as lobectomy), video-assisted thoracic surgery (VATS), and either resection of at least 2 lobes or sleeve lobectomy (referred to as extended lobectomy) was recorded. Adjuvant therapy was divided into three categories; namely, chemotherapy only, radiation only, and chemo-radiation. The use of ten specific chemotherapeutic agents including etoposide (eto), amurubicin (amu), irinotecan (iri), docetaxel (doc), gefitinib (gef), carboplatin (car), paclitaxel (pac), cisplatin (cis), gemcitabine (gem), or vinorelbine (vin) was surveyed, and combinations of these chemo-agents were also investigated (Pimentel et al. 2006; Maniadakis et al. 2007; Ng et al. 2007; National Cancer Institution. 2008a, 2008b). In Japan, charges for hospital care are determined by a standardized fee-for-service payment system, and are considered to be good estimates of healthcare costs (Hirose et al. 2005). This study used length of stay (LOS) and total charges (TC; US$1 = ¥100) billed during hospitalization as indicators of total in-hospital cost. TC in our study included physician fees, instrument costs, laboratory costs, imaging tests or pharmaceutical agents, and administration fees.

Statistical analysis

Categorical data were reported as frequencies and proportions and were analyzed using Fisher's exact test. The Mann-Whitney test was used to compare differences in LOS or TC by pathological diagnosis. Effect of pathological diagnosis on LOS and TC was measured using a multiple linear regression model. In this model, distributions of LOS and TC were skewed to the right and log-transformed. Statistical analysis was performed using SPSS, Version 16.0. All reported p-values were two-tailed, with the level of significance set at 0.05.

Results

Of the 20,567 LC patients analyzed, 14,507 were treated at 257 community hospitals and 6,060 at 58 academic hospitals. We identified 3,571 SCLC (17.4%) and 16,996 NSCLC patients (82.6%) (Table 1). Of these, 1,002 SCLC and 5,058 NSCLC patients were treated at academic hospitals. The median age was 70 and 69 years for SCLC and NSCLC patients, respectively. The proportion of patients ≥ 65 years was 69.5% for SCLC and 63.4% for NSCLC patients, which was significantly different. Males composed 80.4% and 70.1% of the population of SCLC and NSCLC patients, respectively. Emergency status at admission was noted for 3.8% of SCLC and 3.2% of NSCLC patients ($p = 0.054$). There were 1,939 cases of mortality, comprising 391 (10.9%) SCLC patients and 1548 (9.1%) NSCLC patients. The proportion of Stage 3 or Stage 4 patients varied significantly between SCLC (88.9%) and NSCLC patients (72.0%). A significant difference in the absence of chronic comorbidities (according to the CCI) between SCLC (43.7%) and NSCLC patients (49.5%) was also observed (Table 1).

Use of diagnostic imaging is shown in Table 2. CT

TABLE 1. Patient characteristics by pathological diagnosis (*n*, %).

	SCLC (*n* = 3,571)	NSCLC (*n* = 16,996)	*P*
Number of hospitals	272	306	
Median number of patients per hospital < >	7 <1 - 84>	33 <1 - 532>	
Age, median	70 [13]	69 [14]	< 0.001*
≥ 65 years of age	2,482 (69.5)	10,779 (63.4)	< 0.001
Male	2,872 (80.4)	11,914 (70.1)	< 0.001
Use of ambulance	136 (3.8)	538 (3.2)	0.054
Outcome (mortality)	391 (10.9)	1,548 (9.1)	< 0.001
Classification of stage			< 0.001
Stage 0 or 1	215 (6.0)	3,651 (21.5)	
Stage 2	180 (5.0)	1,152 (6.8)	
Stage 3	1,290 (36.1)	5,011 (29.5)	
Stage 4	1,886 (52.8)	7,182 (42.3)	
Charlson Comorbidity Index			< 0.001
1	691 (19.4)	2,850 (16.8)	
2	226 (6.3)	1,268 (7.5)	
3	752 (21.1)	3,212 (18.9)	
≥4	343 (9.6)	1,258 (7.4)	
Procedure-related complications	11 (0.3)	281 (1.7)	< 0.001
Hospital type			
Academic	1,002 (28.1)	5,058 (29.8)	0.044

SCLC, Small cell lung carcinoma; NSCLC, Non-small cell lung carcinoma.
[ ], interquartile range; < >, range; *, compared by Mann-Whitney test, others by Fisher's exact test.

was the most common diagnostic imaging technique, utilized in 53.3% of SCLC and 47.8% of NSCLC patients. MRI was the second most common imaging technique, utilized in 17.2% of SCLC and 14.7% of NSCLC patients. Chemotherapy only or chemo-radiation therapy was administered to significantly more SCLC compared with NSCLC patients (63.7% and 10.8%, respectively). Eto, car and cis were most frequently used chemotherapeutic agents in SCLC (36.8%, 34.8%, and 24.4%, respectively), whereas pac, gem and vin were so in NSCLC patients (18.0%, 10.4%, and 10.1%, respectively) (Table 2). As for combination chemotherapy, three regimens containing 4 chemotherapeutics (car + eto, cis + iri or cis + eto) were used in 60.6% of SCLC patients receiving any of the study chemotherapeutics. In comparison, seven combinations of chemotherapeutics were needed to reach 64% of cumulative relative frequency in NSCLC patients (car + pac, gef, doc, vin ± gem, cis + vin or car + gem) (Table 3).

The proportion of LC patients who underwent surgical procedures was significantly different between SCLC (2.7%) and NSCLC patients (18.2%) (Table 2). Median LOS was significantly different between SCLC (20 days) and NSCLC patients (18 days). TC was also significantly different between SCLC (US$6,015) and NSCLC patients (US$6,993).

After controlling for demographic and clinical variables, the treatment categories 'radiation only or chemo-radiation' were found to be significantly correlated with LOS and TC, whereby estimation values were 1.093 or 1.484 in LOS, and 1.057 or 1.506 in TC, respectively (Table 4). Some surgical procedures were significantly correlated with TC, in that the estimation in TC for VATS or extended lobectomy was 1.769 or 1.743, respectively. Compared with the impact of other study variables, pathological diagnosis was statistically significant determinant of LOS, but not of TC.

DISCUSSION

Utilization of a Japanese administrative database from 315 hospitals allowed us to analyze practice patterns or costs with regard to pathological diagnosis of LC patients, and an independent effect of pathological diagnosis on LOS and TC. The patients' characteristics, use of diagnostic imaging, use of surgical procedures, combination of adjuvant therapy, or administration of chemotherapeutic agents varied significantly between SCLC and NSCLC patients. Impact of pathological diagnosis or cancer stage on LOS or TC was also modest or minimal, compared with that of other study variables.

Some limitations of this study should be noted. First, as we only analyzed in-hospital claims data, lack of outpatient department (OPD) data may have impacted the results.

TABLE 2. Use of diagnostic imaging, procedures, and costs in hospitalized patients, by pathological diagnosis (*n*, %).

	SCLC (*n* = 3,571)	NSCLC (*n* = 16,996)	*P*
Diagnostic imaging			
CT	1,902 (53.3)	8,129 (47.8)	< 0.001
MRI	614 (17.2)	2,491 (14.7)	< 0.001
Ultrasonography	352 (9.9)	1,418 (8.3)	< 0.001
Scintigraph	678 (19)	2,760 (16.2)	< 0.001
PET	33 (0.9)	252 (1.5)	0.011
Surgical procedure			< 0.001
Video-assisted lobectomy	55 (1.5)	1,865 (11.0)	
Lobectomy	30 (0.8)	857 (5.0)	
Extended lobectomy	13 (0.4)	374 (2.2)	
Adjuvant therapy			< 0.001
chemotherapy only	2,273 (63.7)	7,976 (46.9)	
radiotherapy only	155 (4.3)	800 (4.7)	
chemo-radiation	385 (10.8)	1,293 (7.6)	
Chemotherapeutic agent			
Etoposide	1,315 (36.8)	142 (0.8)	< 0.001
Amurubicin	404 (11.3)	130 (0.8)	< 0.001
Irinotecan	738 (20.7)	587 (3.5)	< 0.001
Docetaxel	49 (1.4)	1,538 (9.0)	< 0.001
Gefitinib	27 (0.8)	1,156 (6.8)	< 0.001
Carboplatin	1,241 (34.8)	3,917 (23)	< 0.001
Paclitaxel	147 (4.1)	3,052 (18.0)	< 0.001
Cisplatin	870 (24.4)	1,690 (9.9)	< 0.001
Gemcitabine	46 (1.3)	1,768 (10.4)	< 0.001
Vinorelbine	31 (0.9)	1,719 (10.1)	< 0.001
Costs			
Length of stay (LOS)	20 days [29 days]	18 days [22 days]	< 0.001*
Total charge	US$6,015 [US$8,835]	US$6,993 [US$10,174]	< 0.001*

SCLC, Small cell lung carcinoma; NSCLC, Non-small cell lung carcinoma.
[ ], interquartile range; *, compared by Mann-Whitney test, others by Fisher's exact test.

Our study did, however, initiate the gathering of OPD information in an electronic format, similar to that of the inpatient data. By combining databases, LC care events may eventually be tracked in the future, and researchers may identify a more realistic practice pattern. A second limitation was that laboratory data on respiratory function at admission were not surveyed, though the present study analyzed pertinent clinical data such as the Hugh Jones classification. Despite the fact that we did not examine respiratory function at admission, it is noteworthy for future studies that the collection of data on the use or prescribed number of bronchodilators may be possible surrogate markers for clinical severity of the disease.

LOS for all acute care hospital admissions is reportedly two to three times longer in Japan (19.8 days in 2005) than in Western countries (5.4 days in France, 7.8 in United Kingdom, 8.5 in Switzerland) (OECD Health Data 2008). One reason for the higher LOS in Japan is the lack of differentiation of hospital function. In general, Japanese hospitals provide rehabilitation and nursing home services in addition to acute medical care. The fiscal impact of these longer LOS includes higher actual costs consumed during each episode of LC (Ishizaki et al. 2002). Therefore, the possibility of greater differences in cost between other relevant study variables, as well as between SCLC and NSCLC patients, could represent a strength of the present study.

Risk adjustment and clinical severity of disease should be considered in health policy research and the establishment of practice guidelines. Clinically relevant characteristics (e.g., age, comorbidities, cancer stage, and pathological diagnosis) often influence costs. Due to the growing financial burden of LC, many economic evaluations of new evolving pharmaceuticals, diagnostic and therapeutic technologies have been conducted (Dooms et al. 2006; Pimentel et al. 2006; Ng et al. 2007; Spiro et al. 2008).

When investigating the quality or efficiency of particular LC treatments, many experts assume that clinical information would affect costs or practice pattern in the acute

TABLE 3. The ten most popular combinations of Chemotherapeutic agents for patients with small cell lung carcinoma and non-small cell lung carcinoma.

Small cell lung carcinoma

No	*N*	Relative frequency (%)	Cummulative relative frequency (%)	Vinorelbine	Gemcitabine	Cisplatin	Paclitaxel	Carboplatin	Etoposide	Amurubicin	Irinotecan	Docetaxel	Gefitinib
1	844	31.8%	31.8%					●	●				
2	387	14.6%	46.3%			●					●		
3	381	14.3%	60.6%			●			●				
4	341	12.8%	73.5%							●			
5	185	7.0%	80.4%					●			●		
6	101	3.8%	84.2%				●	●					
7	86	3.2%	87.5%								●		
8	36	1.4%	88.8%									●	
9	22	0.8%	89.7%										●
10	21	0.8%	90.4%						●				

Non-small cell lung carcinoma.

No	*N*	Relative frequency (%)	Cummulative relative frequency (%)	Vinorelbine	Gemcitabine	Cisplatin	Paclitaxel	Carboplatin	Etoposide	Amurubicin	Irinotecan	Docetaxel	Gefitinib
1	2,463	26.6%	26.6%				●	●					
2	922	9.9%	36.5%										●
3	715	7.7%	44.2%									●	
4	502	5.4%	49.6%	●	●								
5	457	4.9%	54.6%	●									
6	440	4.7%	59.3%	●		●							
7	411	4.4%	63.8%		●			●					
8	333	3.6%	67.4%					●				●	
9	329	3.5%	70.9%				●						
10	290	3.1%	74.0%		●								

TABLE 4. Linear regression analysis of natural log-transformed length of stay (LOS) and total cost (TC).

	Log LOS			Log TC		
	Estimation	S.E.	*P*	Estimation	S.E.	*P*
Intercept	1.786	0.033	< 0.001	7.666	0.027	< 0.001
Age (≥ 65 years)	0.097	0.014	< 0.001	0.054	0.011	< 0.001
Male	−0.029	0.015	0.051	−0.014	0.012	0.230
Use of ambulance	0.123	0.039	0.002	0.127	0.031	< 0.001
Outcome						
Mortality	0.620	0.025	< 0.001	0.602	0.020	< 0.001
Cancer stage (compared to Stage 0 or 1)						
Stage 2	0.190	0.032	< 0.001	0.115	0.025	< 0.001
Stage 3	0.389	0.023	< 0.001	0.251	0.019	< 0.001
Stage 4	0.488	0.024	< 0.001	0.319	0.019	< 0.001
Pathological diagnosis (for small cell carcinoma)						
Non-small cell carcinoma	−0.099	0.018	< 0.001	−0.026	0.014	0.066
Charlson Comorbidity Index (for zero)						
1	0.141	0.019	< 0.001	0.111	0.015	< 0.001
2	0.203	0.026	< 0.001	0.154	0.021	< 0.001
3	0.088	0.019	< 0.001	0.063	0.015	< 0.001
4 or more	0.176	0.026	< 0.001	0.144	0.021	< 0.001
Procedure-related complications	0.064	0.058	0.265	0.083	0.046	0.073
Surgical procedure						
Video-assisted lobectomy	0.890	0.030	< 0.001	1.769	0.024	< 0.001
Lobectomy	1.022	0.037	< 0.001	1.671	0.030	< 0.001
Extended lobectomy	1.052	0.051	< 0.001	1.743	0.041	< 0.001
Adjuvant therapy (compared to no treatment)						
Chemotherapy only	0.337	0.018	< 0.001	0.402	0.014	< 0.001
Radiotherapy only	1.093	0.034	< 0.001	1.057	0.027	< 0.001
Chemo-radiation therapy	1.484	0.028	< 0.001	1.506	0.022	< 0.001
Hospital (compared to community hospital)						
Academic	0.141	0.015	< 0.001	0.162	0.012	< 0.001

F test for the model. Log LOS, $P < 0.001$; Log TC, $P < 0.001$.
Coefficient of determination. Log LOS: 0.210; Log TC: 0.378

care setting. This type of research in LC, however, has largely been based on studies limited either to SCLC or NSCLC cases, and not on overall primary LC studies (Oliver et al. 2001; Conron et al. 2007; Ostgathe et al. 2008). In cases where health services research for LC has been based on the entire LC population, it has often included either outpatient care or palliative medicine for LC (Conron et al. 2007; Podnos et al. 2007). We expect that some medical care might be common to all LC patients, whereas other types of medical care, such as chemotherapy, might be more specific to certain LC patients for whom the clinical severity of disease is higher. A thorough investigation of the effect of relevant elements including clinical information is therefore necessary for health policy to estimate healthcare expenditures and maintain efficiency in resource allocation for LC during the whole course of LC care. For example, if the impact of pathological diagnosis, compared with the impact of clinical severity of the disease, were found to be even slightly higher, use of diagnostic imaging or supportive care should be monitored in the overall LC population. Such an approach may result in a more efficient treatment pattern and better integration of care. In the field of palliative medicine for cancer patients, symptoms or quality of life might determine the nature of the care process or the amount of care, rather than the stage of cancer (Podnos et al. 2007; Ostgathe et al. 2008). Conversely, if the impact of pathological diagnosis is too great to be disregarded, we need to observe practice guidelines and conduct further research on medical care for SCLC and NSCLC separately. This might enable institutions to examine their adherence to the guidelines and improve quality of care. This present study found a wide variation in the use of chemotherapy regimens, particularly for NSCLC patients, for whom there was no popular combination regimen, except for car + pac. There remains a need to determine the optimal combination chemotherapy regimens for LC patients in Japan (Macbeth et al. 2007; Ostgathe et al. 2008). Patient characteristics, choice of surgical procedure or adjuvant therapy, and administration of specific chemotherapeutics were significantly different, although pathological diagnosis or cancer stage had little, if any, association with LOS or TC. Clinical information relevant to disease severity should remain as indicators of whether administering adjuvant therapy is appropriate, including the use of chemotherapeutics.

In conclusion, the current study used an administrative database to present descriptive characteristics and analyze variation in resource use in SCLC and NSLC patients in Japan. The treatment pattern of chemotherapy was quite different in SCLC and NSLC patients. However, the independent effect of pathological diagnosis on TC was found to be not significant. Thus the value of using pathological diagnosis may be limited to monitoring the clinical validity of administering certain medications or performing certain procedures.

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Injury Severity Score, Resource Use, and Outcome for Trauma Patients Within a Japanese Administrative Database

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Background: Injury Severity Score (ISS) is commonly used in prediction models and risk adjustment for mortality. However, few studies have assessed the relationship of ISS to outcomes such as resource use. To test the utility of ISS for investigation of the quality of trauma care, we evaluated the impact of ISS on resource utilization and mortality.

Methods: Of 1,895,249 cases from a Japanese administrative database in 2006, 13,627 trauma patients with ISS were analyzed. Variables included demographics, ISS, number and locations of injured organs, comorbidities, diagnostic and therapeutic procedures recorded during hospitalization, and hospital type. Dependent variables were length of stay (LOS), total charges (TC), initial 48-hour TC, high outliers of LOS or TC, and mortality. Multivariate analyses were used to measure the impact of ISS.

Results: ISS 1 to 9 was most frequent (85.5%) and blunt injury occurred in 93.7% of patients. With increasing ISS, the mortality rate rose to 27.2% at ISS ≥36. LOS was higher at ISS ≥36 whereas TC was higher at 25 to 35. After controlling for study variables, rehabilitation was most strongly associated with LOS, TC, and LOS outliers. ISS 25 to 35 affected initial 48-hour TC most, while ventilation affected mortality most. "Abdomen, pelvic organs" and ISS 25 to 35 or ≥36 were more strongly associated with outcomes.

Conclusions: Specific ISS and injured organs may be used to estimate resource use or mortality for monitoring quality of trauma care. To integrate a more efficient system of trauma care, variations in resource input among hospitals should be investigated.

Key Words: ISS, Resource use, Outcome, Outlier.

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The rapidly increasing aging population and the decreasing birthrate have long been highlighted in public health and policy-making in Japan, where actions toward continuous economic growth are pursued. However, disease management for productive generations should not be ignored, because injuries to young people provide another economic burden. In 2004, inadvertent accidents and intended trauma were ranked in the top three causes of mortality among the population aged from 0 year to 39 years in Japan.[1]

Because of the lack of differentiation in hospital function in Japan, the growing interest in efficient care systems in emergency medicine, including trauma care, might never have occurred.[2] The Japanese Association for Acute Medicine, however, has started to investigate the quality of trauma care through the Japan Trauma Registry and the Japan Trauma Data Bank (JTDB) Report.[3] In addition, the Ministry of Health, Labor, and Welfare has recently started to promote greater efficiency in terms of allocation or distribution of care facilities through regional medical care planning of emergency medicine for trauma or disasters.[2]

When monitoring the quality or efficiency of trauma care in the context of a systemic approach to improve performance, unfair or undesirable consequences might occur unexpectedly in the verification process of trauma centers or payments for optimized trauma care. For example, intensive care unit (ICU) care in Austria is paid on the basis of ICU staffing or number of beds, and the Trauma and Injury Severity Score is used to monitor the appropriateness of the intensive care delivered to patients. Accordingly, healthcare policy-makers should implement quality indicators and risk adjustment methods to comprehensively evaluate trauma medicine.[4–7] The Injury Severity Score (ISS), Trauma Score, and Trauma and Injury Severity Score have been utilized and revised in studies of patient outcomes and trauma care.[8,9] However, few studies have examined the effects or the discriminative ability of these measures of clinical severity on the amount of medical resources spent in the early post-trauma period or the entire duration of hospitalization after trauma.[10,11] Concerns about indices for the clinical severity of trauma and the predictive validation for discharge outcome of trauma patients in Japan await answers. MacLennan et al.[12] reported the association of patient mortality with patient density as a combined marker of patient volume and facility resources rather than resource input. They acknowledged the need to measure resource consumption when examining patient numbers in relation to outcomes. Another recent article from Christensen et al.[13] demonstrated that the greatest component of acute hospital cost was determined by length of hospital stay (LOS), and they concluded that measures designed to reduce LOS would be effective. They assumed that LOS is correlated with cost; however, they did not consider the effective trauma care approach that functions in the real world. This cannot be considered until exploratory research is performed to investigate what kind of care processes or trauma-related clinical information would better explain resource consumption during the early period or the total admission time.

During the initial 48 hours of trauma care or the entire duration of hospitalization, profiling the relationship of trauma-related severity, such as ISS, to the resources used will likely result in useful approaches to measure quality of trauma care or for allocating resources more efficiently in the field of emergency medicine. In the current study, we investigated the association of ISS with resource use or outcomes at hospitals delivering trauma care in Japan. The aim of the study was to identify representative factors that were associated with intensive use of resources.

MATERIALS AND METHODS

This administrative database were originally embedded in a government project on the development of a Japanese case-mix classification system initiated in 2002. This database was used by the Ministry of Health, Labor and Welfare to profile hospital performance and determine hospital payments across 82 academic hospitals (80 university hospitals, the National Cancer Center, and the National Cardiovascular Center), which enrolled in 2003, and has increased in size to include 731 hospitals (82 academic and 649 community hospitals) in 2006. The database contains anonymous medical claims, clinical data, and care processes for procedures performed between July 1 and December 31 of each year.

To refine this trauma-related case-mix system in cooperation with our research team and the Japanese clinical societies, trauma-related severity indices such as ISS and the Acute Physiology and Chronic Health Evaluation (APACHE) II have been used since 2006. We analyzed the data for 2006 provided by hospitals participating voluntarily in our project. These hospitals are located throughout Japan and deliver acute care, medical research, and educate students or residents. This project was approved by the University of Occupational and Environmental Health ethical committee in Kitakyushu, Fukuoka, Japan.

Definition of Variables

Study variables included age, gender, use of an ambulance, mechanism of injury (blunt or penetrating), number and anatomic location of injuries, ISS, comorbidity, diagnostic imaging (roentgenography, computed tomography, abdominal sonography, or angiography including embolization), blood transfusions (packed blood cells, plasma or platelets), surgical procedures, use of artificial ventilation, admission in an ICU, rehabilitation provided during hospitalization, outcome at discharge, and hospital function (academic or community). In addition, our database tracked the number and date of procedures performed during each hospitalization. For resource use, we analyzed the number of surgical procedures or diagnostic imaging, the number of days of ICU stay or ventilation, and the total volume of blood transfusions. We used LOS and total charges (TC; US$1 = 100 yen) billed during admission as proxies for total in-hospital resource use. In Japan, charges for hospital care are determined by a standardized fee-for-service payment system, known as the national uniform tariff table. Fees accrued through the national uniform tariff system are considered to be good estimates of healthcare costs.[14] TC in our study included physician fees, instrument costs, costs of laboratory or imaging tests, and administration fees. We also calculated the TC for the initial 48 hour after admission (initial 48-hour TC). To analyze the proportion of high outliers of LOS and TC, we identified the 95th percentile of these resource uses.

For each ISS, we categorized patients beyond these 95th percentile values and then calculated the proportion of high outliers. Patients were stratified by age into three groups: <15, 15 to 54, and ≥55 years. We used transfer by ambulance as a proxy for emergency status. This database included six categories of severity within the Abbreviated Injury Scale (AIS), in which 1 corresponds to superficial injury; 2, moderate injury; 3, severe, but not life-threatening injury; 4, severe, life-threatening injury; 5, critical injury, survival uncertain; and 6 is unsalvageable injury, in which trauma has occurred to any one or combination of the following six anatomic regions: head and neck, face, chest, "abdomen, pelvic organs," "extremities, pelvic girdle," and external.

ISS was calculated as the sum of the squares of AIS severity (1–5) of the single worst injury in each of the three most affected body regions. ISS must be between 1 and 75 (maximum). Patients with an AIS severity of 6 in any of the six body regions were automatically given an ISS of 75.[15] We categorized ISS into five groups: ISS 1 to 9, 10 to 15, 16 to 24, 25 to 35, and ≥36. The number of damaged organs ranged from 1 to 6. The database records a maximum of four comorbidities per patient. To assess the severity of preexisting conditions, we used the Charlson comorbidity index (CCI), and we calculated the median CCI or categorized patients into three groups; CCI 0, CCI 1, or CCI ≥2.[16] The following patients were excluded from our analysis: trauma patients who died within the first 24 hours of hospitalization, burn victims, patients whose diagnosis did not involve trauma, trauma patients who were diagnosed and treated only in the outpatient department, and trauma patients without AIS codes.

Statistical Analysis

Frequencies and proportions of each categorical variable in the study were determined. Statistical comparisons were made using Fisher's exact test. Continuous variables were compared across ISS groups using non-parametric tests. To analyze the impact of ISS on LOS, TC, and the initial 48-hour TC, we used multiple linear regression analysis for the risk adjustment model. Because the distribution of LOS, TC, and the initial 48-hour TC was right-skewed, all data were log_{10}-transformed in this model. A logistic regression model was used to evaluate the relationship between ISS and either mortality, high outliers of LOS or TC. Statistical analysis was performed using SPSS 16.0. All reported *p* values were two tailed, and the level of significance was set at <0.05.

RESULTS

Of 1,895,249 patients in the database of our research project, we identified 83,327 trauma-related, case-mix patients across 465 hospitals (12,728 cases from 70 academic hospitals and 70,599 cases from 395 community hospitals). Of these patients, 13,627 trauma cases had valid AIS (1,386 cases from 43 academic hospitals and 12,241 cases from 157 community hospitals) and were eligible for analysis in the current study.

There were 11,650 cases (85.5%) in the ISS 1 to 9 category, 528 (3.9%) in 10 to 15, 988 (7.3%) in 16 to 24, 325 (2.4%) in 25 to 35, and 136 (1.0%) in ≥36. Differences in median age and proportions of age, gender, or use of ambulance between the five ISS categories were statistically significant, whereas the proportion of mechanism of injury (penetrating vs. blunt) was not different ($p = 0.443$). "Head and neck" as an anatomic location for traumatic injury was common among patients with ISS ≥16, whereas "Extremity, pelvic girdle" was a common site of traumatic injury among patients with ISS ≤15. Among the patients with ISS 1 to 9, 91.8% experienced trauma to only one organ, whereas 40.6% to 100% of patients in ISS groups ≥10 experienced trauma to two or more organs. The proportion of CCI grades and surgical procedures varied significantly among the ISS groups. The number of surgical procedures performed was statistically different. Community hospitals treated more patients in every ISS group, but the proportion of care delivered by academic hospitals increased with increasing ISS up to 35. The mortality rate increased with increasing ISS (Table 1).

Table 2 presents the results of univariate analyses for the proportion and quantity of care processes across ISS categories. The differences in proportion or quantity of diagnostic imaging, critical care, most kinds of blood transfusions, and rehabilitation were statistically significant between the five ISS categories, except for the number of patients for whom angiography was performed ($p = 0.827$) and the amount of platelets transfused ($p = 0.474$). As ISS increased, the proportion or quantity of critical care, transfusion, and rehabilitation performed increased, except for the already high quantity of ICU stay, transfusions and the high proportion of rehabilitation in patients with ISS 25 to 35. In terms of resource use, LOS and high outliers of LOS increased as the ISS rose. TC, initial 48-hour TC, and high outliers of TC were greatest in patients with ISS 25 to 35 (Table 2).

After adjustment for demographic and clinical variables, ISS, ventilation and rehabilitation had the greatest significant association with LOS. ISS, surgical procedures, ventilation, and rehabilitation were more significantly associated with TC and initial 48-hour TC, except that the association between rehabilitation and 48-hour TC was not significant ($p = 0.701$). Injury to the "Abdomen, pelvic organs" was more strongly associated with LOS, TC, and initial 48-hour TC compared with the other groups of injured organs. Even after adjustment for age, CCI ≥2 was significant associated with LOS and TC (Table 3).

Table 4 shows the results of multiple logistic regression analyses to analyze the associations between study variables and mortality, and high outliers of LOS or TC. Ventilation was most significantly associated with mortality. ISS ≥36, CCI ≥2, and age ≥55 years were stronger predictors for mortality compared with the other study variables. The injured organs associated with mortality in our study were "Abdomen, pelvic organs" and "Extremities, pelvic girdle." Significant determinants of high outliers of LOS were rehabilitation, ISS 25 to 35 or ≥36, and ventilation (Table 4).

DISCUSSION

Using an administrative database of patients from 200 hospitals in Japan, this study presents the descriptive characteristics of trauma patients and assesses the independent effects of ISS on LOS, TC, initial 48-hour TC, and high outliers of LOS and TC. After controlling for independent co-variables, including hospital function, the factors ISS, surgical procedure, ventilation, and rehabilitation were found to consume significantly more resources.

In our study, the anatomic location of the injured organ had no or only a moderate effect on resource use and outcome except for injuries to the "Abdomen, pelvic contents" or "Extremity, pelvic girdle." The mechanism of traumatic injury in most cases in this study was blunt rather than penetrating trauma. In Japan, severe legislative regulation prohibits civilians from possessing guns, even for the purpose of self-defense.

The findings of the current study correlate with the findings in a 2006 report by the JTDB. However, the proportion of ISS categories differs between our study and the JTDB report (ISS ≥36, 8.8%).[17] Our database included 42 hospitals that participated in the Japan Trauma Registry (which comprised data from 90 hospitals in 2006). Because the hospitals in the JTDB study may function either as a trauma center that treats more severely injured patients or as non-trauma center, the finding of this study might better reflect the actual incidence of trauma in Japan.

According to the results of our study, the care of cases with ISS ≥16 involved greater resource utilization than was necessary for cases with ISS <16. However, Table 3 shows that cases with ISS 25 to 35 or ≥36 utilized more resources but exhibited a wider SE. The cases with ISS 25 to 35 or ≥36 might include cases that may be considered unsalvageable, which may prevent the adequate delivery of critical care or cases receiving continuous intensive care. Such cases may incur greater resource consumption but wider variation in resource use. Some of the cases with ISS 25 to 35 were very severe in terms of resource use, a finding that is supported by an association between the quantity of critical care delivered

TABLE 1. Demographic and Clinical Characteristics, and Outcomes According to ISS Category

	ISS					
	1–9	10–15	16–24	25–35	≥36	*p*
Overall	11650 (85.5)	528 (3.9)	988 (7.3)	325 (2.4)	136 (1.0)	
Age (yr)						
<15	1070 (9.2)	25 (4.7)	69 (7.0)	16 (4.9)	4 (2.9)	<0.001
≥55	6928 (59.5)	271 (51.3)	635 (64.3)	206 (63.4)	86 (63.2)	
age (mean, [SD])	55.9 [27.2]	50.8 [24.3]	57.9 [25.0]	56.8 [24.1]	55.8 [22.7]	<0.001*
Gender						
Male	5685 (48.8)	335 (63.4)	662 (67.0)	226 (69.5)	99 (72.8)	<0.001
Ambulance						
Used	5013 (43.0)	429 (81.3)	714 (72.3)	264 (81.2)	115 (84.6)	<0.001
Mechanism of injury						
Blunt	10921 (93.7)	501 (94.9)	924 (93.5)	299 (92.0)	130 (95.6)	0.443
Injured organ						
Head and neck	1382 (11.9)	261 (49.4)	755 (76.4)	259 (79.7)	120 (88.2)	<0.001
Face	662 (5.7)	135 (25.6)	120 (12.1)	38 (11.7)	22 (16.2)	
Chest	797 (6.8)	201 (38.1)	253 (25.6)	114 (35.1)	54 (39.7)	
Abdomen, pelvic contents	660 (5.7)	97 (18.4)	145 (14.7)	51 (15.7)	20 (14.7)	
Extremity, pelvic girdle	8194 (70.3)	311 (58.9)	231 (23.4)	101 (31.1)	49 (36.0)	
External	1180 (10.1)	297 (56.3)	211 (21.4)	83 (25.5)	45 (33.1)	
Number of injured organs						
1	10689 (91.8)	0 (0.0)	587 (59.4)	162 (49.8)	62 (45.6)	<0.001
2	775 (6.7)	366 (69.3)	211 (21.4)	76 (23.4)	21 (15.4)	
3	136 (1.2)	107 (20.3)	103 (10.4)	42 (12.9)	20 (14.7)	
4	30 (0.3)	38 (7.2)	54 (5.5)	27 (8.3)	24 (17.6)	
5	12 (0.1)	5 (0.9)	17 (1.7)	10 (3.1)	4 (2.9)	
6	8 (0.1)	12 (2.3)	16 (1.6)	8 (2.5)	5 (3.7)	
Comorbidity						
Present	1778 (15.3)	58 (11.0)	157 (15.9)	64 (19.7)	25 (18.4)	0.009
Charlson Comorbidity Index	1 [1]	1 [0]	1 [1]	1 [1]	1 [1]	0.106
Surgical procedure						
Present	8198 (70.4)	334 (63.3)	518 (52.4)	254 (78.2)	89 (65.4)	<0.001
Median number	1 [0]	1 [1]	1 [1]	1 [2]	2 [2]	<0.001
Hospital						
Community	10758 (92.3)	409 (77.5)	745 (75.4)	227 (69.8)	102 (75.0)	<0.001
Academic	892 (7.7)	119 (22.5)	243 (24.6)	98 (30.2)	34 (25.0)	
Outcome						
In-hospital mortality	102 (0.9)	7 (1.3)	37 (3.7)	52 (16.0)	37 (27.2)	<0.001

* Compared by Kruskal Wallis test analysis of variance, others by Fisher exact test.
SD, standard deviation.

and blood products transfused. This finding is not a situation in which ISS predicts mortality or high outliers of resource use. For example, the odds ratios were larger for ISS ≥36 than for ISS <36.

Interestingly, in our study, traumatically injured organs located in sites other than "Abdomen, pelvic organs" had only a modest effect on resource use. Furthermore, ventilation or rehabilitation explained more variance of the impact of traumatic injuries to the "Head and neck" or "Extremity, pelvic girdle." In a study by other researchers, traumatic injuries to the "Head and neck" are often associated with acute respiratory failure or acute respiratory distress syndrome, which necessitate the use of ventilation and hence the greater resource use or outliers in this study.[18]

The effect of pre-existing comorbid conditions was evaluated in a study by Wu et al.,[18] who weighted the simplified APACHE II scores. Their study demonstrated that APACHE II scores, which included comorbidities, had no effect on mortality in high resource-consuming patients who required mechanical ventilation for more than 1 week. Furthermore, the APACHE II scores alone might not provide the optimal index for accessing mortality, and the comorbidities in our study should not be ignored when predicting outcomes such as mortality. Because the severity indexes such as the APACHE II scores or ISS may

TABLE 2. Use of Diagnostic Imaging, Procedures, and Resource Use According to ISS Category

	ISS				
	1–9	10–15	16–24	25–35	≥36
Diagnostic imaging					
Plain x-ray					
n (%)	10176 (87.3)	505 (95.6)	916 (92.7)	302 (92.9)	128 (94.1)
Median number [QR]	4 [5]	7 [8]	5 [9]	8 [10]	7 [14]
CT					
n (%)	4713 (40.5)	429 (81.3)	877 (88.8)	288 (88.6)	121 (89)
Median number [QR]	1 [0]	1 [1]	1 [1]	2 [1]	1 [2]
Sonography					
n (%)	1158 (9.9)	151 (28.6)	172 (17.4)	69 (21.2)	24 (17.6)
Median number [QR]	1 [0]	1 [0]	1 [1]	1 [0]	1 [1]
Angiography†					
n (%)	43 (0.4)	13 (2.5)	38 (3.8)	31 (9.5)	11 (8.1)
Median number [QR]	1 [0]	1 [0]	1 [0]	1 [0]	1 [0]
Critical care					
ICU					
n (%)	1123 (9.6)	258 (48.9)	552 (55.9)	214 (65.8)	88 (64.7)
Days [QR]	2 [3]	3 [5.25]	4 [7]	6 [11]	7 [11]
Ventilation					
n (%)	123 (1.1)	27 (5.1)	128 (13.0)	116 (35.7)	58 (42.6)
Days [QR]	2 [6]	4 [10]	5 [10]	5.5 [10]	7.5 [11.75]
Transfusion					
Red blood cells					
n (%)	966 (8.3)	66 (12.5)	136 (13.8)	104 (32.0)	55 (40.4)
ml [QR]	800 [400]	800 [1200]	1200 [1900]	1600 [2000]	1200 [2000]
Plasma					
n (%)	66 (0.6)	17 (3.2)	63 (6.4)	48 (14.8)	27 (19.9)
ml [QR]	480 [595]	450 [400]	800 [1120]	850 [1340]	800 [1320]
Platelets					
n (%)	35 (0.3)	3 (0.6)	19 (1.9)	25 (7.7)	15 (11.0)
Unit [QR]	20 [10]	10 [0]	20 [30]	20 [10]	20 [30]
Rehabilitation					
n (%)	6343 (54.4)	245 (46.4)	391 (39.6)	175 (53.8)	65 (47.8)
Days [QR]	14 [17]	15 [19.5]	13 [22]	16 [22]	19 [26.5]
Resource use					
Median LOS, days [QR]	13 [23]	17 [23]	14 [19]	19 [30.5]	19.5 [36]
LOS high outlier, n (%)	530 (4.5)	31 (5.9)	64 (6.5)	40 (12.3)	19 (14.0)
Median initial 48 h TC, $ [QR]	1079 [1317]	1933 [1925]	2246 [2166]	3382 [6129]	3065 [6259]
Median TC, $ [QR]	5249 [8569]	7567 [10805]	6529 [11152]	14894 [22333]	13851 [22474]
TC high outlier, n (%)	372 (3.2)	54 (10.2)	118 (11.9)	97 (29.8)	40 (29.4)

* Compared by Kruskal Wallis test, others by Fisher exact test.
† Includes embolization.
QR, interquartile range.

show characteristic types and different degrees of risk factors for mortality or greater resource use, combining these indices or the underlying characteristics may better predict the mortality of multiple trauma patients.[18] Indeed, some researchers have criticized the use of ISS in mortality prediction models.[19,20] Instead of using discrete AIS, the use of a continuous severity value in association with damaged organs, weighted comorbidity, or consideration of ventilation as a surrogate for critical respiratory conditions, might improve the discriminative mortality prediction models. Annex Tables 1 and 2 (available online only) show the results of multivariate analyses assessing the effect of interaction between ISS and the injured organs with the study variables presented in Tables 3 and 4. These Annex Tables have shown reasons for the wider variation in resource use at ISS 25 to 35 or ≥36 and because of the higher mortality of "Head and neck" and "Extremity, pelvic girdle" at ISS ≥36, the interaction between ISS and the injured organs should be taken into account. The prediction model, irrespective of whether it is for mortality or for resource consumption, should be further refined by concurrently considering the range of care processes, the

TABLE 3. Linear Regression Analysis of Factors Associated with $\log_{10}$-transformed LOS, TC, and initial 48 h TC

	Log LOS			Log TC			Log initial 48 h TC		
	Estimation	S.E.	*p*	Estimation	S.E.	*p*	Estimation	S.E.	*p*
Intercept									
0.580	0.015	<0.001	3.109	0.013	<0.001	3.008	0.015	<0.001	
Age (yr)									
<15	−0.074	0.011	<0.001	−0.011	0.009	0.253	−0.002	0.011	0.883
≥54	0.145	0.007	<0.001	0.095	0.006	<0.001	−0.097	0.007	<0.001
Male	−0.029	0.006	<0.001	−0.027	0.005	<0.001	0.026	0.006	<0.001
Ambulance									
Used	0.069	0.006	<0.001	0.091	0.005	<0.001	0.037	0.006	<0.001
Outcome									
Death	−0.147	0.025	<0.001	0.053	0.021	0.009	−0.103	0.023	<0.001
Mechanism of injury (reference, penetration)									
Blunt	−0.009	0.012	0.432	0.006	0.010	0.573	−0.043	0.011	<0.001
ISS (reference, ISS 1−9)									
10–15	0.125	0.016	<0.001	0.130	0.013	<0.001	0.108	0.015	<0.001
16–24	0.161	0.013	<0.001	0.182	0.011	<0.001	0.167	0.012	<0.001
25–35	0.162	0.021	<0.001	0.209	0.018	<0.001	0.256	0.020	<0.001
≥36	0.179	0.031	<0.001	0.211	0.026	<0.001	0.228	0.029	<0.001
Injured organ (reference, external)									
Head and neck	−0.064	0.010	<0.001	−0.037	0.008	<0.001	0.030	0.009	0.002
Face	0.039	0.012	0.001	0.026	0.010	0.009	−0.015	0.011	0.178
Chest	0.046	0.011	<0.001	0.052	0.009	<0.001	0.008	0.010	0.418
Abdomen, pelvic contents	0.151	0.012	<0.001	0.143	0.010	<0.001	0.044	0.011	<0.001
Extremity, pelvic girdle	0.033	0.008	<0.001	0.056	0.007	<0.001	−0.013	0.008	0.094
Charlson comorbidity index (reference, zero)									
1	0.093	0.010	<0.001	0.082	0.008	<0.001	−0.040	0.009	<0.001
2 or more	0.122	0.013	<0.001	0.116	0.011	<0.001	−0.078	0.013	<0.001
Surgical procedure	0.098	0.007	<0.001	0.285	0.006	<0.001	0.246	0.007	<0.001
Ventilation	0.168	0.019	<0.001	0.299	0.016	<0.001	0.206	0.018	<0.001
Rehabilitation	0.529	0.007	<0.001	0.430	0.006	<0.001	−0.002	0.006	0.701
Hospital (reference, community)									
Academic	−0.004	0.010	0.670	0.162	0.009	<0.001	0.149	0.010	<0.001

F test for the model. Log LOS, $p < 0.001$; Log TC, $p < 0.001$; Log initial 48 h TC, $p < 0.001$.
Coefficient of determination. Log LOS: 0.508; Log TC: 0.571; Log initial 48 h TC: 0.227. SE, standard error.

quantity of resources used, and the specific ISS or injured organs. If not, health policy shift toward centralization of trauma care institutions will result in undesired consequences such as unfair estimation of hospital performance, deleterious effects on patient management, or deterioration of trauma care services.[12]

Some limitations of the design of our study and the interpretation of the findings should be mentioned. First, information was gathered from discharged patients for only 6 months in 2006, which may limit how well our findings can be generalized. Nevertheless, the administrative database in Japan has increased its sample size each year, while hospitals participating in the JTDB also participate in this research project. On the assumption that trauma centers may pay more attention to record AIS scores effectively to monitor quality of trauma care or to try to avoid preventable death, the findings from this database suggest a potential bias toward better trauma care or results, even though 21% of the study patients were from hospitals registered in the JTDB. Second, the quality of data for AIS coding has not been systematically examined. Under the program of the Association for the Advancement of Automobile Medicine, the coders are educated annually by the Japanese Association for the Surgery of Trauma.[21] Third, the LOS in hospitals in Japan was still 2 to 4 times longer than in Western countries in 2006.[22] Typically, Japanese hospitals provide rehabilitation and nursing home services in addition to acute medical care.[23] The fiscal impact of longer LOS includes the real costs consumed during each episode of trauma care. Therefore, our findings may indicate a more realistic comparison of the effect of ISS severity. From this perspective, the more realistic comparison of the impact of ISS severity represents strength of our study.

In conclusion, the current study used an administrative database to present descriptive characteristics of trauma patients in Japan and to evaluate differences in resource utilization and outcome between ISS groups. Our analysis dem-

TABLE 4. Logistic Regression Analysis of Factors Associated with Mortality, LOS, and TC Outliers

	Mortality Odd Ratio (95% CI)	LOS Outlier Odd Ratio (95% CI)	TC Outlier Odd Ratio (95% CI)
Age (yr)			
15–54	1.000	1.000	1.000
<15	0.341 (0.076–1.522)	1.739 (1.084–2.788)	1.263 (0.755–2.113)
≥55	6.133 (3.687–10.202)	1.578 (1.259–1.979)	1.098 (0.871–1.386)
Gender			
Female	1.000	1.000	1.000
Male	1.355 (0.963–1.907)	1.023 (0.858–1.220)	0.890 (0.730–1.086)
Ambulance			
Not used	1.000	1.000	1.000
Used	1.864 (1.262–2.753)	1.571 (1.323–1.867)	1.976 (1.607–2.430)
Mechanism of injury			
Penetrating	1.000	1.000	1.000
Blunt	1.948 (1.009–3.761)	0.624 (0.443–0.879)	0.948 (0.644–1.395)
Outcome		1.000	1.000
Mortal	*	1.609 (0.963–2.688)	2.051 (1.297–3.243)
ISS			
1–9	1.000	1.000	1.000
10–15	0.988 (0.401–2.434)	1.347 (0.879–2.065)	2.062 (1.395–3.047)
16–24	1.284 (0.755–2.182)	2.024 (1.370–2.989)	2.668 (1.822–3.906)
25–35	3.156 (1.767–5.639)	2.244 (1.387–3.632)	3.486 (2.246–5.411)
≥36	6.113 (3.053–12.24)	2.891 (1.511–5.532)	3.731 (2.020–6.890)
Injured organ			
External	1.000	1.000	1.000
Head and neck	1.531 (0.946–2.480)	1.015 (0.719–1.434)	1.085 (0.779–1.510)
Face	0.646 (0.338–1.234)	0.946 (0.602–1.487)	1.530 (1.045–2.241)
Chest	0.680 (0.418–1.107)	0.979 (0.704–1.363)	1.268 (0.915–1.758)
Abdomen, pelvic contents	0.372 (0.183–0.759)	1.459 (1.027–2.075)	2.366 (1.665–3.363)
Extremity, pelvic girdle	1.529 (1.015–2.302)	1.491 (1.132–1.963)	1.072 (0.815–1.410)
Charlson comorbidity index			
0	1.000	1.000	1.000
1	1.896 (1.255–2.865)	1.118 (0.884–1.414)	1.117 (0.849–1.470)
2 or more	4.407 (2.781–6.984)	1.297 (0.974–1.726)	1.965 (1.448–2.668)
Surgical procedure			
Conservative	1.000	1.000	1.000
Procedure	0.880 (0.609–1.273)	1.872 (1.464–2.393)	11.106 (7.267–16.973)
Ventilation			
Not used	1.000	1.000	1.000
Used	49.842 (32.960–75.372)	2.632 (1.833–3.779)	9.652 (6.947–13.409)
Rehabilitation			
Not used	1.000	1.000	1.000
Used	0.265 (0.186–0.376)	24.780 (16.032–38.300)	19.130 (13.524–27.060)
Hospital			
Community	1.000	1.000	1.000
Academic	0.423 (0.264–0.678)	0.798 (0.562–1.135)	2.677 (2.022–3.545)

Hosmer Lemeshow goodness of fit; high intensity, $p = 0.557$; LOS outlier, $p = 0.486$; TC outlier, $p = 0.001$.
* Not included in regression model.
CI, confidence interval.

onstrated that ISS of 25 to 35 or ≥36 was significantly associated with increased LOS, TC, initial 48-hour TC, and mortality. Thus, ISS is a possible estimator of resource use and mortality. In the future, the impact of the number of comorbidities or respiratory days as surrogate for the severity of respiratory failure, with concurrent consideration of the combination of ISS and injured organs, should also be measured to better predict resource use and mortality. To develop policy for optimizing the trauma care system within a medical care plan, further studies on the influence of hospitals or traumatized patient numbers in addition to the right care process in the right trauma case-mix are needed to assess the quality of trauma care in Japan.

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Original Contribution

Probability of survival, early critical care process, and resource use in trauma patients☆

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Abstract

Background: Trauma Injury Severity Score is a frequently used prediction model for mortality. However, few studies have assessed the probability of survival (*Ps*) and early resource use after trauma. We studied the impact of *Ps* on early critical care or costs to test its applicability to efficient trauma care.

Methods: The relationship between *Ps* in 8207 trauma patients and patients' demographics, organ injured, comorbidities, use of critical care, and total charges during the initial 48 hours was analyzed using multiple regression analyses.

Results: Significant differences were observed among study variables across different *Ps*. A large variability in total charges was observed and explained by critical care, which *Ps* was significantly associated with.

Conclusions: Trauma Injury Severity Score offers a tool for estimating resource use and might improve monitoring of early trauma care quality. Measuring the combined effect of Trauma Injury Severity Score and injured organs would refine the methodology for evaluating the trauma care system.

1. Introduction

Most developed countries have struggled to meet the demands of delivering good quality health care, and intensive care units (ICUs) imperatively have to meet this demand. Although many studies have focused on the mortality of trauma patients, outcomes other than survival, such as functional conditions or reimbursement, require more attention [1,2]. Studies that use risk adjustment with injury-related variables such as Injury Severity Score (ISS) discuss the variability in the process and the costs of trauma care. As such, these studies provide policy implications highlighting high-cost elements in trauma

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management as well as measuring efficient trauma care interventions [3].

The Trauma Injury Severity Score (TRISS) has been used widely for risk adjustment of mortality in the field of trauma, injury, and critical care to evaluate the quality of trauma care systems. Anatomical, physiologic, and age characteristics are included in the TRISS to quantify the probability of survival (*Ps*) at admission depending on the severity of injury [4-6]. This score also serves as a screening tool for case identification in quality assurance reviews and as a means to compare outcomes for patients with various traumatic injuries. Calculated *Ps* for trauma patients could serve as a potential estimate for resource consumption during ICU care or overall hospitalization. In Austria, ICU care has been paid on the basis of ICU staffing or beds and monitored in terms of appropriate intensive care delivery with TRISS, the Therapeutic Intervention Scoring System–28, or the Simplified Acute Physiology Score [7].

However, few studies have documented the association of the ISS or other severity indices with cost, care process, or patient volume [3,8-11]. Christensen et al (2008) [3] reported that a large portion of the cost was explained by length of hospital stay (LOS) and indicated that shortening of LOS would have the greatest impact on reducing costs for blunt trauma care. As LOS and cost are correlated, these 2 variables should be managed separately to determine which injury-related factors would most influence the resource use. Such an investigation could highlight the most relevant causes for high cost and lead to improved efficiency and standardized management of trauma care systems. However, additional efforts should be made a priori to reveal acceptable early critical care or resource use for critical periods such as the first 2 days after hospitalization that would be crucial for optimal quality of overall trauma care.

Consequently, it would be possible to determine if patients with a lower *Ps* or those with a head injury, for example, will need more intensive care input, especially immediately after the trauma. In other words, measuring the impact of *Ps* on the ICU care process or early resource use would bring quality assurance to trauma care, rationalize cost of ICU care, and have policy implications.

The current study aimed to examine the impact of *Ps* on resource use and care process on days 1 and 2 after admission to test the applicability of TRISS on estimating costs and use of critical care.

2. Materials and methods

2.1. Study design and setting

A cross-sectional observational study was performed using the Japanese administrative database from a government project involving the development of a Japanese case-mix classification system. Anonymous claim data with detailed clinical information were collected annually between July 1 and December 31 since 2006. Data from fiscal year 2006 were provided to members of our research team who were engaged in the refinement of case-mix classification in cooperation with the Ministry of Health, Welfare, and Labor.

These data have been used to profile hospital performance and assess hospital payments, and include 82 academic hospitals (80 university hospitals, the National Cancer Center, and the National Cardiovascular Center) and 649 community hospitals. Scattered throughout Japan, these hospitals provide acute care, medical research, and trainee education. This research project was approved by the University of Occupational and Environmental Health Ethics Committee, Fukuoka, Japan.

2.2. Variable definition

Study variables included age, sex, use of an ambulance, mechanism of injury (blunt or penetrating), location and number of anatomical injuries, comorbidities, and hospital category (academic or community). We also investigated surgical procedures requiring general anesthesia in the operating room (OR), time (in minutes) in the OR, need for critical care (ie, use of ICU or artificial ventilation), blood transfusion (packed blood cell, in milliliters), and outcome on days 1 and 2 after admission as well as at the time of discharge.

Injury Severity Score was calculated as the sum of the squares of the Abbreviated Injury Scale (AIS, 1998) of the single worst injury in each of the 3 most injured bodily regions. Abbreviated Injury Scale is an ordinal scale ranging from 1 (minor injury) to 6 (unsalvageable injury). Injury Severity Score ranges between 1 and 75 (maximum). Patients with an AIS severity of 6 in any of the 6 body regions were automatically defined to have an ISS of 75 [5]. Revised Trauma Scores (RTS) were also calculated based on the sum of weighted coded values corresponding to systolic blood pressure, respiratory rate, and Glasgow Coma Scale at admission. The RTS varied from 0 to approximately 8 in noninteger values [6].

We used age (age $\geq$55 or <15 years), mechanism of injury (blunt or penetrating injury), RTS, and ISS to calculate *Ps*, and categorized 7 groups based on every .010 interval of *Ps*. The *Ps* categories therefore ranged from *Ps* less than .9400 to *Ps* of at least .9900 [8]. We also calculated LOS and total charges (TC; US $1 = ¥90) billed during hospitalization. In Japan, charges for hospital care are determined by a standardized fee-for-service payment system known as the *national uniform tariff table*, considered to be a good estimate of health care costs [12]. Total charges included fees for physicians and administration as well as for instruments, laboratory, and imaging, and were the sum of consumed service units multiplied by a price per service unit.

We also calculated TC on days 1 and 2 after admission to determine if patients with more critical injuries would spend more resources immediately after admission. Patients were stratified by age into 3 groups: younger than 15 years, 15 to 54 years old, and 55 years or older. This database records 4 comorbidities per patient. To assess the severity of chronic comorbid conditions, we used the number of preexisting conditions (PEC) from the definition of the Charlson Comorbidity Index (CCI) [13-15]. Risk adjustment is a vital component of health services utilization and outcome studies, where the CCI, which is well validated in many international studies, has been applied [14]. However, the number of PEC was counted instead of CCI itself [15]. Patients were grouped into 3 groups based on the number of PEC: 0, 1, and 2 or more. Patients who died within the first 24 hours, those who were seen only in the outpatient clinic, those with burns or nontraumatic diagnoses, and those who had missing information preventing calculation of *Ps* were excluded from the analysis.

2.3. Statistical analysis

Frequency and proportion of all categorical data including sex, age category, injury mechanism, injured organs and the number of PEC, hospital mortality, hospital type (academic

Table 1 Demographic and clinical characteristics and outcomes by *Ps* (n, %)

		Ps							*P*
		.9900 or more	.9800-.9899	.9700-.9799	.9600-.9699	.9500-.9599	.9400-.9499	<.9400	
Overall		2600 (31.7)	653 (8.0)	1992 (24.3)	1466 (17.9)	246 (3.0)	262 (3.2)	988 (12.0)	
Age	<15 y	533 (20.5)	51 (7.8)	15 (0.8)	3 (0.2)	5 (2.0)	0 (0.0)	79 (8.0)	<.001
	≥55 y	0 (0.0)	385 (59)	1909 (95.8)	1437 (98.0)	222 (90.2)	252 (96.2)	765 (77.4)	
Age, mean, SD		27.3 (14.7)	55.2 (25.2)	72.1 (14.1)	78.1 (12.3)	68.5 (17.9)	73.8 (13.3)	62.7 (24.3)	<.001 [a]
Sex									
	Male	1831 (70.4)	386 (59.1)	805 (40.4)	407 (27.8)	130 (52.8)	127 (48.5)	594 (60.1)	<.001
Ambulance									
	Used	1152 (44.3)	442 (67.7)	932 (46.8)	844 (57.6)	184 (74.8)	166 (63.4)	699 (70.7)	<.001
Mechanism of injury									
	Blunt	2412 (92.8)	580 (88.8)	1822 (91.5)	1447 (98.7)	226 (91.9)	252 (96.2)	869 (88.0)	<.001
Injured organ									
	Head and neck	470 (18.1)	230 (35.2)	231 (11.6)	133 (9.1)	109 (44.3)	149 (56.9)	587 (59.4)	<.001
	Face	261 (10.0)	73 (11.2)	86 (4.3)	31 (2.1)	38 (15.4)	7 (2.7)	127 (12.9)	
	Chest	223 (8.6)	129 (19.8)	191 (9.6)	100 (6.8)	74 (30.1)	43 (16.4)	241 (24.4)	
	Abdomen, pelvic contents	162 (6.2)	66 (10.1)	220 (11.0)	43 (2.9)	34 (13.8)	9 (3.4)	114 (11.5)	
	Extremity, pelvic girdle	1608 (61.8)	174 (26.6)	1402 (70.4)	1248 (85.1)	145 (58.9)	68 (26.0)	451 (45.6)	
	External	471 (18.1)	256 (39.2)	195 (9.8)	86 (5.9)	62 (25.2)	7 (2.7)	228 (23.1)	
No. of injured organs									
	1	2165 (83.3)	481 (73.7)	1724 (86.5)	1349 (92)	119 (48.4)	249 (95)	587 (59.4)	<.001
	2	322 (12.4)	108 (16.5)	229 (11.5)	72 (4.9)	69 (28.0)	6 (2.3)	205 (20.7)	
	3	82 (3.2)	38 (5.8)	23 (1.2)	35 (2.4)	39 (15.9)	6 (2.3)	91 (9.2)	
	4	21 (0.8)	17 (2.6)	9 (0.5)	8 (0.5)	12 (4.9)	1 (0.4)	65 (6.6)	
	5	4 (0.2)	5 (0.8)	4 (0.2)	1 (0.1)	2 (0.8)	0 (0.0)	22 (2.2)	
	6	6 (0.2)	4 (0.6)	3 (0.2)	1 (0.1)	5 (2.0)	0 (0.0)	18 (1.8)	
No. of PEC									
	0	2516 (96.8)	572 (87.6)	1583 (79.5)	1033 (70.5)	201 (81.7)	209 (79.8)	819 (82.9)	<.001
	1	80 (3.1)	69 (10.6)	334 (16.8)	340 (23.2)	43 (17.5)	47 (17.9)	141 (14.3)	
	≥2	4 (0.2)	12 (1.8)	75 (3.8)	93 (6.3)	2 (0.8)	6 (2.3)	28 (2.8)	
Hospital category									
	Community	2219 (85.3)	524 (80.2)	1842 (92.5)	1408 (96.0)	206 (83.7)	234 (89.3)	745 (75.4)	<.001
	Academic	381 (14.7)	129 (19.8)	150 (7.5)	58 (4.0)	40 (16.3)	28 (10.7)	243 (24.6)	
Outcome									
	Mortality (n on days 1 and 2)	2 (0)	4 (0)	12 (0)	26 (1)	7 (0)	11 (0)	110 (16)	.261

[a] Compared by analysis of variance. Others by Fisher exact test.

Table 2 Trauma severity, care volume on days 1 and 2, stratified by *Ps*

	Ps							*P*
	.9900 or more	.9800-.9899	.9700-.9799	.9600-.9699	.9500-.9599	.9400-.9499	<.9400	
RTS	7.84 (0)	7.84 (0)	7.84 (0)	7.84 (0)	7.55 (0.94)	7.84 (0.94)	6.68 (3.1)	<.001 [a]
ISS	4 (1)	1 (15)	4 (0)	9 (0)	12 (4)	16 (7)	16 (16)	<.001 [a]
Critical care, n (% of overall cases)								
Blood transfusion								
n (%)	21 (47.7)	31 (66.0)	50 (30.5)	70 (19.8)	24 (57.1)	21 (65.6)	160 (67.8)	<.001
Ventilation								
n (%)	10 (76.9)	19 (63.3)	17 (60.7)	11 (36.7)	17 (89.5)	11 (73.3)	195 (85.9)	<.001
ICU care								
n (%)	423 (96.8)	192 (95.0)	189 (87.9)	123 (76.9)	87 (94.6)	90 (92.8)	460 (98.3)	<.001
Use of OR								
n (%)	666 (68.9)	62 (55.9)	203 (37.5)	101 (20.4)	21 (28.8)	17 (39.5)	210 (66.7)	<.001

[a] Compared by Kruskal-Wallis test. Others by Fisher exact test.

or community hospital), use of ambulance, and study care service were analyzed and compared using Fisher exact test. The proportion of mortality, care such as blood transfusion or ventilation, ICU admission, and OR use up to day 2 after admission relative to that for the entire hospital stay was calculated. Continuous variables (TC, OR time, and blood transfusion volume on days 1 and 2) were compared across *Ps* groups using nonparametric tests and displayed in box charts. Age was compared using an analysis of variance. Multiple linear regression analysis was used to identify the impact of *Ps* on TC on days 1 and 2. Because the distribution of TC on days 1 and 2 was right skewed, the data were log10 transformed. Multiple logistic regression analysis was used to determine the effect of study variables on use of OR, ventilation, and blood transfusion on days 1 and 2. Age and injury mechanisms were not included in this model to avoid

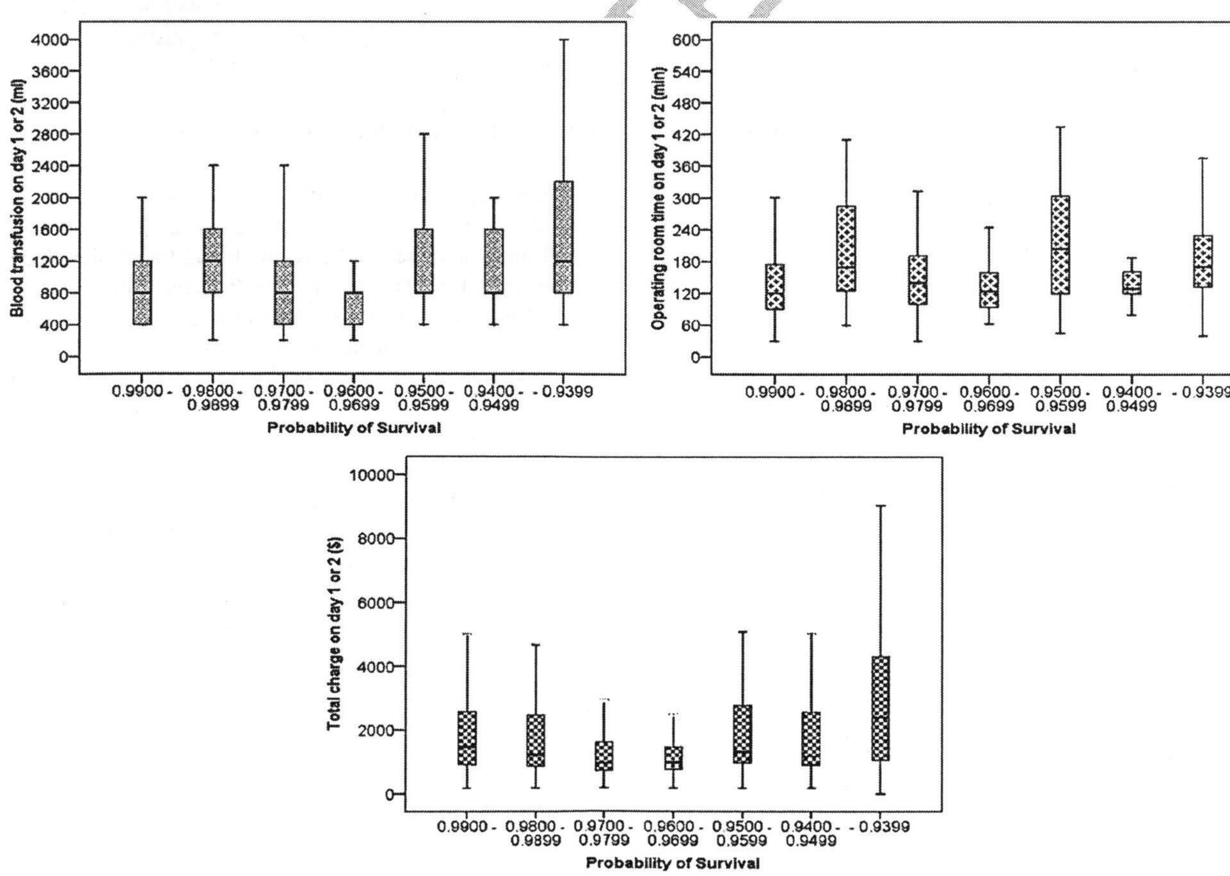

Fig. 1 Blood transfusion, OR time, and TC (in US dollars) on days 1 and 2.