J Clin Epidemiol Vol. 45, No. 6, pp. 613–619, 1992
Printed in Great Britain

0895-4356/92 $5.00 + 0.00
Pergamon Press Ltd

# ADAPTING A CLINICAL COMORBIDITY INDEX FOR USE WITH ICD-9-CM ADMINISTRATIVE DATABASES

RICHARD A. DEYO,[1,2,4]* DANIEL C. CHERKIN[2,3,5] and MARCIA A. CIOL[2]

Departments of [1]Medicine, [2]Health Services and [3]Family Medicine, University of Washington, Seattle, WA, [4]Northwest Health Services Research and Development Field Program, Seattle Veterans Affairs Medical Center, Seattle, WA and [5]Center for Health Studies, Group Health Cooperative of Puget Sound, WA, U.S.A.

*(Received 30 January 1992)*

**Abstract**—Administrative databases are increasingly used for studying outcomes of medical care. Valid inferences from such data require the ability to account for disease severity and comorbid conditions. We adapted a clinical comorbidity index, designed for use with medical records, for research relying on **International Classification of Diseases** (ICD-9-CM) diagnosis and procedure codes. The association of this adapted index with health outcomes and resource use was then examined with a sample of Medicare beneficiaries who underwent lumbar spine surgery in 1985 ($n = 27,111$). The index was associated in the expected direction with postoperative complications, mortality, blood transfusion, discharge to nursing home, length of hospital stay, and hospital charges. These associations were observed whether the index incorporated data from multiple hospitalizations over a year's time, or just from the index surgical admission. They also persisted after controlling for patient age. We conclude that the adapted comorbidity index will be useful in studies of disease outcome and resource use employing administrative databases.

Comorbidity    Administrative data    Lumbar spine

## INTRODUCTION

There is increasing interest in the use of administrative databases for studying the outcomes of medical services. Obtaining valid inferences from such databases depends in part on being able to stratify or otherwise control for varying levels of disease severity and comorbid illnesses. Unfortunately, there is no widely accepted measure of comorbidity for use with such databases. Some investigators have developed comorbidity indexes based on medical record review, which incorporate a variety of well-defined diagnoses [1–4]. These indexes have sometimes been validated by testing the association between index score and subsequent patient mortality. We sought to adapt one such clinical index for use with an administrative database which recorded ICM-9-CM diagnoses. We hypothesized that if the adapted index were meaningful, increasing comorbidity scores would be associated with higher levels of in-hospital complications, postoperative mortality, blood transfusion in the peri-operative period, discharge to a nursing home, and use of hospital resources. We sought to test such an index for use in studying the outcomes of lumbar spine surgery.

## METHODS

### *Data sources*

Data from a listing of all Medicare claims for beneficiaries who underwent lumbar spine

*All correspondence should be addressed to: Dr Richard A. Deyo, Back Pain Outcome Assessment Team, Department of Health Services, JD-23, University of Washington, Seattle, WA 98195, U.S.A. [*Tel*: (206) 543-4943; *Fax*: (206) 685-3467].

surgery in 1985 was obtained from the Health Care Financing Administration. This was based on Part A Medicare claims. In addition, we obtained linked data for all previous hospitalizations for 1 year prior to the index hospitalizations. The index hospital claims were also linked to Medicare mortality information, including the date of death, from the beneficiary entitlement and demographics data file. Patients were only included in the sample if they were continuously eligible for Medicare for at least 1 year prior to the index admission. In addition, patients who were Medicare beneficiaries because of end-stage renal disease or Social Security Disability Insurance (SSDI) were excluded from the sample, because pre-existing disabling conditions could adversely affect the outcomes of back surgery in a misleading manner. This had the effect of excluding persons with a known life-threatening condition (end stage renal disease) and patients already known to be disabled. However, it retained patients with a wide range of comorbid conditions of uncertain functional impact, to examine the potential impact of these diagnoses on surgical outcome. Such patients would have comorbid conditions relatively typical of persons their age, rather than the unusually severe problems that result in premature withdrawal from the workforce (usually the case for SSDI recipients).

Medicare mortality data are obtained from multiple sources, including report forms from funeral homes to the Social Security Administration; procedures for following up returned social security checks; reports from relatives; and information in Medicare provider claims. Most deaths are reported within 4 months of their occurrence, and less than one in 10,000 is subsequently found to be in error.

*Patient selection*

Patients undergoing lumbar spine surgery were identified with an algorithm which combined ICD-9-CM diagnosis and procedure codes. Because we were interested only in lumbar spine problems, patients with codes indicating cervical or thoracic spine problems were excluded. We also excluded any case with a diagnosis during the index admission which indicated a neoplasm, spinal infection, spine fracture, or ankylosing spondylitis. Finally, patients with a second major surgical procedure (e.g. coronary artery bypass grafting or prostatectomy) during the index admission were excluded. The complete case selection algorithm is described in more detail elsewhere [5].

*Adaptation of the comorbidity index*

We adapted a comorbidity index developed by Charlson and her colleagues which was based on medical record review. The index included a variety of diagnoses and, in some cases, previous surgical procedures, which were associated with subsequent 1-year mortality among inpatients on a medical service. Although the index was not created using ICD-9-CM codes, most of the diagnoses and procedures included could be matched with similar ICD-9-CM diagnoses and procedures. Table 1 shows the ICD-9-CM codes which were used in adapting the Charlson index.

Some of the diagnoses included in the Charlson index (e.g. myocardial infarction, acute stroke) could be complications of lumbar spine surgery. If such diagnoses were listed in the index surgical hospitalization, we would have no way to discern whether they were comorbid conditions or operative complications, since we could not perform medical record reviews. Thus, certain diagnoses listed in Table 1 were included only if they appeared during a hospitalization which occurred during the year prior to the index admission. Other diagnoses, which clearly indicated chronic conditions (e.g. dementia, chronic pulmonary disease, arthritis), were included in the index whether they occurred during the index admission or a previous admission. Because our

Table 1. Derivation of the 1985 study cohort from Medicare hospital claims

| | |
|---|---|
| Hospitalizations for lumbar spine surgery | 35,292 |
| Excluded for malignancy, infection, fracture, trauma, ankylosing spondylitis, other major surgery during index admission | 1792 |
| Hospitalizations excluded as multiple admissions for same person | 807 |
| Excluded because Medicare eligibility based on end-stage renal disease or SSDI | 3560 |
| Excluded for lack of full prior-year Medicare eligibility | 2022 |
| Index hospitalizations for unique patients | 27,111 |

selection process excluded patients with a diagnosis of neoplasm during the index admission or patients who were Medicare-eligible due to end-stage renal disease, many patients with malignancy or renal failure were completely excluded from the sample.

*Definition of outcome variables*

In-hospital complications were identified by the ICD-9 codes which are clearly labeled as complications of surgical and medical care (996–999) or misadventures of patients during surgical or medical care (E870–E876). A small number of additional diagnoses, which could logically only occur postoperatively (their preoperative occurrence in the same hospitalization would be a contraindication to surgery) were also included. These were acute myocardial infarction, pulmonary embolism, and pneumonia. Complications which could not logically be related to lumbar spine surgery (e.g. those related to organ transplantation) were excluded. While it is difficult to assess the severity of many complications listed in the ICD-9 rubrics, we found that having at least one of these complications coded during the index admission was associated with substantially increased length of stay (by an average of 5 additional days) and hospital charges (by an average of an additional $4000), even after controlling for patient age and sex.

Postoperative deaths were defined as those occurring either during the index admission or a 6-week period following hospital discharge. Patients were said to have perioperative blood transfusions if any transfusion was noted in the Medicare abstract for the index admission. Discharges to nursing homes were counted only if the patient was not admitted from a nursing home. Charges were the totals for hospitalization, but did not include professional fees.

*Analysis*

The adapted comorbidity index was tested for associations with the dichotomous outcome measures (complications, mortality, blood transfusion, and nursing home discharge) using chi-square analysis. The association of the index with mean length of stay and total hospital charges was tested by analysis of variance. Finally, the association of the index with the outcome measures was tested controlling for age. This was done using logistic regression analyses for dichotomous outcomes, and multiple linear regression for length of stay and hospital charges. These analyses employed the SAS statistical program.

## RESULTS

There were 35,292 Medicare hospitalizations for lumbar spine surgery in 1985. Table 1 shows the numbers of hospitalizations excluded by the eligibility criteria. There remained 27,111 patients who met the inclusion criteria. Their mean age was 71.8 years, and 57.1% were women. The racial composition of this group included 92.7% whites, 3.7% blacks, and 3.6% other ethnicity. Table 2 shows the percentages of patients with each of the diagnoses included in the comorbidity index.

Table 3 shows the distribution of patients according to the adapted Charlson comorbidity index scores. The majority of patients (71%) had a Charlson index score of 0. This probably reflects the careful selection of only relatively healthy patients for what is usually an elective surgical procedure. Because the population was relatively healthy, the range of comorbidity scores was relatively small, with very few patients having a score of three or more. Thus, for the analyses presented here, the comorbidity index was truncated to show outcomes according to scores ranging from zero to three or more. The mean age varied by only 1 year across the index scores shown, although even this modest difference was statistically significant due to the large sample size.

The proportion of patients with in-hospital complications of surgery rose monotonically with increasing index scores, from 7.9% in the lowest category to 10.5% in the highest, a 33% increase. The proportion of patients receiving perioperative blood transfusions rose consistently with comorbidity scores, resulting in a transfusion rate 50% higher among those with the highest index scores compared with the lowest. The proportion of patients discharged to a nursing home generally increased with index score, though not monotonically. Nonetheless, the index created patient subgroups with more than a 2-fold variation in the rate of nursing home placement. Postoperative mortality rates rose monotonically, with more than a 5-fold difference between those with the highest index scores and those with the lowest. Hospital length of stay increased by approximately 1 day for each one-point increase in the index score. Similarly, hospital charges rose consistently

Table 2. Translation of Charlson comorbidity index components into ICD-9-CM codes

| Diagnostic category | Number (%) of patients in study dataset | ICD-9-CM codes | Description |
|---|---|---|---|
| Myocardial infarction | 892 (3.3) | 410–410.9 | Acute myocardial infarction |
| | | 412* | Old myocardial infarction |
| Congestive heart failure | 595 (2.2) | 428–428.9 | Heart failure |
| Peripheral vascular disease | 698 (2.6) | 443.9* | Peripheral vascular disease, incl. intermittent claudication |
| | | 441.441.9* | Aortic aneurysm |
| | | 785.4* | Gangrene |
| | | V43.4* | Blood vessel replaced by prosthesis |
| | | procedure 38.48 | Resection and replacement of lower limb arteries |
| Cerebrovascular disease | 940 (3.5) | 430–438† | Cerebrovascular disease |
| Dementia | 59 (0.2) | 290–290.9* | Senile and presenile dementias |
| Chronic pulmonary disease | 2466 (9.1) | 490–496* | Chronic obstructive pulmonary disease |
| | | 500–505* | Pneumoconioses |
| | | 506.4* | Chronic respiratory conditions due to fumes and vapors |
| Rheumatologic disease | 440 (1.6) | 710.0* | Systemic lupus erythematosus |
| | | 710.1* | Systemic sclerosis |
| | | 710.4* | Polymyositis |
| | | 714.0–714.2* | Adult rheumatoid arthritis |
| | | 714.81* | Rheumatoid lung |
| | | 725* | Polymyalgia rheumatica |
| Peptic ulcer disease | 544 (2.0) | 531–534.9 | Gastric, duodenal and gastrojejunal ulcers |
| | | 531.4–531.7 | Chronic forms of peptic ulcer disease* (subset of above listing) |
| | | 532.4–532.7 | |
| | | 533.4–533.7 | |
| | | 534.4–534.7 | |

| | | | |
|---|---|---|---|
| Mild liver disease | 54 (0.2) | 571.2* | Alcoholic cirrhosis |
| | | 571.5* | Cirrhosis without mention of alcohol |
| | | 571.6* | Biliary cirrhosis |
| | | 571.4–571.49* | Chronic hepatitis |
| Diabetes | 2828 (10.4) | 250–250.3* | Diabetes with or without acute metabolic disturbances |
| | | 250.7* | Diabetes with peripheral circulatory disorders |
| Diabetes with chronic complications | 74 (0.3) | 250.4–250.6* | Diabetes with renal, ophthalmic, or neurological manifestations |
| Hemiplegia or paraplegia | 178 (0.7) | 344.1* | Paraplegia |
| | | 342–342.9* | Hemiplegia |
| Renal disease | 123 (0.5) | 582–582.9* | Chronic glomerulonephritis |
| | | 583–583.7* | Nephritis and nephropathy |
| | | 585* | Chronic renal failure |
| | | 586* | Renal failure, unspecified |
| | | 588–588.9* | Disorders resulting from impaired renal function |
| Any malignancy, including leukemia and lymphoma | 550 (2.0) | 140–172.9 | Malignant neoplasms‡ |
| | | 174–195.8 | Malignant neoplasms‡ |
| | | 200–208.9 | Leukemia and lymphoma |
| Moderate or severe liver disease | 11 (0.04) | 572.2–572.8* | Hepatic coma, portal hypertension, other sequelae of chronic liver disease |
| | | 456.0–456.21* | Esophageal varices |
| Metastatic solid tumor | 137 (0.5) | 196–199.1 | Secondary malignant neoplasm of lymph nodes and other organs |
| AIDS | 0 | 042–044.9§ | HIV infection with related specified conditions |

*Asterisked codes were included if listed during index or prior admissions. Other codes were included only if recorded prior to the index admission.
†Only code 438 (late effects of cerebrovascular disease) was included during an index admission.
‡These codes exclude skin cancer other than melanoma.
§These ICD codes were effectively excluded from this analysis because they only became effective 1 October 1986.

Table 3. Outcomes of lumbar spine surgery and resource use according to adapted Charlson comorbidity index scores

| | Charlson score | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 or more |
| Number of patients | 19,167 | 5478 | 1626 | 840 |
| Mean age (yr)* | 71.7 | 71.8 | 72.2 | 72.7 |
| In-hospital complications (%)† | 7.9 | 8.4 | 9.1 | 10.5 |
| Blood transfusion (%)* | 13.9 | 14.5 | 18.0 | 21.0 |
| Mean length of stay (days)* | 12.9 | 14.0 | 15.0 | 16.1 |
| Total hospital charges ($)* | 6597 | 7463 | 8213 | 8968 |
| Discharged to nursing home (%)* | 2.2 | 2.9 | 4.4 | 3.8 |
| 6-week postoperative mortality (%)* | 0.5 | 1.0 | 1.8 | 2.7 |

*Differences significant at $p < 0.0005$ (chi-square or analysis of variance).
†Differences significant, $p = 0.01$.

with the index score, resulting in a 35% difference between patients with the highest scores and those with the lowest.

Multivariate analyses showed that the adapted Charlson index was significantly associated with each of the outcomes listed in Table 3 even after controlling for patient age [data not shown]. This was not surprising since age was only weakly related to the index scores in this sample of Medicare beneficiaries, most of whom were necessarily over age 65.

Many investigators using administrative files may have access only to cross-sectional data, without the opportunity to examine recorded diagnoses for a year of hospitalization experience. We therefore repeated the analyses in Table 3 using only those comorbid diagnoses recorded during the index 1985 hospitalization. Only the asterisked codes in Table 2 were included in the comorbidity index for this analysis.

As expected, more patients had a comorbidity score of zero when only data from the index hospitalization were included (Table 4). The distribution of scores overall was shifted downward, resulting in very few cases with scores of 3 or greater. Nonetheless, the associations between comorbidity score, short term outcomes, and resource use described in Table 3 were still apparent. In some cases, statistical significance of the associations decreased, probably because of the statistically less favorable distribution of index scores. The magnitude of outcome differences according to Charlson index score was maintained, however, and was in some cases even more striking than in Table 3. This result may seem surprising, since the listing of comorbid conditions is necessarily less complete than that using a full year of hospital experience. However, we speculate that some diagnoses recorded at previous hospitalizations may be resolved or substantially improved by the time of the index admission. Only the most active or currently problematical diagnoses are likely to be recorded during the index admission. This may explain the higher mortality and resource use among those with a comorbidity score of 3 based on index hospitalization diagnoses (Table 4) as opposed to those having this score based on a full year of hospitalization experience (Table 3).

## DISCUSSION

It appears that the Charlson comorbidity index was successfully translated into a set of

Table 4. Outcomes of lumbar spine surgery using the adapted Charlson index based only on comorbid diagnoses recorded during the index surgical hospitalization*

| | Charlson score | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 or more |
| Number of patients | 22,721 | 3922 | 419 | 49 |
| Mean age (yr)† | 71.8 | 71.6 | 71.6 | 72.3 |
| In-hospital complications (%)† | 8.1 | 8.0 | 9.1 | 10.2 |
| Blood transfusion (%)‡ | 14.3 | 15.0 | 18.6 | 28.6 |
| Mean length of stay (days)‡ | 13.1 | 14.1 | 16.6 | 21.9 |
| Total hospital charges ($)‡ | 6751 | 7705 | 9452 | 12,969 |
| Discharged to nursing home (%)‡ | 2.4 | 2.8 | 2.9 | 12.2 |
| 6-week postoperative mortality (%)‡ | 0.6 | 1.0 | 2.6 | 8.2 |

*Only the asterisked diagnoses in Table 1 were included.
†Differences not statistically different at $p < 0.05$.
‡Differences significant at $p < 0.005$.

ICD-9-CM codes. Even in this sample of patients with a constricted range of comorbidities and age, the adapted index was related to several short-term outcomes of lumbar spine surgery and to hospital resource use. These associations persisted even after controlling for patient age.

We conclude that the Charlson index can be valuable when used with ICD-9-CM administrative databases. The index clearly adds explanatory power to patient age alone in accounting for variations in outcomes following lumbar spine surgery. We anticipate that it may be similarly useful in studying the outcomes of other surgical procedures or medical services by use of administrative databases.

The value of such an index in the study of administrative databases depends on the completeness and accuracy of diagnostic coding. Previous analysis of a similar database to examine the outcomes of lumbar spine surgery reported that primary diagnosis and procedure codes were correctly recorded 96% of the time, when compared with medical record reviews [6]. The accuracy of secondary diagnoses was not reported. The accuracy of coding appears to have improved since the institution of diagnosis-related groups (DRGs) as a means of providing Medicare reimbursement to hospitals [7]. Reimbursement incentives under the DRG system could result in more complete coding of comorbid diagnoses over time, but could also result in excessive "up-coding" [8] to include relatively trivial diagnoses.

Because most administrative databases can only record a limited number of diagnoses, important comorbid conditions may be omitted. This may be especially true when a patient is undergoing elective surgery, when the surgical diagnosis and possible complications must be recorded. This leaves even less space for the recording of important comorbid conditions. This problem can be circumvented in part by searching previous hospitalizations for relevant comorbid diagnoses. If a patient were not hospitalized during the year prior to the index admission, or if a condition was not coded during the index admission, it would not be identified in this analysis. Thus, some comorbid conditions may have been unidentified, although the most severe are likely to have been counted. The analysis using diagnoses recorded only at a single admission suggests that even this use of the index is helpful in explaining short term outcomes and resource use.

We anticipate using the adapted Charlson index in our future analyses of surgical outcomes based on administrative claims. Other investigators may find the adapted index (as described in Table 2) helpful for similar analyses. Further assessment of the index in different clinical cohorts may well suggest important refinements, but this study establishes the feasibility of translating the clinical comorbidity index into ICD-9 codes, and demonstrates its application in administration databases.

*Acknowledgements*—William Kreuter provided expert computer programming assistance, and Darlena Bursell assisted in preparing the manuscript. John Wiesman was instrumental in acquiring data and equipment, and meeting other administrative needs.

Supported by Grant No. HS-06344 from the Agency for Health Care Policy and Research (the Back Pain Outcome Assessment Team) and by the Northwest Health Services Research and Development Field Program, Seattle Veterans Affairs Medical Center.

## REFERENCES

1. Charlson ME, Pompei P, Ales KL, Mackenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. **J Chron Dis** 1987; 40: 373–383.
2. Greenfield S, Blanco DM, Elashoff RM *et al.* Development and testing of a new index of comorbidity. **Clin Res** 1987; 35: 346A.
3. Kaplan MH, Feinstein AR. The importance of classifying initial co-morbidity in evaluating the outcome of diabetes mellitus. **J Chron Dis** 1974; 27: 387–404.
4. Parkerson GR, Michener JL, Wu LR, Finch JN, Muhlbaier LH, Magruder-Habib K, Kertesz JW, Clapp-Channing N, Morrow DS, Chen AL-T, Jokerst E. Associations among family support, family stress, and personal functional health status. **J Clin Epidemiol** 1989; 42: 217–229.
5. Cherkin DC, Deyo RA, Volinn E, Loeser JD. Use of the International Classification of Diseases (ICD-9-CM) to identify hospitalizations for mechanical low back problems in administrative databases. **Spine** In press.
6. Ramirez LF, Thisted R. Using a national health care data base to determine surgical complications in community hospitals: lumbar discectomy as an example. **Neurosurgery** 1989; 25: 218–225.
7. May JJ, Wasserman J. Selected results from an evaluation of the New Jersey Diagnosis-Related Group system. **Health Serv Res** 1984; 19: 547–559.
8. Hsia DC, Krushat WM, Fagan AB, Tebbutt JA, Kuserow RP. Accuracy of diagnostic coding for Medicare patients under the prospective-payment system. **N Engl J Med** 1988; 318: 352–355.