METHODS

The Estimated Survival Probability Index of Trauma Severity

By Paul S. Levy, Ross Mullner, Jack Goldberg, and Henry Gelfand

An index of survival rates associated with ICDA injury codes was constructed with data from the 1973 Hospital Discharge Survey (HDS). Discharge records from three regions covered by the HDS allowed estimation of survival rates among patients suffering single injuries coded under 92 ICDA integers. These estimated rates were then applied to records from the fourth HDS region, including those for patients suffering multiple injuries: estimated survival probability index values were generated as the product of the single-condition survival rates for each patient's various injuries. Mortality rates predicted from the index values correlated well with mortality rates estimated for the universe of patients discharged in 1973 from the fourth region. The index is intended for retrospective analysis of discharge records as a possible approach to care evaluation.

The outcome of emergency medical care depends on the severity of injury as well as on the quality of care. Although several indexes of severity have been proposed over the past decade (Gibson [1] has reviewed 17 of these indexes), none of them offers a reliable and valid method of scaling injury severity retrospectively from information likely to be on hospital records, as would be useful for care-evaluation studies. In this article we describe and evaluate a severity index that we call the estimated survival probability (ESP) index, which is based entirely on ICDA codes and which we believe is particularly suited to retrospective analyses of patient records.

The index we propose has some similarities to an index proposed by Sacco et al. [2] in that both indexes are ICDA-based, both use survival as an outcome variable, and both are estimates of survival probabilities for individuals afflicted with one or more traumas. Our methodology, however, is quite distinct from that used by Sacco and his coworkers.

Data and Methods

Data Source

We obtained data for the year 1973 from the Hospital Discharge Survey (HDS), which is a continuous nationwide survey of inpatient

This research was supported in part by grant no. RO 1 HS 20118-01 from the National Center for Health Services Research, DHEW.

Address communications and requests for reprints to Paul S. Levy, Professor of Biometry, School of Public Health, University of Illinois Medical Center, P.O. Box 6998, Chicago, IL 60680. Ross Mullner is assistant professor of epidemiology, Jack Goldberg is a research associate in epidemiology, and Henry Gelfand is director of the epidemiology program, all at the University of Illinois Medical Center.

0017-9124/78/1301-0028/$00.80/0

utilization of nonfederal short-term hospitals [3]. In the HDS, data are abstracted from the face sheets of medical records of discharged patients. The items abstracted include age, sex, race, marital status, discharge status (alive or dead), and length of stay. In addition, listed diagnoses (up to five) and surgical procedures (up to three) are abstracted. Diagnostic and surgical data are coded according to the Eighth Revision, International Classification of Diseases, Adapted for Use in the United States (ICDA).

The HDS data were purchased from the National Center for Health Statistics (NCHS) in the form of tape transcripts [4]. The 1973 tape contained 224,784 sample records representing approximately 32.1 million discharges in the United States. From these records a working tape was constructed consisting of the 26,886 records in which any ICDA code from 800 to 999 (which includes accidents, injuries, poisoning, and burns, among other traumas) was mentioned. Decimal ICDA numbers were collapsed into integer codes: for example, code 800.5 was listed as 800 (because the ICDA code is not continuous, the range from 800 to 999 includes only 187 integer categories).

Since the HDS is a probability survey of discharges, each record represents a certain number of hospital discharges. This number is based on the selection probabilities, which vary for each record depending on size and location of the hospital and other characteristics of the sampling frame. In our calculations each record is weighted by the portion of the sampled universe that it represents, so that the results can be extrapolated to all 1973 discharges from U.S. nonfederal short-term hospitals or to discharges from various geographic or demographic subsets.

Construction of the Index

We divided the records in the working tape into two groups. The source group, used in constructing the index, consisted of all 18,596 records from hospitals in the northeast, north central, and west regions as defined by the NCHS [3]. We used the records in this group to obtain the parameters on which to base the index. The test group, on which the index was validated, consisted of all 8,290 records from the south region.

We scanned each discharge record in the source group and used the 15,117 records that reported only one trauma condition to construct the index. For each integer ICDA code i, from 800 to 999, an estimated single-condition survival rate, P_i, was calculated as

$$P_i = \sum_{j \in I} W_j X_{ij} \Big/ \sum_{j \in I} W_j$$

where I = the set of all records j reporting ICDA code i

X_{ij} = 1 if record j (reporting ICDA code i) showed discharge status "alive," 0 if discharge status was "dead"

W_j = weight for record j, determined as the reciprocal of the selection probability of record j

With the single-condition survival rates P_i calculated for the source group, one may compute ESP_j, the estimated survival probability index for a particular hospitalized patient j, as

$$ESP_j = \prod_{i \in J} P_i \qquad (1)$$

where J = the set of ICDA codes i that describe the traumas suffered by patient j

Validation

The test group included about the same proportions of single and multiple injuries as did the source group; we used all test-group records to investigate the performance of the index. We evaluated the ability of the index to measure severity by computing ESP_j for each record in the test group (using the estimated single-condition survival rates P_i obtained from the source group) and comparing mortality rates predicted from these index values with mortality rates estimated from the test-group data. The test group was stratified into five subgroups on the basis of the calculated ESP: for group 1, $ESP \leqslant 0.80$; for group 2, $0.81 \leqslant ESP \leqslant 0.90$; for group 3, $0.91 \leqslant ESP \leqslant 0.95$; for group 4, $0.96 \leqslant ESP \leqslant 0.99$; and for group 5, $\mathrm{ESP} = 1.00$. These five subgroups were each stratified further into three age classes: younger than 45, 45 to 64, and 65 and older. In addition, the test group as a whole was stratified separately by these age classes, by race (white and nonwhite), by sex, and by three classes of size of the hospital of discharge.

From the records for these various strata g, we estimated the percentage discharged dead for the whole south region, weighting each record by the portion of all discharges in the south region that it represented:

$$m_g = 100 \sum_{j \in G} W_j d_j / \sum_{j \in G} W_j$$

where m_g = estimated percentage discharged dead among all 1973 discharges in stratum g of the south region
G = the set of all test-group records j in stratum g
d_j = 1 if record j reported discharge status "dead," 0 otherwise

For the same strata, we also calculated the predicted percentage discharged dead among all south region discharges, m_g^*, on the basis of the index score ESP_j for each record:

$$m_g^* = 100\,[1 - (\sum_{j \in G} W_j ESP_j / \sum_{j \in G} W_j)]$$

We then compared the estimated and predicted death rates among the various strata; for the age, sex, race, and hospital-size strata of the entire test group we calculated correlation coefficients (Pearson's r) between m and m^*.

Results

Of the 187 integer ICDA codes from 800 to 999, 167 appeared as single trauma conditions in the source group. Of these only 92 appeared on 20 or more records. The single-condition survival rates, P_i,

Table 1. Distribution of Integer ICDA Codes* from Source Group in Ranges of Estimated Single-condition Survival Rate, P_i

P_i range	No. of codes in range
All	92
0–0.80	1
0.81–0.90	3
0.91–0.95	8
0.96–0.99	31
1.00	49

* Only codes appearing as single conditions on at least 20 records were used.

were calculated only for these 92 codes; the full list of these codes and their P_i values is available from the authors on request. Table 1 shows the distribution of the 92 codes in five ranges of P_i value.

Table 2 shows m and m^* for the test group stratified by *ESP* range

Table 2. Estimated (m) and Predicted (m^*) Mortality Percentages Among Discharges from South Region, by Age Class and Index Value (*ESP*) Ranges

(Values of N shown are estimated for all 1973 south discharges on the basis of sample weights W_j)

ESP range	Age class			
	All ages†	<45	45–64	>64
All ranges†, N	1 268 069	735 895	268 318	264 986
m, %	2.1	1.1	2.2	4.9
m^*, %	2.2	1.9	2.1	3.1
Under 0.80, N	6 357	3 911	1 308	1 305
m, %	19.5	15.1	36.7	25.7
m^*, %	22.4	23.5	20.4	20.9
0.81–0.90, N	37 717	25 204	5 931	6 819
m, %	10.5	7.8	14.0	20.8
m^*, %	12.9	13.1	12.6	12.4
0.91–0.95, N	138 936	62 263	23 128	54 281
m, %	6.4	5.2	8.2	8.2
m^*, %	7.1	6.7	7.0	7.6
0.96–0.99, N	735 701	411 605	165 801	158 402
m, %	1.4	0.4	1.4	4.1
m^*, %	1.6	1.5	1.8	1.9
1.00, N	349 358	232 932	72 150	44 179
m, %	0.4	0.3	0.5	0.5
m^*, %	0.0‡	0.0‡	0.0‡	0.0‡

† Column and row totals do not exactly equal values for all ages and all *ESP* ranges because patients of unknown ages are omitted from range/age cells.
‡ Predicted deaths < 0.05%.

Table 3. Correlation Between Estimated and Predicted Mortality Percentages in Various Stratifications of Test Group

Stratification	Coefficient of correlation*
None	
Whole test group	0.999†
Age	
Under 45	0.995†
45–64	0.968†
Over 64	0.972†
Race	
White	0.919‡
Nonwhite	0.912‡
Sex	
Male	0.996‡
Female	0.859
Hospital size (beds)	
6–99	0.210
100–499	0.942‡
>499	0.995†

* Pearson's *r*.
† Significant with $p < 0.01$.
‡ Significant with $p < 0.05$.

and age class; since these estimates were weighted by W_j, the estimated N shown for each stratum is the estimated number of records (in the universe of all 1973 discharge records from the south region) represented by that stratum of the test group. Agreement between the estimated mortality rate and that predicted on the basis of *ESP* values is better for some cells of Table 2 than for others, but for the test group as a whole and within each age stratum estimated mortality rates decline consistently as the estimated survival probability increases.

Table 3 shows the coefficients of correlation between m and m^* calculated for the whole test group and for the test group stratified separately by age, race, sex, and hospital size. For each of the three broad age strata, correlation was significant; it was also significant for the two race strata. In the sex strata, correlation between m and m^* was significant for males but not for females; in the hospital-size strata, correlation was significant for hospitals with 100–499 beds and for those with more than 499 beds, but not for hospitals with fewer than 100 beds.

In addition to these correlations, we also calculated correlation coefficients between *ESP* values (in the age strata) and two other measures: time to death, for those discharged dead, and length of stay, for those discharged alive. One would expect that, among those who died, those with low *ESP* scores would be the more severely injured and would die more quickly than those who had higher values.

Table 4. Correlation of *ESP* Values in Test Group Age Strata with Time to Death for Nonsurvivors and Length of Stay for Survivors

Stratum	Correlation*	
	ESP vs. time to death	*ESP* vs. length of stay
Whole test group	0.03	-0.25
Under 45	0.05	-0.25
45–64	0.11	-0.22
Over 64	0.01	-0.26

* Pearson's *r*.

Among those who survived, those with low *ESP* values should be more severely injured and require more care, and thus they would be expected to stay longer in the hospital than those with higher scores.

The results are shown in Table 4. Although these correlations are small, they are positive between *ESP* and time to death among those who did not survive and negative (and somewhat larger) between *ESP* and length of stay among those who did survive. Thus these correlations are in the expected direction.

Reliability and Validity

Gibson, in his review of severity indexes [1], suggested three criteria against which a severity index should be evaluated: reliability, validity, and the nature of the data required. We quote his criteria below and describe how the ESP index meets them.

Reliability.

> The index should comprise numerical ratings with clear and objective decision rules for deriving and summing the scores, so that the same rater over time or different raters at the same time will derive an identical score for the same case. Evidence should be presented on inter and intra rater reliability.

The ESP index is based entirely on estimated single-condition survival rates (P_i) associated with ICDA codes. These P_i are estimated with the data from three regions sampled by the 1973 Hospital Discharge Survey, and the reliability of the index is a function of the stability and reliability of these data in the coding of trauma conditions and reported mortality.

Validity.

> The index should have a high and known correlation with mortality and/or morbidity so that the index can predict mortality/morbidity (outcome validation) and should have a high correlation with other indexes of the same concept or variable being measured. The index should have been validated prospectively as well as retrospectively and in settings with patients dissimilar from those used to develop the index. The index should be applicable to many rather than few clinical conditions and settings.

Our results show that predictions from the index correlate well with mortality (Table 3); in terms of the differences between m and m^* in Table 2, the predicted mortality, m, was in general closer to m^* for the 45–64 age group than for the other two. Among those younger than 45, m tended to be less than m^* ($p = 0.06$), whereas it tended to be greater than m^* for those 65 and older. Among each of the three age groups, a monotonic decrease in mortality was observed with increase in the index. The index also correlates, to a small extent but in the predicted direction, with time to death and with length of stay among survivors.

Because the data we used to develop and validate the ESP index were drawn from a national sample, we believe that the results are generalizable. We plan to validate the index prospectively in future studies, predicting mortality in advance for special groups of trauma patients. The index would be applicable to many clinical settings, although it should be carefully tested before being used in any particular setting. It is applicable to as many clinical conditions (integer ICDA codes) as can be found occurring in a sufficient number of records that include mortality reports.

Data Requirements.

> Preferably, the index should require data . . . routinely collected in the hospital emergency department (whether or not the patient is admitted) and/or critical care units. If the index is to be used in the prehospital place for triage or severity assessment, the index should depend only on information and judgment available at that stage. The index should primarily reflect the mortality resulting from the initial insult to the body, and not the variable nature of subsequent clinical intervention. The index should use ratings which can be determined by nonclinicians and not require complex or subjective judgment by clinicians.

The ESP index is not intended for use in triage or in prehospital assessment of severity. It is based on ICDA codes for diagnoses, which are or should be on every hospital record. The ICDA codes reflect initial insult and are not related to subsequent clinical intervention. If the codes are recorded, any nonclinician can compute the *ESP* value mechanically as the product of the single-condition survival rates over all trauma codes shown in the record. The process of recording an ICDA code for the physician's summary is a routine function for medical record librarians and requires no complex judgment beyond the diagnosis.

Discussion

The ESP index is proposed as a tool for grading the severity of injuries. Its major usefulness would be in retrospective analysis of hospital records, where often the only reliable and valid data relating to severity, available for all patients, are the ICDA-coded diagnoses. The index is based on the estimated single-condition survival rates, P_i, estimated from the 1973 Hospital Discharge Survey. The user need only apply these values, according to Eq. 1, to the set of records being studied.

The conceptual framework for this index lies in the assumption that an individual's chance of surviving if afflicted with several trauma conditions is equal to the product, over all the conditions, of the probability of surviving each of them singly.

Although this assumption ignores the possible synergistic effects of multiple injuries, the result appears to correlate well with survival rates in an independent data set including both single and multiple injuries. One would expect that existence of synergistic effects from multiple conditions would result in overestimates of survival probabilities. Overestimates did in fact occur in age groups 45–64 and >64, but not with those younger than 45. We must emphasize, however, that the P_i values are not age-specific but (because of limited sample size) are based on all records in the source group having listed codes as single conditions. Thus synergistic effects in our data cannot be separated from the possible effects of using crude rather than age-specific P_i values. We are planning future studies on several years of HDS data to obtain age-specific P_i values; these studies may provide insight into the nature and magnitude of the synergistic effect. Meanwhile, the high correlations and strong monotonic relationship observed between predicted and estimated mortality in our present results indicate the usefulness of this index in its present form for stratifying a set of hospital records by injury severity.

The estimated single-condition survival rates are based on national data and would not be sensitive to local variations, which might make them inappropriate to a particular data set. The limited size of the data set did not permit the P_i to be obtained for individual decimal codes within a particular ICDA integer. Both of these problems should be considered by any potential user before the index is applied to a particular data set; however, the high correlations reported in Table 3 lead us to postulate that the index should prove useful on a wide variety of data sets.

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