Factors associated with hospital mortality in Rio Grande do Sul SUS network in 2005: Application of a Multilevel Model

Abstract

Objective: To use a multilevel analysis methodology to evaluate hospital mortality from the data available in the Hospital Information System of the National Unified Health System. **Methods:** Cross-sectional study with data obtained from Authorization Forms for Hospital Admissions in Rio Grande do Sul, Brazil in 2005. The modeling was performed using multilevel logistic regression, with variables from the individual level (hospital admissions) and the context level (hospital profile). The variability originated from individual variables was analyzed as well as the participation of the profile of hospitals in the rate of hospital mortality. **Results:** The crude death rate calculated for all hospitals was 6.3%. The variables "Use of Intensive Care Unit" followed by "Patient Age" were the main predictors for hospital death at the individual level. The context variables that were related most closely to hospital death (outcome) were: size of hospital, legal nature, and average length of stay. The OR for deaths at large hospitals was 1.85 times the odds for small hospitals and the OR for medium hospitals was 1.69 times the odds for small ones. The chance of deaths in public hospitals was 67% higher than in private ones. **Conclusions:** The hospital profile has an important role in hospital mortality in the Hospital Information System of the National Unified Health System. Multilevel analysis should be used to estimate the contribution of the profile of mortality in hospitals.

Keywords: Hospital mortality. Multilevel analysis. Multilevel logistic regression models. Quality Care. Evaluation of health services. Unified Health System.

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Introduction

Hospital mortality is an important and traditional indicator of hospital performance[1]; as the final outcome of treatment in hospital, it is a crucial measure of the quality of care provided. No other characteristic of health care is more closely linked to the mission of health institutions than their activities to prevent or to delay death[1]. Hospital mortality rate, whether observed or estimated, should be used by hospitals, professionals and funding agencies both as a measure of the quality of care given to patients, and to give a better appreciation of how such care can be improved[1].

The evaluation of health service performance has been focused on services of medical assistance. This is a consequence of the search for greater efficiency by ensuring that health service systems perform their functions in the best possible way, under conditions of ever greater financial stringency[3]. Emphasis on the evaluation of health care provided by hospitals is important both to promote better knowledge of care effectiveness and to ensure greater efficiency of programmes for evaluating and controlling assistance[4].

Differences in mortality rates between hospitals may be a consequence of differences in general health of the populations that they serve[5], and of institutional characteristics[6]. When studying such differences, there are hierarchical differences in the available information, at the micro level on the one hand, and at the macro level on the other: that is, at the individual case level, and at the contextual (hospital) level. Multilevel models have been developed for the purpose of distinguishing between such sources of variation, given data organized hierarchically with the existence of intraclass or within-group correlation[7-9].

A number of authors have therefore proposed the use of multilevel modeling for evaluating hospital mortality. However in contrast to what happens at the international level, few studies at the national level have been reported which use multilevel models to evaluate hospital performance in terms of their mortality rates[10,11].

In Brazil, the Unified Health Service's Hospital Information System (SUS-HIS)[12] has proved a good way of analyzing hospital internments since it holds extensive records which are available for use shortly after the period of hospitalization[4], although information about secondary diagnostics[13,14], the nature of the costs involved, and the clinical condition of patients are limitations that must be recognized. However a number of studies[6,13] have verified that the SUS-HIS archive holds reliable data for use in evaluating hospital performance.

Under these conditions, it is possible, opportune and useful to evaluate hospital mortality by using multilevel analysis of data both of patients and hospitals, held in the SUS-HIS data-base.

Methods

The data-base was derived from the record of periods spent in the SUS hospitals of Rio Grande do Sul for the year 2005, and were abstracted from the Hospital Information System SUS-HIS. The Authorizations for Hospital Admission (AHAs) form an information data-bank that is processed nationally by SUS-HIS and is internet-accessible for public use. The AHA is the instrument for information and costings of all SUS services. To develop the model, a sample of 10 000 Type I AHAs was selected randomly from the total record of 453 515 admissions to medical and surgical clinical specialization in Rio Grande do Sul in the year 2005. Thus admission was the basic unit for statistical analysis.

Where data are hierarchically structured into two groups belonging to different levels, units within the same group are rarely independent. The fact that units share the same environment, or are otherwise more similar to each other than to units in other groups, may also result in greater similarity in the outcomes of interest[7-9]. Failure to take account of hierarchy can result in over-estimation of model coefficients and false conclusions that differences are statistically significant because magnitudes of standard errors have been under-estimated[7-9]. Multilevel models were developed as a means of overcoming analytical difficulties when data are organized hierarchically and intraclass or within-group correlations exist. They take hierarchies into account and correctly estimate variances of model coefficients, thus allowing risk factors at levels higher than the first to be analyzed directly and efficiently[7-9]. It is also possible to adjust for confounding between factors at the same level and at different levels, to estimate possible interactions between effects at individual and contextual levels, and to model complex variance structures[7-9].

The multilevel model is made up of a fixed component which measures the magnitude of associations between the variables, and a random component which shows the differences between second-level components and the variances in the different levels[15]. The random coefficients are measures of the random effects derived from variability between units, shown either as variation between intercepts or as variation between slopes in fitted regression lines[16].

The multilevel modeling followed recommendations of Snijders and Bosker[17] and Rasbash et al.[18]. When evaluating hospital mortality a hierarchical two-level structure is found: the first level being admissions and the second, hospitals. Mortality as an outcome of hospitalization can vary as a function of explanatory variables which might be measured at the first level, as characteristics of admissions, or at the second, in terms of hospital profiles, with both individual and contextual effects estimated.

The multilevel logistic model used was given by the equation[10] $\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)=\beta' x_{ij}+\gamma' z_j+u_j$, where $\ln\left(\frac{p_{ij}}{1-p_{ij}}\right)$ is the natural logarithm of the odds that patient i dies in hospital j;x_{ij} is the matrix of explanatory variables at the individual level; and z_j is the matrix of explanatory variables at the hospital level; β and γ are vectors of parameters, respectively associated with individual and hospital variables. The random effect u_j, which captures the correlation between observations, is assumed to be Normally distributed with mean zero and variance σ^2_u.

Model parameters corresponding to the second level can be written as $\beta_{0j} = \beta_0 + u_{0j}$ and $[u_{0j}] \sim N(0,\Omega_u):\Omega_u = [\sigma^2_{u0}]$, where the random intercept β_{0j} consists of two terms: a fixed component β_0 and a component specific for the contextual level. Thus the random effect u_{0j} represents random variation at the second level. It is assumed that the intercept β_0 varies randomly between hospitals and that u_{0j} has a Normal distribution with mean zero and variance σ^2_{u0} $\sigma^{2}{}_{u0}$. With these assumptions a value can be calculated that is two standard deviations larger than the mean, giving the increased odds of a patient dying in hospital, from the expression[10] $e^{2x\sqrt{\sigma^2_{u0}}}$.

The multilevel regression model yields a statistic termed the intraclass correlation coefficient (ICC), defined as $\rho = \sigma^2_{u0}/(\sigma^2_{e0} + \sigma^2_{u0})$, where σ^2_{e0} and σ^2_{u0} are the first- and second-level variances respectively. The ICC gives the proportion of total residual variation (the sum of the variances at first and second levels) which is attributable to hospital (the second level). In the logistic model it is assumed that the first-level variance is $\pi^2/3 \approx 3.29$.

The variables derived from AHA data that were chosen as explanatory variables at the admission (first) level, were: *sex, patient age, UTI (*time spent in intensive care unit*); type of treatment* (medical and surgical clinical), *type of admission* (voluntary/emergency), *length of hospital stay*. In this study, the diagnosis variable was considered most important, following the chapters of CID-10. The variable *type of treatment* was subsequently eliminated because it is highly correlated with the variable *diagnosis*. After fitting the model at the individual level, variables at the hospital level were subsequently included.

Whether or not variables were retained in the model was determined by theoretical considerations, by statistical significance[9] using a Wald test ($p \leq 0.05$), and by whether a smaller ICC was obtained, within the specific theoretical context.

Variables at the hospital (second) level were selected from AHA data and also from information about institutional profiles given in the National Register of Health Service Establishments (CNES) which was obtained from State Secretary for Health. Variables used at the hospital level were: *mean age of admitted patients, mean time spent in hospital, hospital size (small, medium or large), mean rate of transfer (where patients are transferred to other hospitals), hospital legal status (public, private), complexity of treatment (low, medium, high), presence of teaching activities (yes, no)* and *mean number of admissions.*

It is also possible in multilevel models to analyze whether the effects of explanatory variables are different for different units at the second level. By adding a random component to the explanatory variables, its effect can be observed on variability at the second level. Thus with another random term contributing to variance at the second level, we have β_{xj}, where x is the explanatory variable at the second level, with $\beta_{0j} = \beta_0 + u_{0j}$ and $\beta_{xj} = \beta_x + u_{xj}$, with

$$\begin{bmatrix} u_{0j} \\ u_{xj} \end{bmatrix} \sim \mathrm{N}\left(0, \Omega_u\right) : \Omega_u = \begin{bmatrix} \sigma^2_{u0} & \sigma_{u0x} \\ Sim & \sigma^2_{ux} \end{bmatrix}$$

All first-level explanatory variables were tested to see whether there were differences between estimated coefficients obtained for second-level units (hospitals).

Variables were put into discrete form for the analysis, so that continuous variables were dichotomized and classed as greater than, or less than, their mean values. Tables 1 and 2 show the cut-off points for each category together with the categories used. Interactions were not tested.

Data were analyzed using the statistical programs SPSS version 13 and MLwiN version 2.0.

Results

The set of 332 hospitals (453 515 AHAs) had an overall mortality rate of 6.3%.

The mean age of patients at admission was 54.6 years, the mean length of stay in hospital was 6.1 days, the mean rate of admissions was 1366 admissions/hospital and the transfer rate per 100 admissions over all 453 515 AHAs was about 1.6, but fell to 1.2 after high values from certain hospitals with unusual profiles were omitted. Teaching activities were undertaken in 23.30% of hospitals. Over all hospitals, 2.40% gave treatment of low complexity, 39.06% of medium complexity and 58.54% of high complexity.

Table 1 shows admission characteristics and hospital profiles in the data-base derived from the 332 hospitals (453 515 AHIs) and of the random sample of 10 000 AHIs used to develop the multilevel model.

Table 2 shows the final model fitted in the multilevel analysis. This was the model which, as well as including variables shown to be important from theoretical considerations and/or from their statistical significance ($p \leq 0.05$), showed less variability in mortality between hospitals. The final model, developed from the random sample of 10.000 AHAs, had area under the ROC curve ROC=0.805 (CI95% 0.788-0.822) when fitted, and area under the ROC curve 0.780 (CI95%=0.762-0.798) when validated. The model was therefore considered adequate for predicting hospital deaths.

At the individual level, time spent in intensive care (UTI) is the variable which in this context was the best predictor of the chances of death, which were greater for those who had spent time in intensive care than for those who had not. However it was found that the chances of death did not increase with the length of time spent in intensive care. Patients older than 60 years had greater chance of death in hospital than patients aged between 18 and 39. For patients diagnosed at admission as having infecto-parasitic or respiratory illnesses, the chances of death were greater. No difference between the sexes was found.

With respect to hospital profiles, the chance of death was found to increase with hospital size, with patients more likely to die in large or medium-sized hospitals,

Table 1 - Caracteristics of admissions and hospitals studied. AHAs, RS, 2005.

Variables	Total (N=453 515)				Calibration sample (n=10000)			
	N	(%)	Deaths	(%)	n	(%)	Deaths	(%)
First level: Admissions								
Sex								
Female	232 486	51.26	12 995	5.59	5 086	50.86	294	5.78
Male	221 028	48.74	15 617	7.07	4 914	49.14	339	6.90
Age								
18 to 39 years	106 130	23.40	2 419	2.28	2 333	23.33	50	2.14
40 to 59 years	154 886	34.15	6 958	4.49	3 367	33.67	143	4.25
60 years or more	192 499	42.45	19 235	9.99	4 300	43.00	440	10.23
Diagnostic (CID-10)								
Chap. I - infec/parasitic	27 444	6.05	3 334	12.15	582	5.82	65	11.17
Chap. II - neoplasias	49 341	10.88	4 020	8.15	1 137	11.37	89	7.83
Chap VI - nervous system	9 953	2.19	970	9.75	212	2.12	16	7.55
Chap IX - circulatory system	96 209	21.21	6 824	7.09	2 091	20.91	150	7.17
Chap X - respiratory system	77 814	17.16	6 869	8.83	1 692	16.92	180	10.64
Chap XVIII - abnormal signs/ symptoms	6 018	1.33	829	13.78	147	1.47	12	8.16
Others	186 736	41.18	5 766	3.09	4 139	41.39	121	2.92
Type of admission								
Voluntary	85 887	18.94	1 738	2.02	1 921	19.21	39	2.03
Emergency	367 628	81.06	26 874	7.31	8 079	80.79	594	7.35
Use of Intensive Care Unit								
not used	419 186	92.43	19 364	4.62	9 279	92.79	422	4.55
1 a 2 days	12 335	2.72	3 471	28.14	242	2.42	72	29.75
3 a 7 days	15 174	3.35	3 362	22.16	333	3.33	81	24.32
8 days or more	6 820	1.50	2 415	35.41	146	1.46	58	39.73
Second level: Hospitals								
Hospital legal status								
Public	106 212	23.42	7 639	7.19	2 290	22.90	178	7.77
Private	347 303	76.58	20 973	6.04	7 710	77.10	455	5.90
Hospital size								
Small	54 299	11.97	1 713	3.15	1 146	11.46	39	3.40
Medium	159 618	35.20	8 776	5.50	3 636	36.36	207	5.69
Large	239 598	52.83	18 123	7.56	5 218	52.18	387	7.42
Length of hospital stay								
Below average (≤6.14)	263 678	58.14	13 507	5.12	5 800	58.00	301	5.19
Above average (> 6.14)	189 837	41.86	15 105	7.96	4 200	42.00	332	7.90

AHAs - Authorizations for Hospital Admission.

Table 2 – Multi-level logistic model of hospital death. Estimates, standard errors (SE), OR of the fitted model for first and second levels. n=10.000. AHAs, RS, 2005.

Variable	Coefficient	SE	OR	(CI 95%)
Constant	-6.364	0.296		
First level: Admissions				
Sex				
Female	-	-	1	
Male	0.112	0.090	1.119	(0.937-1.334)
Age				
18 to 39 years	-	-	1	
40 to 59 years	0.572	0.176	1.772	(1.254-2.501)
60 years or more	1.491	0.163	4.442	(3.226-6.113)
Diagnostic (Chap.CID-10)				
Chap I - infec/parasitic	1.319	0.175	3.740	(2.653-5.269)
Chap II - neoplasias	0.709	0.157	2.032	(1.493-2.764)
Chap VI - nervous system	0.697	0.297	2.008	(1.121-3.593)
Chap IX - circulatory system	0.161	0.139	1.175	(0.894-1.542)
Chap X - respiratory system	1.024	0.135	2.784	(2.136-3.627)
Chap XVIII - abnormal signs/symptoms	0.563	0.345	1.756	(0.892-3.452)
Others	-	-	1	
Type of admission				
Voluntary	-	-	1	
Emergency	1.130	0.183	3.096	(2.162-4.431)
Use of Intensive Care Unit				
Not used	-	-	1	
1 to 2 days	2.251	0.166	9.497	(6.859-13.14)
3 to 7 days	1.821	0.152	6.178	(4.586-8.322)
8 days or more	2.364	0.194	10.633	(7.270-15.553)
Second level: Hospitals				
Hospital legal status				
Públic	0.514	0.140	1.672	(1.271-2.199)
Private	-	-	1	
Hospital size				
Small	-	-	1	
Medium	0.529	0.189	1.697	(1.171-2.458)
Large	0.616	0.206	1.852	(1.236-2.772)
Length of stay				
Below average (≤6.14)	-	-	1	
Above average (> 6.14)	0.241	0.130	1.273	(0.986-1.641)
Variance of random effects				
$\hat{\sigma}^2_{uo}$	0.152	0.055		
$\hat{\sigma}^2_{u1}$	0.208	0.067		
$\hat{\sigma}^2_{u2}$	0.093	0.045		
$\hat{\rho}_0$	0.044			
$\hat{\rho}_1$	0.059			
$\hat{\rho}_2$	0.027			

$\hat{\sigma}^2_{uo}$ variance of second level without explanatory variables (null model); $\hat{\sigma}^2_{u1}$ variance of second level with only explanatory variables of individual level; $\hat{\sigma}^2_{u2}$ variance of second level with explanatory variables of individual and hospital level; $\hat{\rho}_0$ intra-unit correlation without explanatory variables (null model); $\hat{\rho}_1$ intra-unit correlation with explanatory variables of individual level; $\hat{\rho}_2$ intra-unit correlation with explanatory variables of individual and hospital level.

than in small ones. The chance of death in public hospitals was greater than in private hospitals. Length of hospital stay showed no significant relationship with hospital death.

The variance of the random effect at hospital level in the null model, before the inclusion of any explanatory variables, was 0.152, corresponding to an intraclass correlation of 4.4%. This shows that 4.4% of the total unexplained variation in outcome is associated with the hospital, and is an indicator of the value of grouping the data and of the magnitude of the hospital effect. The variance of this random effect decreased to 0.093 after inclusion of the explanatory variable in the final model, so that inclusion of the explanatory variables reduced the intraclass correlation to 2.7%, a reduction of 39% in unexplained variation.

Although variance of the random effect was small, it could have an important effect on the chance of patient death. Recalling that the random effect is Normally distributed with variance 0.093, it was computed that a patient admitted to a hospital with mortality rate two standard deviations greater than the mean mortality rate, would have chances of death in hospital increased by 84% ($e^{2\sqrt{0,093}} = 1,84$).

There was close correlation between the variable *teaching activities present* and the variables *legal status* and *size*. Other models tested were found to have greater variability at the hospital level than the final model given in Table 2, showing that they offered no improvement in model fit. Although included in the final model, the variable *teaching activities present* was not statistically significant.

Discussion

Few studies in Brazil have used hospital characteristics to evaluate hospital performance by multilevel modelling[10,11]. Including both comparisons between hospitals as well as characteristics of admissions and the patients admitted, it was decided to compare results from the present study with those of others done in the country. However caution is needed because other studies had different objectives, methods and target populations from the work reported here.

Regarding admission characteristics and/or the people admitted, various studies have been undertaken to evaluate hospital mortality using variables such as use of UTI[19,20], principal diagnosis[14,21], age[14], sex[10,21] and nature of admission[14].

Since the variable use of UTI was the most important predictor of hospital death, it should be mentioned that other authors[19] found that patients who spent longer in UTI (>9 days) had higher risk of dying than patients who were there for a shorter time (from 3 to 9 days). Other research[22] found that children who died while in hospital showed higher probability of being sent to UTI than those who had survived. These findings agree with the premise that the variable *use of UTI* is an indirect measure of the gravity of a patient's condition. In the present study, patients in the intermediate group for time spent in UTI (from 3 to 7 days) had less chance of dying than those in the lower (from 1 to 2 days) or higher (8 days or more) groups. This may be related to the fact that patients who survive for 48 hours in UTI may be in a less grave condition than those who spent less time there, or who spent 8 days or more.

In terms of the contribution of hospital profile to mortality rate, results of the present study both agree and disagree with those reported elsewhere in the literature. They disagree with the results of Martins et al.[10], who studied admissions for circulatory and respiratory problems in SUS and non-SUS hospitals in the region of Ribeirão Preto; their results showed greater chances of death in public hospitals (OR=1.69) than in private hospitals. However after including *hospital size*, measured by the number of beds, in their model, the effect of a hospital's *legal status* (public, private) was altered, with public hospitals then having lower chances of death (OR=0.41) than private hospitals. Contrary to what these authors found, in the present study chances of death in public hospitals remained greater, even in the fitted multilevel model that included variables describing hospitals.

The higher chances of death in public hospitals may be related both to the gravity of the patient's condition and, possibly, to less successful treatment, especially in public hospitals in the interior of the state.

A study of the mortality of elderly patients in the city of Rio de Janeiro[21] has been reported which did not include variables at the hospital level. Overall, it was found that mortality rate was lower in university hospitals. In that study, although fitting for patient characteristics reduced the differences in mortality rates between establishments, university hospitals continued to have mortality rates that were significantly lower than those of other hospitals. However in the present study the presence or otherwise of teaching activities did not significantly affect mortality rate.

As in other reports[10], hospital-level variables such as volume of admissions, mean age of patients and length of hospital stay showed no evidence of statistical significance. Although the use of length of hospital stay as a variable in predictive models may be controversial since it may indicate either the gravity of cases as well as low treatment quality[1], it was decided to retain it in the present study. The result is consistent with that of Martins et al.[10] who found that the length of hospital stay was greater for patients who died than for those who lived. In the present study, length of hospital stay reduced variability at the hospital level and, as expected, showed that hospitals where length of stay was longer had higher chances of death. In addition, the mean time of hospital stay was greater for public than for private hospitals, which is consistent with another study[22] that reported lower times of hospital stay in contracted/philanthropic hospitals. In both studies, public hospitals and hospitals with longer durations of hospital stay had higher probabilities of hospital death.

Noronha et al.[19], who evaluated the volume of surgical operations for miocardial revasculation (CRVM) and its relation to hospital deaths, found that, in hospitals with higher volumes of CRVM, patients who were operated were less likely to die than those in hospitals where the volume of surgical operations was smaller. In the present study, the volume of admissions did not contribute greatly to the model, which is consistent with Martins et al.[10]. Volume of admissions is probably more important in studies which, unlike the one reported here, aim to relate hospital mortality to specific diagnoses.

The limitations of the work are related to the use of an administrative data-base with relatively few variables; also, since the inherent purpose of AHAs is to evaluate costs, the information supplied may be biased, although this should be minimized by the aggregation of diagnoses. The limited information on hospital profiles that relates to the care process and hospital structure, especially where human resources are concerned, may be such that a better evaluation at hospital level is not possible. Extending the number of clinical variables recorded on patients, together with variables which better describe hospital profiles, could improve estimates of the probability of hospital death in different establishments within the SUS-HIS system.

However, although on the one hand the limited number of published national studies of the issue, all with different methodologies or target populations, makes comparison of results difficult, on the other hand it underlines the relevance of the present study.

Conclusion

From the multilevel model constructed using SUS-HIS data, it was possible to quantify the contribution of variables at hospital level to the estimation of hospital mortality amongst adults admitted to the SUS network of hospitals in Rio Grande do Sul during the year 2005. The analysis, by means of the multilevel model, using characteristics of admissions and of hospitals, allowed the possible influences to be evaluated of aggregated (contextual) variables on estimates of hospital mortality.

Collaborators

AS Gomes reviewed the literature, did the statistical analysis and drafted the paper. Riboldi e JMG Fachel advised on the statistical analysis and revised the text. MM Klück advised on interpretation of the results and commented on the manuscript.

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