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Risk adjusted mortality after hip replacement surgery: a retrospective study

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Abstract

Introduction. Hip replacement (HR) operations are increasing. Short term mortality is an indicator of quality; few studies include risk adjustment models to predict HR outcomes. We evaluated in-hospital and 30-day mortality in hospitalized patients for HR and compared the performance of two risk adjustment algorithms.

Materials and methods. A retrospective cohort study on hospital discharge records of patients undergoing HR from 2000 to 2005 in Tuscany Region, Italy, applied All-Patient Refined Diagnosis Related Groups (APR-DRG) and Elixhauser Index (EI) risk adjustment models to predict outcomes. Logistic regression was used to analyse the performance of the two models; C statistic (C) was used to define their discriminating ability.

Results. 25 850 hospital discharge records were studied. In-hospital and 30-day crude mortality were 1.3% and 3%, respectively. Female gender was a significant ($p < 0.001$) protective factor under both models and had the following Odds Ratios (OR): 0.64 for in-hospital and 0.51 for 30-day mortality using APR-DRG and 0.55 and 0.48, respectively, with EI. Among EI comorbidities, heart failure and liver disease were associated with in-hospital (OR 9.29 and 5.60; $p < 0.001$) and 30-day (OR 6.36 and 3.26; $p < 0.001$) mortality. Increasing age and APR-DRG risk class were predictive of all the outcomes. Discriminating ability for in-hospital and 30-day mortality was reasonable with EI (C 0.79 and 0.68) and good with APR-DRG (C 0.86 and 0.82).

Conclusions. Our study found that gender, age, EI comorbidities and APR-DRG risk of death are predictive factors of in-hospital and 30-day mortality outcomes in patients undergoing HR. At least one risk adjustment algorithm should always be implemented in patient management.

Key words
- hip replacement
- mortality
- risk adjustment
- APR-DRG
- Elixhauser index

INTRODUCTION

Total hip replacement was introduced in the 1960s and revolutionized management of elderly patients crippled with arthritis, showing very good long term results. Over the years it has developed into one of the most successful treatments in modern medicine [1, 2]. It improves function, reduces pain and increases overall performance in daily activities, improving patients' quality of life [3-5]. In the past, indications for HR were restricted to the elderly, infirm or locomotor activity limited; today, unacceptable deterioration of quality of life is a valid indication for HR (even among younger patients). Better devices and minimally invasive surgery facilitate and accelerate discharge and rehabilitation. Patients seek so-called high performance hips to meet their expectations and aspirations [1]. As a consequence of demographic changes and procedural safety, hip replacement will see a significant numerical increase in the near future [4, 6]. It is therefore essential to assess the risk factors associated with higher mortality for better peri-operative patient management [4, 7-10]. Better risk stratification adjustment is essential to obtain quality improvement, to offer payer and patient indicators of orthopaedic surgery quality, to better allocate hospital resources and to improve the predictability of HR outcomes [9, 11]. Mortality associated with HR is an acknowledged indicator of orthopaedic surgery quality [12]. Though low, mortality after hip replacement [4, 9, 12] is an objective event that must be evaluated because of the large number of operations performed

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in the world and the importance of predictive factors for outcome. Several studies have shown that dementia, renal disease, cerebrovascular disease and diabetes are associated with mortality after HR [9]. Risk adjustment seems to be an effective and useful tool for proper comparisons, especially if we have to evaluate quality improvement. Risk adjustment is used in hospital quality and efficiency reports, and as frequent input for health plan capitation calculations. These are increasingly used for measuring and reporting the performance of physicians and various health treatments [13-15]. Since few studies have used risk adjustment in evaluating in HR outcomes, the aims of this study were: i) to evaluate in-hospital and 30-day mortality of HR patients; ii) to investigate and compare the ability and performance of two risk adjustment tools to predict our outcomes.

MATERIALS AND METHODS

Settings

We studied the hospital discharge records in a retrospective cohort of patients undergoing HR surgery from 2000 to 2005 in twelve local and three university hospitals in Tuscany (Italy). We chose this period due to the availability of complete data related to the hospital discharges of these patients. Every Local Health Unit has at least one hospital for general care. Tuscan hospitals belong to three Health Areas, HA1, HA2 and HA3, measuring 4845, 6588 and 11 561 km^2 with population densities of 319, 189 and 70 persons/km^2, respectively [15].

Data sources and criteria selection

Using hospital discharge records and diagnosis/treatment data, we selected the following inclusion/exclusion criteria: at least one primary surgery code for total hip replacement (procedure ICD code 81.51) or partial hip replacement (procedure ICD code 81.52), or revision of hip replacement (ICD 81.53), classificated as "replacement of hip joint" according to All-Patient Refined Diagnosis Related Group (APR-DRG) (code 301) but excluding hospitalizations with procedures having codes ICD 81.51 and ICD 81.53 or ICD 81.52 and ICD 81.53. The outcomes evaluated were: i) in-hospital mortality: patients who died during the case index hospitalization; ii) 30-day mortality: patients who died in or out of hospital within 30 days of surgery. We considered the general in-hospital and 30-day mortality after Hip replacement and not those of each subcategory of surgery (total, partial or revision), because patients are already stratified by APR-DRG. In fact, this tool stratifies each case on the base of DRG (which consider the general group of "hip joint replacement"), primary and secondary diagnoses, age and procedures. Moreover, further stratifications by subgroups of surgery would reduce the sample size of each one with consequences on the inferential analysis. For the Elixhauser Index (EI), comorbidities are evaluated from the diagnosis in the hospital discharge records and diagnosis-related groups of the last three years.

Tools

Two risk adjustment tools were used to predict outcomes: All-Patient Refined Diagnosis Related Groups (APR-DRG) and Elixhauser Index (EI). APR-DRG is an admissions classification system which stratifies by iso-severity. Among the descriptors there are two measures related to severity of illness, *i.e.* the extent of physiologic decompensation or organ system loss of function, and risk of death (ROD), *i.e.* the likelihood of dying. These two measures vary from 1 (minor) to 4 (extreme risk) and refer to diseases and procedures in the hospital discharge records [16, 17]. The other tool was EI, a set of measurements indicating 30 categories of comorbidity. Each comorbidity category is dichotomized: present/absent. Outcomes are related to the presence of comorbidities and worsen as they increase [18].

Statistical analysis

Descriptive analysis by age, ROD and gender was performed for in-hospital and 30-day mortality. We used logistic regression to find the best fitting and most parsimonious clinically interpretable model describing the relationship between outcomes and a set of independent (predictors) variables [19]. The performance of the models was assessed by measures of calibration using the Hosmer-Lemeshow (HL) method and the area under the ROC curve. Discrimination indicates model ability to recognize outcomes from the predictors; calibration measures the distance between predicted and observed values. We also compared 30-day mortality, crude and adjusted with the EI and APR-DRG models, between university and local hospitals. The analysis was performed with STATA software 10.0 (Data Analysis and Statistical Software. Copyright 1996-2013 StataCorp LP). Statistical significance was set at $p < 0.05$.

RESULTS

The number of hospitalizations for hip replacements in the period 2000-2005 was 26 277. After applying the inclusion/exclusion criteria described above, we finally evaluated 25 850 cases, 83% of whom were patients over 65 years of age and 70% of whom were females. Ninety nine percent of cases had a minor or moderate ROD (*Table 1*). Among these patients, comorbidities were generally not very frequent: 3.4% had diabetes and only 1.6% had chronic lung disease.

Females were significantly less likely to die in hospital, OR = 0.64 (95% CI: 0.50-0.81; $p < 0.001$), or within 30 days, OR = 0.51 (CI: 0.44-0.61; $p < 0.001$). For ROD in class 2 we found an OR of 7.40 (CI: 5.62-9.63; $p < 0.001$) for in-hospital mortality and 4.94 (CI: 4.05-6.03; $p < 0.001$) for 30-day mortality. ROD in classes 3 and 4, which were combined due to the small number of individuals, was strongly associated with in-hospital mortality (OR = 49.70; CI: 36.24-68.10; $p < 0.001$) and 30-day mortality (OR = 28.67; CI: 21.59-38.08; $p < 0.001$). Age was significantly associated with in-hospital and 30-day mortality and the strength of this association increased with age, from OR = 2.54 (CI: 1.05-6.14; $p = 0.039$) and OR = 2.39 (CI: 1.38-4.14; $p = 0.002$) for ages 65-74, to OR = 18.20 (7.96-41.43; $p < 0.001$) and OR = 19.62 (CI: 11.79-32.63; $p < 0.001$) for ages > 85, respectively (*Table 2*).

Table 1
Descriptive analysis by age, ROD and gender for in-hospital and 30-day mortality

Patient characteristics		In-hospital mortality (%)	Total (%)	Patient characteristics		30-day mortality (%)	Total (%)
Age	< 65	6 (0.14)	4376 (17)	Age	< 65	16 (0.37)	4376 (17)
	65-74	29 (0.38)	7524 (29)		65-74	67 (0.89)	7524 (29)
	75-84	139 (1.47)	9468 (37)		75-84	274 (2.89)	9468 (37)
	85+	167 (3.76)	4437 (17)		85+	347 (7.82)	4437 (17)
	1	167 (0.69)	24 249 (94)		1	443 (1.83)	24 249 (94)
ROD	2	89 (6.82)	1305 (5)	ROD	2	152 (11.65)	1305 (5)
	3-4	85 (33.86)	251 (1)		3-4	109 (43.43)	251 (1)
Gender	M	126 (1.62)	7793 (30)	Gender	M	278 (3.57)	7793 (30)
	F	215 (1.19)	18 012 (70)		F	426 (2.36)	18 012 (70)

The Elixhauser Index also associated age and gender with in-hospital and 30-day mortality. It estimated the role of the following comorbidities for in-hospital mortality: heart failure with an OR of 9.29 (CI: 6.09-14.17; $p < 0.001$) and liver disease with an OR of 5.60 (CI: 2.84-11.05; $p < 0.001$). Chronic pulmonary diseases and diabetes were also related to in-hospital and 30-day mortality with an OR of 2.11 (CI: 1.31-3.42; $p < 0.001$) and OR = 1.85 (CI: 1.20-2.84; $p = 0.012$), respectively. The Elixhauser Index also identified a further comorbidity related to 30-day mortality: neurological disorders with an OR of 2.22 (CI: 1.45-3.42; with $p < 0.001$) (*Table 2*).

The variables used in the models proved able to predict in-hospital and 30 day-mortality with both risk adjustment models. APR-DRG showed good discrimination for in-hospital (C = 0.86) and 30 day-mortality (C = 0.82). Similarly, EI predicted in-hospital (C = 0.79) and 30 day (C = 0.78) mortality. The calibration (HL test) for APR-DRG in-hospital and 30-day mortality was 4.81 ($p = 0.30$) and 4.36 ($p = 0.36$), respectively, and for EI 6.63 ($p = 0.25$) and 1.81 ($p = 0.87$), respectively.

Stratification by hospital (15 hospitals: 12 local and 3 university) made it possible to compare crude and adjusted 30 day-mortality with APR-DRG and EI (*Figure 1*). On one hand, significant differences were not found between crude and adjusted outcomes for each hospital, nor did crude or adjusted 30 day-mortality change with EI or APR-DRG. On the other hand, using EI, three hospitals (11, 12 and 15 in *Figure 1*) proved to have a risk of mortality significantly higher than the regional average and two hospitals (8 and 10) had significantly lower risk of mortality than the regional average. Using APR-DRG, statistical differences were only confirmed for hospitals 8 and 11. Moreover, six hospitals (2, 3, 6, 8, 11 and 14) showed similar crude and adjusted 30-day mortality values with EI. With APR-DRG, six hospitals (2, 3, 7, 8, 12 and 14) did not show significant differences with respect to each other. Hospitals 2, 3, 8 and 14 did not show differences in 30-day mortality with either risk adjustment model (*Figure 1*).

DISCUSSION

Our study evaluated whether risk adjustment tools could be useful for risk evaluation of in-hospital and 30-day mortality in a population of hip replacement patients, before surgery. Both models offered advantages and proved useful for identifying centres of excellence and critical situations. By creating comparable groups, adjusted for severity of illness or risk of death, they make it possible to assess hospital procedure [13, 17]. Increasing age and female gender were found to be predictors of in-hospital and 30-day mortality with both risk adjustment models. Thirty-day mortality has also been reported in other studies [20, 21]. Regarding the EI model, several comorbidities were found to be predictive of outcome: congestive heart failure, diabetes, chronic lung diseases and liver disease.

The literature confirms that some comorbidities are important for short-term outcomes after hip replacement, including mortality [9, 10, 12]. In particular Soohoo, *et al.* identified age, diabetes complications and Charlson comorbidity index score among factors predictive of complications after HR (including mortality). Hunt *et al.* identified comorbidities at admission that influence mortality for hip replacement [10, 12]. Patients with severe liver disease, cancer, congestive heart failure, myocardial infarction and kidney disease are particularly at risk of death after hip replacement; special efforts to reduce mortality should be focused on these groups, and these patients should be informed of the risks related to surgery [12]. APR-DRG predicted mortality for patients undergoing hip replacement, especially in cases with age > 75 years, ROD > 2 and male gender. Comparing EI with APR-DRG, we found that APR-DRG showed slightly better performance in predicting mortality, at least for HR and also for patients with heart failure [22]. On the other hand, EI has the advantage of being readily available and free and, in any case, it is able to predict even if with lower performance than APR-DRG.

Evaluating crude and adjusted 30-day mortality for each hospital, some interesting aspects emerged. First, mortality values did not significantly differ after risk adjustment with either tool; second, we found that crude

Table 2
Logistic regression models using APR-DRG and Elixhauser methods by age, ROD and gender for in-hospital and 30-day mortality*

In-hospital mortality				
APR-DRG model	**Odds ratio**	**p**	**[95% CI]**	
Age 65-74	2.54	0.039	1.05	6.14
Age 75-84	7.63	< 0.001	3.34	17.41
Age 85+	18.20	< 0.001	7.96	41.43
ROD 2	7.40	< 0.001	5.62	9.63
ROD 3-4	49.70	< 0.001	36.24	68.10
Females	0.64	< 0.001	0.50	0.81
Elixhauser model	**Odds ratio**	**p**	**[95% CI]**	
Age 65-74	2.89	0.02	1.19	6.95
Age 75-84	11.08	< 0.001	4.88	25.18
Age 85+	28.98	< 0.001	12.76	65.79
Females	0.55	< 0.001	0.44	0.70
Chronic pulmonary disease	2.11	< 0.001	1.31	3.42
Diabetes	1.85	0.012	1.20	2.84
Congestive heart failure	9.29	< 0.001	6.09	14.17
Liver disease	5.60	< 0.001	2.84	11.05
30-day mortality				
APR-DRG model	**Odds ratio**	**p**	**[95% CI]**	
Age 65-74	2.39	0.002	1.38	4.14
Age 75-84	7.05	< 0.001	4.24	11.74
Age 85+	19.62	< 0.001	11.79	32.63
ROD 2	4.94	< 0.001	4.05	6.034
ROD 3-4	28.67	< 0.001	21.59	38.08
Females	0.51	< 0.001	0.44	0.61
Elixhauser model	**Odds ratio**	**p**	**[95% CI]**	
Age 65-74	2.56	< 0.001	1.48	4.42
Age 75-84	8.70	< 0.001	5.24	14.46
Age 85+	25.13	< 0.001	15.14	41.70
Females	0.48	< 0.001	0.42	0.57
Chronic pulmonary disease	1.98	< 0.001	1.37	2.84
Diabetes	1.53	0.012	1.10	2.13
Congestive heart failure	6.36	< 0.001	4.37	9.27
Liver disease	3.26	< 0.001	1.75	6.08
Neurological disorders	2.22	< 0.001	1.45	3.42

* Only significant variables are shown

and adjusted 30-day mortality were similar in some hospitals (2, 3, 6, 8, 11 and 14 using APR-DRG and 2, 3, 8, 12 and 14 using EI). These results show that 30-day mortality, was not conditioned by the variables considered. In these hospitals, outcome therefore did not seem to be influenced by confounders such as age, gender, severity of illness, risk of death or comorbidities. In other words, it seemed that 30-day mortality of patients, regardless of their condition, depended on the hospital where they underwent HR, indicating that other factors play a role in this outcome. Although it is not possible to fully determine the factors that influence this outcome or the relative "weight" of each with our data, some hypotheses can be advanced. As the literature suggests, the overall mortality rate for hip surgery has decreased, presumably due to decades of experience, improvements in surgical techniques, anaesthesia and rehabilitation [7, 23]. Shorter hospitalization also helps prevent postoperative complications [7]. Increased awareness about cardiovascular screening and follow-up may also help reduce mortality, because most deaths in high-risk patients depend on cardiovascular complications [7]. Consequently, orthopaedic team experience, surgical techniques and the technological level of the hospital

ORIGINAL ARTICLES AND REVIEWS

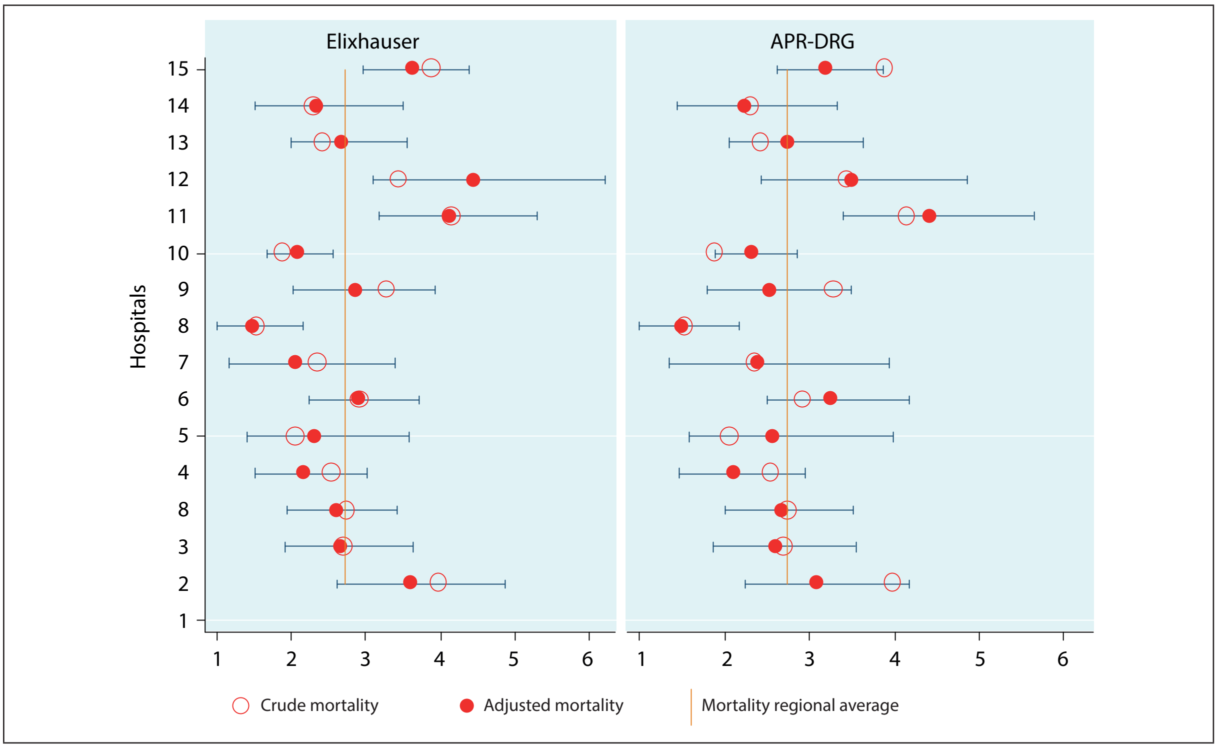

Figure 1
Crude and adjusted 30-day mortality (95% confidence interval) of hospitals with Elixhauser index and APR-DRG risk adjustment.

may be more important for patient "survival" and the success of HR operations than clinical condition. Similar importance seems likely for anaesthesia, in all its aspects, before, during and after surgery. Rehabilitation, length of stay and postoperative care, including assessment of risk factors (especially cardiovascular) may also be of fundamental importance for outcome.

Another interesting aspect is that in some cases (hospitals 8 and 11 of the *Figure 1*), the two risk adjustment models seem to discriminate differences between 30-day mortality and average regional mortality in a similar and consistent way. In other cases (hospitals 10, 12 and 15 of *Figure 1*), we found different discrimination capacity: the statistical difference from average regional mortality seemed to depend on the risk adjustment model used, possibly on their different discriminating ability. In fact, the results of the C statistic showed a slight difference between the two tools. Similarly, a previous study on risk adjustment for heart failure by Messina *et al*. showed some differences between APR-DRG and EI. The ability to predict hospital mortality was acceptable with the former and slightly less with the latter. Readmission within 30 days for any reason was not, however, successfully predicted with either [22]. Other factors may of course be involved and further research is needed to answer this question.

CONCLUSION

In conclusion, gender, age, EI comorbidities and APR-DRG ROD proved to be predictive factors of in-hospital and 30-day mortality of patients undergoing HR. Our study shows the significant importance of risk adjustment, suggesting that at least one risk adjustment algorithm should be used in patient management.

Conflict of interest statement

The authors have no competing interests to disclose.

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