Comorbidity and age are both independent predictors of length of hospitalization in trauma patients

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Background: Length of hospitalization is a good indicator of resource utilization. Older patients are increasingly suffering trauma, and comorbid medical conditions are also increasing. Our objective was to determine the separate and combined effect of these 2 factors on length of hospital stay for trauma patients in a tertiary trauma centre. **Methods:** All 994 consecutive trauma patients surviving to hospital discharge between Apr. 1, 2000, and Mar. 31, 2001, were identified. Patient characteristics, injury severity and length of hospitalization were obtained from the hospital trauma registry. Each medical record was then reviewed for completeness of information and assessment of comorbid conditions. A multivariate linear regression model was developed to predict logarithmic length of stay from age and presence of a cormorbid condition while adjusting for the Injury Severity Score (ISS). **Results:** The mean age of the patients was 49.7 (range from 14–100) years and median ISS was 9 (range from 1–50). At least 1 comorbid condition was present in 321 (32%) patients. Mean length of hospital stay was 15.3 days. The proportion of patients with a comorbid condition increased steadily with age, from 8.7% before the age of 55 years to 92% at 85 or more years of age ($p < 0.001$). According to the multivariate model, the presence of comorbidity, age and ISS were all independent predictors of hospital stay ($p < 0.001$). When applied to patients with the mean ISS value of 9, the model showed an increase in length of hospitalization for patients with a comorbid condition over those without; (3.6 v. 13.1 d for patients <55 and ≥85 yr respectively). Length of hospital stay increased particularly with neurologic and pulmonary problems. **Conclusions:** Comorbidity and age were both independently significant predictors of length of hospitalization over and beyond that which is expected based on the severity of the injuries. With an aging population, this phenomenon should severely affect resource utilization in trauma centres in the near future. Researchers should take account of both age and comorbidity in order to compare trauma populations.

Contexte : La durée de l'hospitalisation est un bon indicateur de l'utilisation des ressources. Les patients plus âgés subissent plus souvent des traumatismes, et les comorbidités sont aussi à la hausse. Nous voulions déterminer l'effet séparé et combiné de ces deux facteurs sur la durée de l'hospitalisation des patients traumatisés dans un centre de traumatologie tertiaire. **Méthodes :** On a identifié les 994 patients traumatisés consécutifs qui ont survécu après leur congé d'hôpital entre le 1er avril 2000 et 31 mars 2001. On a tiré du registre des traumatismes de l'hôpital les caractéristiques des patients, la gravité de la blessure et la durée de l'hospitalisation. On a ensuite revu dans chaque dossier médical l'intégrité de l'information et l'évaluation des problèmes de comorbidité. On a mis au point un modèle de régression linéaire à variables multiples pour prédire la durée logarithmique du séjour à partir de l'âge et de la présence d'une comorbidité tout en corrigeant le résultat en fonction de l'indice de gravité de la blessure (IGB). **Résultats :** L'âge moyen des patients s'établissait à 49,7 (intervalle de 14 à 100) ans et l'IGB médian, à 9 (intervalle de 1 à 50). Il y avait au moins une comorbidité chez 321 (32 %) des patients. La durée moyenne de l'hospitalisation a été de 15,3 jours. Le pourcentage des patients qui avaient un problème de comorbidité a augmenté régulièrement avec l'âge pour passer de 8,7 % avant 55

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ans à 92 % à 85 ans ou plus (p < 0,001). Selon le modèle à variables multiples, la présence d'une comorbidité, l'âge et l'IGB étaient tous des prédicteurs indépendants de la durée du séjour à l'hôpital (p < 0,001). Lorsqu'on applique le modèle aux patients dont la valeur moyenne de l'IGB s'établit à 9, il montre que la durée de l'hospitalisation augmente chez les patients qui ont une comorbidité par rapport à ceux qui n'en ont pas (3,6 c. 13,1 j pour les patients de <55 ans et de ≥85 ans respectivement). La durée de l'hospitalisation a augmenté particulièrement en présence de problèmes neurologiques et pulmonaires. **Conclusions :** La comorbidité et l'âge sont tous deux et indépendamment des prédicteurs importants de la durée de l'hospitalisation en plus de la durée prévue en raison de la gravité des blessures. Comme la population vieillit, ce phénomène devrait avoir sous peu un effet sérieux sur l'utilisation de ressources dans les centres de traumatologie. Les chercheurs devraient tenir compte à la fois de l'âge et de la présence d'une comorbidité afin de comparer les populations de patients traumatisés.

Traumatology, formerly a study related to young people,[1] has become a geriatric discipline. Patients over 65 years of age represent the fastest growing segment of the population treated in trauma centres.[2] A 25% increase in admissions for trauma patients older than 65 years has been noted in the last decade.[2] Elderly people sustain increased morbidity and higher mortality than younger people for the same severity of injury.[2–6] Elderly trauma patients have an increased length of stay (LOS)[7–9] in hospital, which implies greater related costs.[10–13] Elderly patients consume a larger portion of the trauma care budget relative to the general trauma population.[14–16]

Along with an aging trauma population, we are now facing a higher number of patients with comorbid medical conditions.[2] Reports on the overall prevalence of comorbidity in the trauma population vary between 8% and 19%.[1] These rates reach 69% for patients over the age of 75 years.[17] The death rate from trauma is associated with the presence[18] and number[17] of pre-existing conditions. However, the observed effect of comorbidity on prognosis appears to be independent of age.[9,17–20] Comorbidity is also a predictor of LOS[9,13,21,22] and contributes to increased costs.[9]

Although there is some disagreement about the contribution of LOS to the cost of hospitalization,[8] it remains useful as an indicator of resource utilization in trauma.[23] Demographic data are important in planning resource requirements when trauma systems are being implemented. The trauma population is dynamic as demonstrated by its evolution and changing pattern. Moreover, there can be significant differences between populations and their specific needs. The objective of this project was to determine the separate and combined impact of age and comorbidity on LOS for trauma patients in a Canadian tertiary trauma centre.

Methods

The study population comprised all 1071 consecutive trauma patients aged 14 years and older admitted to a regional tertiary trauma centre in Quebec between Apr. 1, 2000, and Mar. 31, 2001. All patients were identified through the hospital trauma registry and the hospital administrative database. Codes from 800.0 to 959.9 of the clinical modification of the *International Classification of Diseases*, 9th revision (ICD-9-CM), were considered.

Patients were excluded if they were either dead on arrival at the hospital or if they died during their hospital stay. Dead on arrival was defined as arrival at the Emergency Department with no vital signs and declared dead within 30 minutes of arrival. Repeat admissions for the same trauma or admission for complications of a previous trauma were also excluded (ICD-9-CM 905–909). Patients were also excluded if they were admitted electively or transferred to another centre within 72 hours of admission. Patients with foreign bodies (ICD-9-CM 930–939) and isolated burns (ICD-9-CM 940–949) were also excluded. This left 994 patients for study.

All records were individually reviewed by a single investigator (E.B.). Data were compiled on a flow sheet and transcribed in an Excel database. The following variables were collected: age, sex, mechanism of injury, Glasgow Coma Scale (GCS) score, Revised Trauma Score (RTS), Injury Severity Score (ISS), presence of comorbidity, LOS and status at discharge.

The RTS was calculated as previously described.[24] To ensure completeness of data, a maximum score was attributed each time "normal vital signs" could be derived from the chart review. Patients were collected from the review of all clinical notes, operative and pathological findings, and imaging reports. The ISS[25] was then calculated from the Abbreviated Injury Scale.[26]

The following comorbid conditions were noted: pulmonary disease (ICD-9-CM 490–496 and 500–505); cardiac disease (ICD-9-CM 410–414 and 420–429); diabetes (ICD-9-CM 250); coagulopathy or anticoagulation (ICD-9-CM 286 and 287); neurologic disease or dementia (ICD-9-CM 330–340); hepatic insufficiency (ICD-9-CM 571); chronic renal insufficiency on dialysis (ICD-9-CM 582 and 585); active neoplasia of the hematologic or lympatic system (ICD-9-CM 200–208) or metastatic cancer (ICD-9-CM 190–199); hypertension (ICD-9-CM 401–405); and psychiatric disorders (ICD-9-CM 295–299).

A comorbid condition was defined as any of the 3 following situations: a previous disease was known at the time of trauma according to the patient or the family; a disease was documented in the patient's medical record; or chart review revealed the use of medications for a specific condition.

The contribution of comorbidity and age to predicting LOS was assessed in linear regression models among patients surviving to hospital discharge, while adjusting for injury severity. We used a logarithmic transformation for LOS first to normalize the distribution of the LOS, which is extremely positively skewed due to a high proportion of low values and second to approximate a linear relationship between LOS and independent variables. One extreme LOS observation of 335 days was excluded from regression analyses as it compromised the fit of the model, leaving 993 patients for analysis.

Age and ISS were both treated as categorical variables for ease of interpretation and because the categorical transformation of both variables explained more deviance (higher r^2) than their continuous form. ISS was divided into 5 categories following cut-off points suggested by Copes and associates,[27] and age was recoded in 5 categories as in the ASCOT methodology.[28]

Parameter estimates and adjusted means of LOS were generated from the linear regression models including age, ISS and comorbidity. The exponential of adjusted means of log LOS are presented. By applying parameter estimates obtained in the linear regression model, we calculated predicted values of LOS for each combination of age, ISS and comorbidity. We then subtracted the predicted value for those with no comorbid condition from the estimate for those with at least 1 comorbid condition. This gave us the average increase in LOS for patients with a comorbid condition compared to those without a comorbid condition in each subgroup of age and ISS. Analyses investigating the influence of the number and the type of comorbid conditions were performed within the population of patients with at least 1 comorbid condition (n = 321). All models were adjusted for age and ISS.

Results

Of the 993 survivors to discharge in the study and who were available for analysis, 565 (56.9%) were men and 428 (43.1%) were women. Median age was 47 (range from 14–100) years; 40% were 55 years of age or older. Of the total survivors, 955 (96.1%) had blunt trauma and 39 (3.9%) had penetrating injuries. Median ISS was 9 (range from 1–50) and median LOS was 6 (range 1–169) days. Overall, 321 (32.3%) patients presented with at least 1 comorbid condition. Among these patients, the median age was 74 (range from 19–100) years, median ISS was 9 (range from 1–43) and median LOS was 17 (range from 1–169) days. Table 1 presents the study population's characteristics in relation to the comorbidity status.

Age, ISS and comorbidity status (but not RTS and GCS score) were all statistically significant independent predictors of LOS in the multivariate regression analysis (Table 2). Adjusted means indicate that even after age and ISS were taken into account, patients with at least 1 comorbid condition at the time of hospital admission for trauma had, on average, a hospital stay almost twice as long as those with no comorbidity (28.9 v. 15.2 days, p < 0.001). Patients aged 55–64 years had a similar adjusted mean LOS to those younger than 55 years, but LOS increased thereafter with each age group 65 years and older. ISS was the variable that explained most of the variation in LOS. All possible interactions were investigated but none yielded significant changes in parameter estimates.

The logistic regression model developed with age and ISS categories and the presence of comorbidity was applied, and the predicted LOS days are calculated in Table 3. The prolonged LOS observed for patients with comorbidity increased with age and ISS. Indeed, among patients younger than 55 years with an ISS less than 9, those with a comorbid

Table 1

Characteristics of trauma survivors by comorbidity status

Characteristics	No. patients (n = 993)	With comorbidity, no. (%) (n = 321)	p value*
Age, yr			
14–54	587	51 (8.7)	
55–64	120	38 (31.7)	
65–74	103	74 (71.8)	
75–84	121	101 (83.5)	
85–100	62	57 (91.9)	<0.001
Injury Severity Score			
1–8	350	93 (26.6)	
9–15	464	185 (39.9)	
16–24	95	21 (22.1)	
25–40	72	21 (29.2)	
41–50	12	1 (8.3)	0.8
Revised Trauma Score			
7.84	913	304 (33.3)	
<7.84	80	17 (21.2)	0.03
Glasgow Coma Scale score			
15	867	290 (33.4)	
<15	126	31 (24.6)	0.05

*p values are taken from the χ^2 distribution.

condition had an average LOS only 2 days longer than those without a comorbid condition. The LOS increased steadily with age group and more quickly with ISS category to reach almost 85 days among patients 85 years or older with an ISS between 41 and 50 (Table 3).

Among patients with comorbidity, 146 (14.7% of all patients) had 1, 95 (9.6% of all patients) had 2, 46 (4.6% of all patients) had 3 and 34 (3.4%) had 4 or more pre-existing diseases. The general linear regression model on the subgroup of patients with at least 1 comorbid condition showed that LOS increased with the number of pre-existing diseases. The adjusted mean LOS was 17.5 days when 1 comorbid condition was present; it was 19.3 days with 2 ($p > 0.05$), 25.4 days with 3 ($p = 0.03$) and 37.4 days with 4 or more comorbid conditions ($p = 0.001$).

Finally, the specific types of comorbidity within the population with at least 1 comorbid condition were compared. The general linear regression model includes age and ISS in categories as previously described. Among these 321 patients, 58 (18%) had a pulmonary, 131 (41%) a cardiac and 111 (34%) a neurologic comorbid condition; 66 (20%) had diabetes and 171 (53%) suffered from hypertension at the time of admission for trauma. Other types of comorbidity were too infrequent to be representative. Patients with pulmonary problems had a higher adjusted mean LOS than those without a pre-existing pulmonary condition (27.7 v. 19.1 d, $p = 0.01$). In addition patients with a neurologic condition had a much higher adjusted mean LOS than their counterparts (28.8 v. 17.4 d, $p < 0.001$). No other specific condition studied was associated with a significant increase in LOS.

Table 2

General linear regression model testing the association between the presence of comorbidity and length of hospital stay

Characteristics	Adjusted mean length of stay*	Parameter estimate (and SD)*	*p* value†
Presence of comorbidity			
No	15.2		
Yes	28.9	0.64 (0.08)	<0.001
Age, yr			
14–54	11.5		
55–64	12.9	0.12 (0.09)	0.2
65–74	21.1	0.61 (0.11)	<0.001
75–84	33.7	1.08 (0.11)	<0.001
85–100	38.7	1.22 (0.14)	<0.001
Injury Severity Score			
1–8	5.8		
9–15	10.4	0.58 (0.06)	<0.001
16–24	23.5	1.40 (0.10)	<0.001
25–40	40.6	1.94 (0.12)	<0.001
41–50	70.5	2.50 (0.26)	<0.001
Revised Trauma Score			
7.84	19.7		
<7.84	24.5	0.18 (0.10)	0.08
Glasgow Coma Scale score			
15	19.7		
<15	23.5	0.21 (0.12)	0.09

*Adjusted means of length of hospitalization and parameter estimates are generated by the general linear regression model including comorbidity, age and Injury Severity Score.
†Compared with baseline category.
SD = standard deviation.

Table 3

Mean additional length of stay (LOS) attributed to presence of comorbidity by age groups and injury severity

Injury Severity Score	Age, yr; mean LOS, d				
	14–54	55–64	65–74	75–84	85–100
1–8	2.06	2.32	3.80	6.07	6.96
9–15	3.69	4.17	6.80	10.87	12.46
16–24	8.35	9.42	15.38	24.59	28.18
25–40	14.42	16.26	26.54	42.44	48.64
41–50	25.04	28.23	46.10	73.70	84.47

Predicted values were generated from the general linear regression model presented in Table 2.

Discussion

The pattern of trauma has changed in recent years with an increase in the geriatric trauma population.[2] The association between age and death in trauma is well documented.[2,3,5,6,10,17,20,29–33] However, even if the association between age and increased costs has been demonstrated,[10–16] it has not been described in detail.

We wanted to evaluate the possible independent and additional contribution of comorbidity over other factors used in the Trauma and Injury Severity Score (TRISS) system. LOS has been used as a proxy to hospital costs[13,17,20,33–36] as this information is difficult to evaluate in our health care context. Although LOS is not a perfect reflection of costs,[37,38] it remains a useful indicator of resource use in trauma,[23] but intensive care unit use and duration of stay, and types and number of procedures would also be useful.

For 1 year we identified and reviewed all records individually to ensure completeness of information. In such a case, there is a possible bias toward more complete information in patients with a longer LOS. However, we tried to adhere to the strict definitions in the methods section to minimize this possibility. We also used categories of ISS as suggested[27] since this variable is not strictly continuous in nature. We eliminated nonsurvivors in the analysis of factors associated with hospital LOS. The shorter LOS due to death in these patients would have falsely diminished the parameter estimates had they been included in the regression models.

Information on comorbid conditions had to be collected directly from patients' medical files since these are not included in our trauma registry.[39] This information is also inconsistently collected in other databases.[17,21,35,40] Comorbid conditions investigated in this study are those reported as associated with a worse outcome in trauma, namely pulmonary disease, cardiac disease, diabetes, coagulopathy, neurologic disease, hepatic insufficiency, chronic renal insufficiency and cancer.[3,6,17,18,20,21,29,31,33,41,42] Hypertension and psychiatric diseases are specifically associated with longer hospitalization.[2] In this study, only pulmonary and neurologic diseases reached statistical significance. However, the presence of any comorbidity significantly increased the predicted LOS for any level of age and ISS. Moreover, this study identified a cumulative effect of the number of comorbid conditions.

Trauma registries are used for both trauma research and resource planning.[43–46] We have demonstrated that the presence of comorbidy is independently related to LOS and is therefore an important factor in case-mix control when comparing populations in trauma research. Our findings also imply that comorbidity influences resource needs.[9] This study underlines, therefore, the importance of systematically recording information on all comorbid conditions in trauma registries. Future research should study further the effect of comorbidity on different trauma outcome indicators.

Conclusions

This study demonstrates that age and comorbidity are independent predictors of LOS and consequently may influence hospital costs. The increase in LOS is beyond that which is expected given the severity of injuries and the patients' age groups. Information on comorbid conditions should be collected in trauma registries because of the potential impact on future resource utilization in trauma centres. Both age and comorbidity should be considered essential parameters for case-mix control in trauma research.

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