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ORIGINAL ARTICLE

Factors affecting recovery during the first 6 months after hip fracture, using the decision tree model

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Abstract

Summary Pelvic fractures are one of the most common orthopedic problems that can reduce the quality of life in the elderly. In this prospective study, we found that osteoporosis, depression, and socioeconomic status were the most important factors associated with patients' recovery during the first 6 months after pelvic fracture.

Purpose Hip fractures are one of the most common orthopedic problems that can reduce the quality of life in the elderly. Considering that, we aimed to provide a comprehensive assessment of the factors affecting recovery during the first 6 months after hip fracture.

Methods All patients with hip fracture admitted to any of the orthopedic hospitals during July 10, 2011 to July 9, 2012 in Shiraz, Iran were included in this prospective cohort study. Patients' demographic data and also information regarding their performance and mobility after hip fracture was collected in two interviews at intervals of 6 months. All analyses were done in R software and mostly by party packages and PCAmixdata package. Tree and forest models of conditional inference were used to evaluate the factors affecting the recovery after hip fracture.

Results Two hundred sixty-six out of 514 patients (51.75%) with hip fracture recovered completely after a 6-month follow-up period. Osteoporosis, new-onset depression after hip fracture, and socioeconomic status (SES) were the most important predictors of patients' mobility status 6 months after hip fracture. In identifying predictor variables, the conditional inference forest method provided a more appropriate fit for the data than the conditional inference tree.

Conclusions Awareness of the factors that affect patients' recovery can be helpful in improving the patients' health, as well as improving care services, thereby increasing the success of treatment. Osteoporosis, new-onset depression after hip fracture, and SES were the most important factors associated with patients' recovery. Therefore, focusing on these variables is essential.

Keywords Hip fractures · Follow-up studies · Decision tree model · Iran

Introduction

Proximal femoral fracture or hip fracture is one of the most common orthopedic problems [1, 2]. These fractures are among the most common causes of hospitalization in developed countries [3]. According to an estimation in 2000, there were about 1.6 million hip fractures around the world, which is estimated to increase to 6.3 million by 2050, due to an increase in life expectancy and an increase in the number of elderly people [4]. Hip fracture is a significant injury that can lead to an increase in risk of mortality, reduced or loss of mobility, and serious effects on the health and quality of life of individuals [2, 5]. These fractures usually occur in elderly people and those who have already been exposed to medical problems [1, 6, 7].

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As a result of high prevalence of hip fracture in elderly people, it is considered as an important medical and social problem. Most people agree that surgery is the preferred treatment to reduce the mortality of these patients after injury. Surgery will also provide effective and functional results for the remaining years of life [8].

Despite the effectiveness of surgery in treating these patients, evidence suggests that returning to optimal postoperative levels is not entirely dependent on the type of surgery and the pre-existing conditions or complications after the operation [1]. According to previous studies, the death rate during the first month after hip fracture was 13.3%, and the 6-month mortality rate was generally 19%, although this increase from 16 to 25% was found over time [4, 9]. In general, in the early months of the fracture, there is a higher rate of mortality, but this decreases in subsequent months [4, 10].

Prognostic factors for hip fracture are very different in different studies [8]. Several factors such as age, pre-accident functional status, cognitive status, weight bearing after surgery, and rehabilitation after discharge, affect the recovery of post-traumatic injury [11].

Studies have shown that stroke, depression, and cognitive and neurological disorders have a negative effect on hip fracture rehabilitation [1]. In developing countries, life expectancy is rising; therefore, bone fractures need to be given more attention [12].

The incidence of hip fractures varies widely across different countries [13]. In a study conducted between 2011 and 2012 in the city of Shiraz, one of Iran's southern cities, the age-standardized incidence of the hip fracture (standardized according to the population of white Americans in 2000) for the total population was equal to 79.55 per 100,000 people [12].

Considering that the Iranian population, as in most other countries, is growing and aging, this can affect the trend of hip fractures; it is, therefore, important to study the factors affecting the mobility of patients with hip fracture and determine which factors are most important indicators in the recovery of these patients. Therefore, the aim of this study was to provide a comprehensive assessment of the factors affecting the recovery during the first 6 months after hip fracture.

Methods and materials

This study was a prospective cohort study of hip fracture recovery. All patients with hip fractures, who were admitted to any of the hospitals providing orthopedic services in Shiraz, were included in the study. Inclusion criteria were having any type of non-pathologic hip fracture due to mild trauma, being alive, and hospitalized between the period from July 10, 2011 to July 9, 2012, age 50 and above, as well as the satisfaction of the patient or his companions to participate in the study. In this study, patient death was considered as an exclusion criterion.

After receiving approval from the ethics committee of Health Policy Research Center affiliated to Shiraz University of Medical Sciences, data were collected through two interviews conducted at intervals of 6 months by two trained interviewers. The first interview was directed face-to-face and took place at the time of the patient's admission to the hospital. Interviews were conducted at the bedside if the patient agreed to participate. Three phone numbers were requested from the patient/ interviewee to be followed up in 6 months. Hence, the second interview was conducted over the phone 6 months after the date of the hip fracture. In order to conduct the second interview, if contact with the patient was not successful at first, they were contacted three times at different times, and if the contact was again unsuccessful, the patient was excluded from the study. Besides, those who decline to be interviewed were excluded.

The first checklist filled during the patients' hospital admission included two parts: demographic, clinical information and his/her living status. Clinical information comprised the patient's past medical history, medication history, and substance use. Medication history of the patient was verified by a physician and hospital admission records. The patients' living status information consisted of physical activity, where the patient lived (lonely at home, with a family member, or nursing home) and mobility status (from completely dependent to bed to walking normally). The second interview was directed based on the checklist consisted of 8 subjects including the patient's lifestyle as well as his/her ability to perform daily activities, postoperative mobilization status, history of re-fracture, infections, depression (confirmed by a physician), physiotherapy rehabilitation, and being treated for osteoporosis. The dependent variable was the functional mobility of the patient during the past 6 months, which was considered as a ranking variable. Accordingly, the rankings from small to large indicated that there was no remarkable problem while walking or climbing the stairs, having difficulty walking on smooth and uneven surfaces, moving with help of walkers or relatives, and ultimately hospitalization or being dependent to the bed. This question was also asked in the first phase of the study; accordingly, those patients who reported the same or better functional mobility were considered as those who recovered hip fracture completely.

After collecting data and importing data into the software, all analyses were performed in R software, mostly by party packages and PCAmixdata. In order to identify the factors, influenced the patients' recovery, which were measured in a ranked manner, tree and forest models of conditional inference were used [14]. The reasons for choosing these methods are ease of understanding the model due to their prominent visual intuition and their dramatic ability to identify unbiased variables that affect the mass of variables provided by the

conditional tree and forest, respectively [15]. By using a conditional inference forest model, there is no limitation in the number of predictive variables entered into the model. Hence, the model is fitted by using all suspected effective variables simultaneously and will determine the real determinant factors of the desired outcome.

Since these methods are among the methods of machine learning, therefore, similar to all learning algorithms, they are prone to over fitting. Thus, in order to prevent the overestimation of the prediction accuracy of the models, the data was divided into two train and test sets with ratios of 63.2% and 36.8%, respectively [15, 16]. Variable importance measurement was performed based on Gini index [17]. The criteria used to evaluate the fitness of models were accuracy in prediction and Brier scour error.

As the patients' socioeconomic status was estimated through 24 variables including both quantitative and qualitative measurements, the mixed-PCA method was used to combine them and extract a unified index indicating socioeconomic condition. It is worth noting that this method applied multiple correspondence analysis (MCA) in addition to ordinary principal component analysis (PCA) [18].

Results

Five hundred fourteen out of 631 patients who experienced hip fracture from July 10, 2011 to July 9, 2012 accepted to participate in this study. The findings showed that 266 (51.75%) patients had completely improved after 6 months. The prevalence of osteoporosis and new-onset depression after hip fracture, among patients was 416 (80.93%) and 171 (33.26%), respectively. Overall, the prevalence of osteoporosis in patients who did not recover was 232 (93.54%) and significantly decreased mobility in these patients ($P < 0.001$). Findings showed that osteoporosis and depression caused a 36-fold and 18-fold increase in the risk of failure in patients with hip fracture. The mean and mode age of patients in this study were 74.93 ± 11.45 and 77 years, respectively, which were also factors influencing the motor ability of the patients ($P < 0.001$).

The two factors of socioeconomic status of patients and their calcium intake significantly influenced fracture improvement (significant levels were 0.047 and 0.031, respectively).

In this study, we used machine learning methods such as conditional inference tree and conditional inference method to investigate the factors influencing patients' recovery. Figure 1 shows the fitting of the conditional inference tree on the information of patients with hip fracture. A conditional inference tree consists of several nodes, which divide the patients based on different variables. Based on this learning algorithm, first osteoporosis and secondly depression are the most important factors that can predict the patient's recovery. As outlined in leaf No. 11 in Diagram 1, about 95% of patients who have not had osteoporosis and depression have completely improved. Age and socioeconomic factors were also effective in predicting the condition of the patients. The conditional inference tree determined the points 71 and 50 to distinguish patients based on age and socioeconomic factors, respectively. The difference in the recovery rate of patients in different leaves (especially in leaves 4 and 11) showed well the ability of trees to differentiate patients based on their level and recovery rate, which was confirmed by the chi-square test ($P < 0.001$).

Factors that have been identified using the forest algorithm of conditional inference to be effective on patient's recovery were osteoporosis, depression, socioeconomic status, infection, exercise, overweight, duration of each patient for sitting tasks, smoking, calcium intake, cardio and cerebrovascular diseases, and patients' age. In the conditional inference forest method, the model is fitted each time with and without a particular variable, and the model error difference is measured in these two modes. The index that measures this model error is called the Gini index. Any variable that reduces most of the Gini index is more important in predicting the model. Figure 2 shows the statistically significant variables in order of estimated values. In other words, it could be deduced that by controlling these variables, a better rate of recovery from hip fracture would result. According to the forest algorithm, 74.78% of predicted patient recovery status is possible only with the use of osteoporosis (43.77%) and depression (31.01%) variables that were identified as the most important variables in this method. This means that these two variables are the most important factors in predicting patient's recovery. Socioeconomic status with 8.49% and infection with 2.77% decrease in Gini index were the third and fourth important factor in predicting the outcome. Although exercise with 1.51% and overweight with 1.38% decrease in Gini index were predictors of patient's recovery, their contribution was small. Other factors like watching TV, opium use, calcium intake, cerebro and cardiovascular diseases, and age had less than 1% contribution in outcome prediction.

The results of the comparison of fitness and the ability to predict the conditional inference tree and forest prediction algorithms are summarized in Table 1. Comparisons showed that in both train and test sets, the forest method had more predictive accuracy and less predictive error. Hence, based on these two good-fitness indicators, the conditional inference forest provided a better fit for data. In comparison to the fittings, for both algorithms, the training set was more accurate and had less error than the test set, although the observed differences in these two sets were negligible and could be neglected.

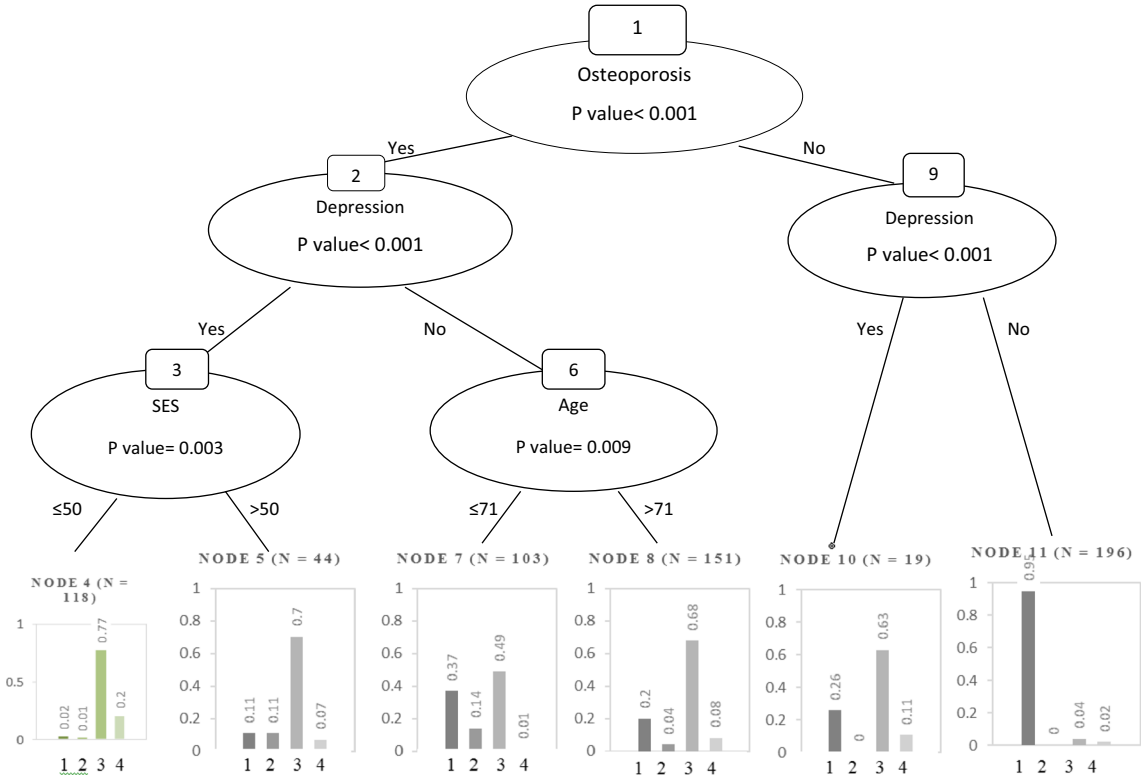

Fig. 1 Conditional inference tree for distinguishing patients based on the failure rate of pelvic bone fracture

Discussion

In this study, of all patients with hip fracture, 43% were completely recovered after 6 months. The factors influencing the recovery were osteoporosis, depression, socioeconomic status, infection, exercise, overweight, the duration each patient spends while doing sitting tasks, smoking, calcium intake, cardiovascular status, and ultimately the age. Osteoporosis and depression were the most important factors that predicted patients' recovery. Prediction of about two-thirds of patients' recovery status was possible using osteoporosis and depression, which indicated the importance of these two variables.

As stated, osteoporosis and depression were the most important factors affecting the recovery after hip fracture. The importance of osteoporosis in other studies has also been confirmed [10]. For example, findings of a study showed that athletes with more physical activity had higher bone density than others and thus experienced hip fractures at older ages and also had a better recovery after hip fracture [19]. In the present study, the depression variable was a combination of several questions that eventually determined the individual's status. Depression had a negative effect on patients' recovery. Other studies also showed that the more severe the depression and cognitive impairment, it is associated with a weaker and slower recovery and rehabilitation after hip fracture [20]. In another study that investigated the relationship between depression and hip fracture, depression was predictive of hip fracture, and even after the adjustment for some variables (such as age, gender, physical activity level), depression continued to play a predicting role in improvement and recovery [21].

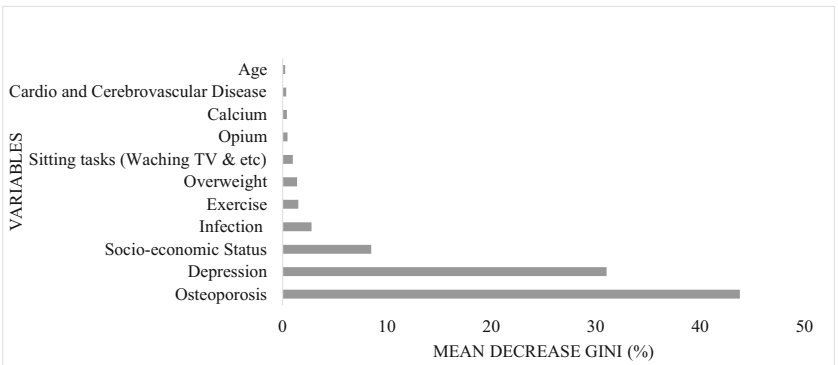

Fig. 2 Determination of variable importance in prediction of recovery rate from pelvic fracture using conditional inference forest

Table 1 The results of comparing the fitness of conditional inference tree and forest train and test data sets

Model	Accuracy		Brier score	
	Train	Test	Train	Test
Conditional tree	0.88	0.86	0.12	0.13
Conditional forest	0.89	0.87	0.08	0.09

According to our findings, the socioeconomic status in other studies was also recognized as one of the important factors in the incidence and status of the improvement of hip fractures. Studies have shown that people with higher incomes have a lower incidence of fracture and also the socioeconomic status significantly affected the discharge of people after fracture [9, 22]. In another study, the variables of employment, household income, and type of housing were presented as risk scores for hip fracture [23].

In contrast to the study by Folbert et al. [10] that urinary tract infections had been investigated and these infections had no significant effect on hip fracture recovery, the effect of infection on the recovery process was also significant in the present study. One of the possible reasons for this is the fact that in our study, in addition to urinary tract infections, the effects of other infections have also been studied. The results of this study also showed that calcium intake significantly affected the hip fracture recovery process, which was not far from expected due to inadequate calcium intake in Iranian men and women [24]. Moreover, adequate calcium and vitamin D intake can reduce the risk of hip fracture by 21% [24].

Age was also one of the important predictors in patients' recovery in this study, which is in line with the results of other studies [4]. In a study that was performed on patients with hip fracture, the increase in age was associated with a significant increase in the chance of difficulty during the treatment period after hip fracture [10]. According to the results of studies, the increase in age was also significantly effective in increasing the costs and duration of hospitalization of patients with hip fracture [2].

One of the strengths of this study is that the present study is the first study in Iran that evaluates risk factors in all patients with hip fracture. Therefore, it may be possible to use the identified risk factors for national assessment and research, although this requires further research on patients in other areas of the country to confirm these results. Another strength of this study was the use of machine learning methods such as conditional inference tree and conditional inference forest in order to find new variables that have been used less frequently in other studies. One of the benefits of these methods is that important variables could be selected among many variables.

A 6-month follow-up period was a limitation for this study. Based on recommendations of the previous studies, a 1-year follow-up might be better. So, in future studies, this issue can also be addressed.

To conclude, the complete recovery rate after hip fracture with a 6-month follow-up was 43%, which is low. Therefore, it is necessary for measures to be taken to improve the condition of these patients. Awareness of the factors that affect patients' recovery and mobility can be helpful in improving the patients' health, as well as improving care services, thereby increasing the success of treatment. Based on the results of this study, osteoporosis, depression, and socioeconomic status were the most important factors associated with patients' recovery. Therefore, focusing on these variables as well as other identified variables can influence the improvement of the condition and even the quality of life of these patients.

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Compliance with ethical standards

Conflict of interest None.

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