The Elders Risk Assessment Index, an Electronic Administrative Database–Derived Frailty Index, Can Identify Risk of Hip Fracture in a Cohort of Community-Dwelling Adults

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Abstract

Objective: To determine whether an Elders Risk Assessment (ERA) index can predict incident hip fractures without the need for physician-patient encounter or bone mineral density testing.

Patients and Methods: A retrospective cohort study was conducted in a community-based cohort of 12,650 patients aged 60 years and older. An ERA score was computed for each subject at index time (January 1, 2005). Incidents of hip fracture from January 1, 2005, through December 31, 2006, were obtained from electronic medical records. We divided the cohort into 5 groups, with the lowest ERA scores forming group A (<15%); 15% to 49%, group B; 50% to 74%, group C; 75% to 89%, group D; and the top 11%, group E. With group A as a reference group, we used logistic regression to compute odds ratios of sustaining hip fracture during a 2-year period (January 1, 2005, through December 31, 2006) for groups B, C, D, and E. Sensitivity and specificity of each possible ERA score were calculated, and a receiver operating characteristic curve was created.

Results: Two hundred sixty-five patients (2.1%) sustained at least 1 hip fracture from January 1, 2005, through December 31, 2006. Odds ratios (95% confidence intervals) for groups B, C, D, and E were 1.6 (0.7-3.4), 4.5 (2.2-9.4), 6.9 (3.3-14.3), and 18.4 (8.9-37.9), respectively. The area under the receiver operating characteristic curve was 74.5%.

Conclusion: An electronic medical record–based, easily derived ERA index might be useful in hip fracture risk stratification.

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Although there has been a decline in incident hip fractures over the past decade in North America,^{1,2} hip fractures continue to be one of the most serious medical events geriatric patients might experience. A hip fracture greatly affects the quality of life for patients and their families, and it considerably increases patients' morbidity. After sustaining a hip fracture, the odds ratio (OR) for a subsequent hospitalization is 3.31 (95% confidence interval [CI], 2.64-4.15).³ There is also a substantial increase in mortality after a hip fracture.⁴ In the first 3 months after a hip fracture, the mortality relative hazard is 5.75 (95% CI, 4.94-6.67) for women and 7.95 (95% CI, 6.13-10.30) for men.⁵ Fifty-eight percent of patients need placement in a skilled nursing facility at the time of dismissal from hospitalization for a hip fracture.⁶ One year after surviving a hip fracture, approximately 50% of patients have a walking disability,⁷ and only 40% independently perform all activities of daily living.⁸ Predicting the risk of hip fracture in the primary care setting is vital, both for physicians to make appropriate recommendations and for patients to make informed decisions about management.

Traditionally, femoral neck bone mineral density (FNBMD) has been the cornerstone of hip fracture risk stratification. Although FNBMD is easily applicable, it is not optimal because it requires performing a radiology test but ignores other known risk factors for hip fracture (primarily fall risks). In essence, FNBMD places patients into 2 risk groups: patients with or without osteoporosis. Other methods for predicting hip fractures, such as the Fracture Risk Assessment (FRAX), have used bone mineral density scores in combination with other selected risk factors, including several demographic characteristics and illnesses.^{9,10} Although these methods are more inclusive than FNBMD alone, they still require bone mineral density testing and may require time for the physician to interview the patient and apply the tool.^{10,11} There are inherent challenges with implementing ongoing screening programs designed to identify elderly patients with a high risk of hip fracture in the community. The health care system already faces considerable challenges with resource shortages and extreme care demands. Testing for FNBMD would considerably add to the cost of health care delivery when we consider the whole population. The physician time required to apply a

risk stratification tool may pose additional limitation in a time-strained primary care practice setting. Providing an innovative risk stratification tool that saves on health care expenses and physician time would be very valuable and relevant to current challenges of the health care system. What is currently unknown is the utility of an administrative data index system to help predict possible hip fracture. To answer this question, we proposed using the Elders Risk Assessment (ERA) index, which is a universal scoring system that predicts hospitalization and emergency department visits in adults older than 60 years of age in a primary care practice.¹² The ERA index has been implemented in the daily practice within the Primary Care Internal Medicine (PCIM) division at Mayo Clinic in Rochester, Minnesota. At each patient-physician encounter, an ERA score is automatically computed using a software program without any intervention from the physician.¹² We used a retrospective cohort study, stratified by the ERA scores, and examined incident hip fractures. We hypothesized that a higher ERA score indicates a higher risk for sustaining hip fracture.

PATIENTS AND METHODS

Study Design

This was a community-based retrospective cohort study of community-dwelling older adults. This study was reviewed and approved by the Institutional Review Board at Mayo Clinic. All of the research was conducted using the ethical principles of the Declaration of Helsinki.

Setting

The study cohort consisted of all patients 60 years of age and older who were enrolled in the PCIM division at Mayo Clinic in Rochester, Minnesota, on the conception day of January 1, 2005. The PCIM division is a mixed internal medicine and geriatric outpatient practice that serves residents of Olmsted County. Olmsted County has a population of 144,248, with 86% white, 5% Asian, 5% African American, and 4% Hispanic proportions.¹³ With the exception of a higher proportion of health industry employees, the population of Olmsted County represents the American white population.

Participants and Inclusion and Exclusion Criteria

Patients were identified via the electronic medical record (EMR) system. Record-keeping at the PCIM division is entirely computerized, and the EMR provides a complete list of all followed cases. By inclusion criteria, all research patients were 60 years of age or older and were community dwelling or lived

in an assisted living facility on January 1, 2005. Participants were excluded if they resided in a skilled nursing facility on January 1, 2005, or gave no consent for medical record review.

Outcome Variable

The outcome was defined as sustaining 1 or more hip fractures within the follow-up period (January 1, 2005, through December 31, 2006). The diagnosis of hip fracture was made by medical physicians during care encounters and documented in the EMR and/or billed as a hip fracture. The clinical identification of hip fracture was based on the *International Classification of Diseases, Ninth Revision (ICD-9)* and the hospital adaptation of the *International Classification of Diseases* adapted billing codes. Hip fracture frequently comes to medical attention because of the pain associated with weight bearing.

Independent Variable

The ERA index was chosen to be the independent variable in our analysis. An ERA score was calculated for each patient included in the study cohort as of January 1, 2005. The ERA index is a risk stratification instrument that uses several risk factors—age, marital status, hospitalization in the past 2 years, and history of diabetes, heart disease, stroke, emphysema, cancer (excluding nonmelanomatous skin cancer), and dementia—to calculate a total score for each patient.¹² With a score range of −1 to 32, the ERA index was found to predict the number of hospitalizations and emergency department visits in the subsequent 2 years in this cohort of patients.

Data Collection

All variables, including the demographic information and comorbid conditions of the ERA index and incident hip fracture in the subsequent 2 years, were abstracted electronically from the EMR and the patient registration databases of Mayo Clinic's medical record system. The EMR includes care delivered at the hospital, emergency department, nursing home, and outpatient clinic. Most factors were classified as having occurred or did not occur, including the outcome variable of hip fracture, as outlined. No individual chart abstraction was performed.

Statistical Analyses

Mean $\pm$ SD and frequency (percentage) were used to summarize the data. All risk factors were compared between the group with hip fractures in 2 years vs the group without by either a Pearson χ^2 test or a 2-sample *t* test. Afterward, ERA scores were

computed for each subject at the index time of enrollment. We divided the cohort into 5 groups, using the ERA scores, with the lowest percentile scores forming group A (<15%); 15% to 49%, group B; 50% to 74%, group C; 75% to 89%, group D; and the highest 11%, group E. We used a logistic regression model that included groups B, C, D, and E, with the lowest scoring group as the reference group. We computed the OR with 95% CI of sustaining hip fracture for each of these groups using multiple logistic regression analyses.

The sensitivity and specificity of predicting hip fracture at each possible ERA cutoff score were calculated. A receiver operating characteristic (ROC) curve was plotted and the area under the curve was obtained. We identified the best cutoff point by using the ERA score that provided the highest sum of sensitivity and specificity. All information was electronically retrieved from clinic databases and converted to Microsoft Excel spreadsheets, version 2003 (Microsoft, Redmond, WA), and SAS version 9.2 software (SAS Institute Inc, Cary, NC) was used for all statistical analyses.

RESULTS

On January 1, 2005, 13,457 patients 60 years of age or older were enrolled in the PCIM practice and eligible for study enrollment. Eight hundred seven patients (6%) did not agree to medical record review, which led to a total study cohort of 12,650 patients (94%) who met inclusion criteria. ERA scores ranged from -1 to 32, with patients in group A with an ERA score of -1, group B score 0 to 3, group C score 4 to 8, group D score 9 to 15, and group E 16 and greater. A total of 265 patients (2.1%) sustained at least 1 hip fracture during the follow-up period (January 1, 2005, through December 31, 2006). Thus, we found a 2-year incidence of 2.1% of hip fracture in the overall cohort.

The comparison between the 265 patients with hip fracture and those without hip fracture is noted in Table 1. Patients with a hip fracture were older, more likely to be female, and less likely to be married. (Each subject was classified to be either "married" or "not married." "Not married" included single, divorced, or widowed.) They were also more likely to have a previous hip fracture, a previous fall,

TABLE 1. Comparison Between the Study Patients With and Without Hip Fracture Sustained in 2005-2006^{a,b}

Variable	Did not sustain hip fracture (n=12,385)	Sustained hip fracture (n=265)	P value
Age (y), mean $\pm$ SD	72.55 $\pm$ 8.76	81.4 $\pm$ 8.88	<.001
Sex			<.001
Female	7076 (57)	191 (72)	
Male	5309 (43)	74 (28)	
Married	8140 (66)	123 (46)	<.001
Hospitalized in 2003-2004	3415 (28)	140 (53)	<.001
No. of hospital days in 2003-2004, mean $\pm$ SD	2.02 $\pm$ 6.40	5.48 $\pm$ 8.85	<.001
Previous hip fracture	336 (3)	98 (37)	<.001
Cancer	2899 (23)	89 (34)	<.001
Diabetes	3014 (24)	68 (26)	.62
Stroke	1484 (12)	63 (24)	<.001
Fall	1431 (12)	86 (32)	<.001
COPD	1429 (12)	49 (18)	<.001
CAD/MI/CHF	3845 (31)	126 (48)	<.001
Cognitive impairment or dementia	1544 (12)	83 (31)	<.001
ERA score category			<.001
Group A (scores -1)	1718 (14)	8 (3)	
Group B (scores 0-3)	4400 (36)	33 (13)	
Group C (scores 4-8)	3096 (25)	66 (25)	
Group D (scores 9-15)	2079 (17)	66 (25)	
Group E (scores $\geq$ 16)	1092 (9)	9 (35)	

^aCAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; ERA = Elders Risk Assessment; MI = myocardial infarction.

^bValues are presented as No. (percentage) unless indicated otherwise.

and all comorbidities included in the ERA index except diabetes. (Comorbidities included in the ERA index are diabetes, heart disease, cancer, cerebrovascular disease, cognitive impairment, and emphysema.) Patients who sustained a hip fracture were more likely to have been hospitalized in the 2 years preceding the index date. Within the ERA score categories, patients with higher ERA scores sustained hip fractures with increased frequency. Of the 265 patients who sustained hip fractures, there were 8 patients in group A (3%), 33 in group B (13%), 66 in group C (25%), 66 in group D (25%), and 92 in group E (35%) (Figure 1). Using group A as the reference group in a logistic regression model, we found that patients in the highest risk group (group E) had an OR of 18.4 (95% CI, 8.9-37.9). Table 2 lists the ORs for all groups. Higher ERA scores resulted in significantly increased odds of hip fracture for groups C, D, and E.

The second aspect of our analysis included constructing the operating characteristics of the ERA for predicting hip fracture. We calculated specificity and sensitivity for each ERA score. We identified an ERA score of 4 to have the largest value of combined sensitivity (81%) and specificity (56%). We constructed a ROC. The area under the curve was 0.745 ± 0.015 (Figure 2).

DISCUSSION

This cohort study suggests that the ERA index, an EMR-derived scoring system, can be a valuable tool used to identify older adults at high risk of sustaining hip fracture, an outcome that can lead to considerable increase in morbidity, functional decline, and mortality.^{3,5,7} The OR for the highest scoring group compared with the lowest scoring group was 18.4 (95% CI, 8.9-37.9). Thirty-five percent of the patients who had a hip fracture in the following 2 years of observation were in the highest risk group. This finding can certainly impact clinical practice for physicians. Odds ratios for the top 3 scoring groups were statistically significant compared with the lowest scoring group. Regarding the individual ERA scores, the ROC curve in our analysis showed an area under the curve of 74.5%. Using a score of 4, we found an optimal combined sensitivity of 81% and specificity of 56%. Thus, in this cohort, patients with lower scores had less risk for hip fracture. Patients with higher scores had a substantial risk for hip fracture. The ERA index may be used to identify individuals who could benefit from further risk modification.

Often hip fracture is a part of a progressive frailty syndrome. We view frailty as a cascade that starts with several risk factors and progresses through a course of increased susceptibility to trauma, falls, and acute illnesses, which leads to

temporary or permanent loss of functional ability, institutionalization, and death. Hip fracture is one of the most important geriatric illnesses that can be a part of the frailty cascade. Investigators have found that frailty can predict the risk for hip fractures.¹⁴ Similarly, we found that an ERA frailty index can predict hip fracture in our study cohort. However, frailty indices usually require performing detailed physical evaluation that can be lengthy and impractical in a busy primary care setting. The novelty of this study is in integrating common administrative demographic and medical diagnoses into a risk stratification index that can predict hip fracture without the need to perform a detailed assessment. No current instrument is designed in such a fashion.

Although osteoporosis is one of the most important risk factors for hip fracture,¹⁵ at least one-third of hip fractures might occur in patients without osteoporosis.¹⁶ Several other factors are known to increase the risk for hip fracture, such as advanced age,¹⁷ region of the world,¹⁸ quadriceps weakness,¹⁹ low body mass index, postural instability,²⁰ previous fracture,²¹ female sex, and history of parent's hip fracture.²²⁻²⁵ Our study, similar to several previous studies, highlights the value of some of these risk factors in hip fracture risk stratification. An Australian study found that frailty-related risk factors such as advanced age, reduced weight, quadriceps weakness, and postural instability were each associated with increased risk of hip fracture.¹⁰ Similarly, our findings have shown that frailty and frailty risk factors are associated with hip fracture risk. The same Australian study reported that combining FNBMD with clinical risk factors, which include age, prior fracture, and falls, provided a nomogram that predicted the risk of sustaining hip fracture over a median follow-up period of 13 years with an area under the ROC curve of 85%.¹⁰ Our study demonstrated that the ERA index had a smaller area under the ROC curve, but the ERA predicted hip fracture

TABLE 2. Odds Ratios for All Groups

Subject groups	ERA score	Sustained hip fractures (No.)	OR (95% CI)	P value
Group A: <15th percentile	(-1)	8	Reference	
Group B: 15th-49th percentile	(0-3)	33	1.6 (0.7-3.4)	.24
Group C: 50th-74th percentile	(4-8)	66	4.5 (2.2-9.4)	<.001
Group D: 75th-89th percentile	(9-15)	66	6.9 (3.3-14.3)	<.001
Group E: ≥90th percentile	(16+)	92	18.4 (8.9-37.9)	<.001

CI = confidence interval; ERA = Elders Risk Assessment; OR = odds ratio.

risk over a shorter period of time and without the need for FNBMD. The ERA index is more appealing because it can be calculated for all older patients regardless of FNBMD status or application of standard frailty instruments.

Other studies of the frailty phenotype have confirmed its usefulness for hip fracture. The Fracture and Mortality (FRAMO) index is based on 4 risk factors (age 80 years or older, weight less than 60 kg, previous fracture, and the need to use arms to rise) and reported a higher risk of hip fracture for women who had 2 or more of these 4 risk factors with an OR of 7.5 (95% CI, 3.0-18.4).²⁰ The FRAMO index is simple and easy to apply, but in contrast to the ERA index, it was developed using an exclusive sample of women. It also requires a functional evaluation that may be difficult to implement in all patients. The binary outcome of FRAMO would result in an undesirable 2-category grouping that does not reflect the variability of hip fracture risk among different patients.

The World Health Organization has developed the FRAX algorithm from studying population-based cohorts from several countries.¹¹ FRAX is widely available, online, and free to use. FRAX integrates FNBMD and other risk factors to compute 10-year absolute risk of sustaining hip fracture. Although FRAX can be used without FNBMD, it is centered on this risk factor and based on the assumption that FNBMD value accounts for several other clinical risk factors that are not included in the index unless entered as a diagnosis of secondary osteoporosis.^{9,26} Although it may be possible to design a software program that integrates FRAX with EMRs to compute FRAX scores automatically, without such software, applying FRAX requires an active intervention from the health care team to calculate the score; thus, there is some risk that FRAX would not be universally used in time-strained primary care medical practice.

At our Primary Care Internal Medicine clinic, we use a software system called Generic Disease Management System (GDMS) that provides a real-time ERA score at each patient encounter. The

GDMS is a Web-based application developed by Mayo Clinic and the Netherlands-based Noader Foundation, which uses General Electric Web Services (General Electric, Fairfield, CT) and an MSQweb.net platform, to retrieve patient-relevant statistics such as vital signs, demographic information, previous diagnoses, allergies, previous radiology tests, and previous preventive services from different clinical information systems. The ERA score is now provided in the GDMS information sheet that is included in the rooming packet for each visit.¹²

The strengths of this study include the community-based nature of the cohort. Although the cohort was obtained from a single facility, the cohort included 94% of patients 60 years of age and older enrolled in one of the main primary care facilities within Olmsted County. The main strength of this study was revealing how readily EMRs can be used in an automatically administered tool such as the ERA index to identify patients at high risk of sustaining hip fracture.

Our study has limitations that bear some discussion. A selection bias with all patients receiving care at only one health system is a potential limitation. Although we cannot exclude selection bias, selecting our patients from a community-based primary care clinic rather than from a referral specialty practice setting has ameliorated a possible selection bias. Future validation of our findings in a population-based cohort would be the most trustworthy and unbiased approach.

The factors included in the ERA score calculation were previously entered in the EMR with the purpose of providing medical care by multiple physicians who were not aware of this study hypothesis. In addition, there is the possibility of missing or mis-

FIGURE 2. Operating characteristics of the Elders Risk Assessment (ERA) for predicting hip fracture.

coded information. It is also possible that some patients had received care from other physicians. All these limitations are inherent to retrospective cohort studies that use EMRs. However, the retrospective collection of risk factors from EMRs is what makes ERA an attractive and easily applied tool, a fact that was essential in this study hypothesis. Coding data might underestimate secondary diagnosis. However, other investigators have found that ICD-9 code administrative data usually matches chart diagnoses.²⁷

The ascertainment of sustaining a hip fracture and the possibility of some patients in our cohort having received care at other health care systems for an incident hip fracture might be viewed as another limitation. However, hip fracture is a diagnosis that frequently comes to medical attention given the pain and need for surgical intervention. There are only a few health care facilities in Olmsted County, and most of the orthopedic care is provided at Mayo Clinic.^{28,29} Moreover, searching EMRs that included primary care visits would likely have identified fractures that happened elsewhere as secondary diagnoses.

The population of Rochester, Minnesota, in 2005 reflects a strong Northern European influence and may not apply to different populations, and this limits the generalizability of this analysis.

Lastly, the analysis did not account for other known important risk factors, which are easy to abstract from EMR but not included in the ERA index, such as previous fractures and primary or secondary osteoporosis. Nonetheless, this study was an initial step in exploring the use of a scale derived from an EMR database in predicting risk of hip fracture. Future studies and EMR database analyses with the primary aim of creating a hip fracture risk stratification index are likely to provide a better tool.

CONCLUSION

An EMR-based, electronically computed frailty index, the ERA index, was a useful tool in identifying elderly patients at risk for sustaining hip fracture within our study cohort. Future studies are needed to validate the ERA prospectively in other cohorts and to compare the index with other hip fracture risk stratification tools. This study has revealed the potential of using an EMR database in creating a risk stratification tool that may save physician time and health system money. Similar uses of EMR databases should be further explored in future studies.

Abbreviations and Acronyms: CI = confidence interval; EMR = electronic medical record; ERA = Elders Risk Assessment; FNBMD = femoral neck bone mineral density; FRAMO = Fracture and Mortality; FRAX = fracture risk assessment; GDMS = Generic Disease Management System; ICD-9 = International Classification of Diseases, Ninth Revision; OR = odds ratio; PCIM = Primary Care Internal Medicine; ROC = receiver operating characteristic

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REFERENCES

- Gehlbach SH, Avrunin JS, Puleo E. Trends in hospital care for hip fractures. *Osteoporos Int*. 2007;18(5):585-591.
- Melton LJ III, Atkinson EJ, Madhok R. Downturn in hip fracture incidence. *Public Health Rep*. 1996;111(2):146-150; discussion 151.
- Wolinsky FD, Fitzgerald JF, Stump TE. The effect of hip fracture on mortality, hospitalization, and functional status: a prospective study. *Am J Public Health*. 1997;87(3):398-403.
- Center JR, Nguyen TV, Schneider D, Sambrook PN, Eisman JA. Mortality after all major types of osteoporotic fracture in men and women: an observational study. *Lancet*. 1999;353(9156):878-882.
- Haentjens P, Magaziner J, Colon-Emeric CS, et al. Meta-analysis: excess mortality after hip fracture among older women and men. *Ann Intern Med*. 2010;152(6):380-390.
- Bentler SE, Liu L, O'Brien M, et al. The aftermath of hip fracture: discharge placement, functional status change, and mortality. *Am J Epidemiol*. 2009;170(10):1290-1299.
- Magaziner J, Fredman L, Hawkes W, et al. Changes in functional status attributable to hip fracture: a comparison of hip fracture patients to community-dwelling aged. *Am J Epidemiol*. 2003;157(11):1023-1031.
- Magaziner J, Simonsick EM, Kashner TM, Hebel JR, Kenzora JE. Predictors of functional recovery one year following hospital discharge for hip fracture: a prospective study. *J Gerontol*. 1990;45(3):M101-M107.
- Kanis JA, Oden A, Johansson H, Borgström F, Ström O, McCloskey E. FRAX and its applications to clinical practice. *Bone*. 2009;44(5):734-743.
- Nguyen ND, Frost SA, Center JR, Eisman JA, Nguyen TV. Development of a nomogram for individualizing hip fracture risk in men and women. *Osteoporos Int*. 2007;18(8):1109-1117.
- FRAX® WHO Fracture Risk Assessment Tool. <http://www.shef.ac.uk/FRAX>. Accessed October 20, 2011.
- Crane SJ, Tung EE, Hanson GJ, Cha S, Chaudhry R, Takahashi PY. Use of an electronic administrative database to identify older community dwelling adults at high-risk for hospitalization or emergency department visits: the elders risk assessment index. *BMC Health Serv Res*. 2010;10:338.
- United States Census Bureau. 2010 Population Finder. <http://www.census.gov/popfinder>. Accessed October 20, 2011.
- Woods NF, LaCroix AZ, Gray SL, et al. Frailty: emergence and consequences in women aged 65 and older in the Women's Health Initiative Observational Study. *J Am Geriatr Soc*. 2005; 53(8):1321-1330.
- Johnell O, Kanis JA, Oden A, et al. Predictive value of BMD for hip and other fractures. *J Bone Miner Res*. 2005;20(7):1185-1194.

16. Schuit SC, van der Klift M, Weel AE, et al. Fracture incidence and association with bone mineral density in elderly men and women: the Rotterdam Study. *Bone*. 2004;34(1):195-202.
17. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. *Lancet*. 2002;359(9319):1761-1767.
18. Kanis JA, Johnell O, De Laet C, Jonsson B, Oden A, Ogelsby AK. International variations in hip fracture probabilities: implications for risk assessment. *J Bone Miner Res*. 2002;17(7):1237-1244.
19. Bensen R, Adachi JD, Papaioannou A, et al. Evaluation of easily measured risk factors in the prediction of osteoporotic fractures. *BMC Musculoskelet Disord*. 2005;6:47.
20. Albertsson DM, Mellstrom D, Petersson C, Eggertsen R. Validation of a 4-item score predicting hip fracture and mortality risk among elderly women. *Ann Fam Med*. 2007;5(1):48-56.
21. Kanis JA, Johnell O, De Laet C, et al. A meta-analysis of previous fracture and subsequent fracture risk. *Bone*. 2004;35(2):375-382.
22. Nguyen TV, Eisman JA, Kelly PJ, Sambrook PN. Risk factors for osteoporotic fractures in elderly men. *Am J Epidemiol*. 1996;144(3):255-263.
23. Kanis JA, Johansson H, Oden A, et al. A family history of fracture and fracture risk: a meta-analysis. *Bone*. 2004;35(5):1029-1037.
24. Nguyen ND, Pongchaiyakul C, Center JR, Eisman JA, Nguyen TV. Identification of high-risk individuals for hip fracture: a 14-year prospective study. *J Bone Miner Res*. 2005;20(11):1921-1928.
25. Kanis JA, Johnell O, Oden A, Jonsson B, Dawson A, Dere W. Risk of hip fracture derived from relative risks: an analysis applied to the population of Sweden. *Osteoporos Int*. 2000;11(2):120-127.
26. Kanis JA, Johnell O, Oden A, Johansson H, McCloskey E. FRAX and the assessment of fracture probability in men and women from the UK. *Osteoporos Int*. 2008;19(4):385-397.
27. Quan H, Parsons GA, Ghali WA. Validity of information on comorbidity derived from ICD-9-CCM administrative data. *Med Care*. 2002;40(8):675-685.
28. Melton LJ III, Crowson CS, O'Fallon WM. Fracture incidence in Olmsted County, Minnesota: comparison of urban with rural rates and changes in urban rates over time. *Osteoporos Int*. 1999;9(1):29-37.
29. Melton LJ III, Kearns AE, Atkinson EJ, et al. Secular trends in hip fracture incidence and recurrence. *Osteoporos Int*. 2009;20(5):687-694.