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Using Administrative Databases to Calculate Framingham Scores within a Large Healthcare Organization

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Abstract

Background and Purpose—Framingham calculators are typically implemented in one-on-one settings to determine if a patient has a high risk of developing cardiovascular disease in the next 10 years. Because health care administrative datasets are including more clinical information, we explored how well administrative data-derived Framingham scores could identify persons who would develop stroke in the following year.

Methods—Using a nested case-control design, we compared all 313 persons who developed a first time stroke at 5 VA Medical Centers with a random sample of 25,361 persons who did not develop a first-time stroke in 2008. We compared Framingham scores and risk using administrative data available at the end of 2007.

Results—Stroke cases had higher risk profile than controls: older age, higher systolic blood pressure and total cholesterol, and more likely to have diabetes, cardiovascular disease (CVD), left ventricular hypertrophy and be on treatment for blood pressure ($p<0.05$). The mean Framingham generalized CVD score (18.0 vs. 14.5) as well as the mean Framingham stroke specific score (13.2 vs. 10.2) was higher for stroke cases than controls (both $p<0.0001$). The c-statistic for the generalized CVD score was 0.68, 95% Confidence Interval (CI); 0.65–0.70 and for the stroke score was 0.64, 95% CI; 0.62–0.67.

Conclusions—Persons who develop a stroke in the following year have a worse Framingham risk profile, as determined by administrative data. Future studies should examine how to improve the stroke predictive tools and to identify the appropriate populations and uses for applying stroke risk predictive tools.

Keywords

Framingham calculator; stroke; administrative database

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Introduction

Stroke is the third leading cause of death and a major cause of disability in the United States.[1, 2] Because a prior history of stroke is the strongest predictor of a future stroke, interventions have rightly focused on secondary stroke prevention.[3, 4] Yet most of the 795,000 strokes that occur in the United States each year are first-time strokes.[2] If a health care organization can predict risk of first-time stroke using information available in its administrative database, then population-based strategies can be developed to prevent the occurrence of a first-time stroke.

Although several stroke risk calculators have been developed for predicting first-time stroke, they are typically employed in one-on-one physician-patient encounters, not in wide-spread population screening. Health care administrative datasets are starting to include sufficiently detailed clinical information to allow calculation of stroke risk. In this study, we investigated how well stroke calculators based on administrative data could identify persons who would develop a first-time stroke in the following year.

Methods

Data Source

The Veterans Administration (VA) Desert Pacific Healthcare Network otherwise known as Veterans Integrated Service Network (VISN) 22 encompasses 5 hospitals and 28 community-based clinics serving 1.2 million veterans residing in southern California and southern Nevada. VISN-22 provides research support through abstraction of electronic medical data from individual VA healthcare facilities through a data warehouse which makes data accessible to investigators for research purposes. The data warehouse has maintained database that includes separate files for patient demographics, outpatient clinic and inpatient utilization and diagnostic codes, vital signs, pharmacy utilization, laboratory data, as well as data on lifestyle habits, such as smoking and exercise since 2002. The database also contains admissions to non-VA hospitals if the VA reimburses those hospitals for the care delivered. The VA Greater Los Angeles Institutional Review Board granted approval for this study.

Study Design

A nested case-control design was used to compare all persons who developed a first-time stroke during fiscal year (FY) 2008 (October 1, 2007 to September 30, 2008) versus a random sample of persons who did not develop a first-time stroke in FY2008 (see Figure 1). Identification of stroke cases and other comorbid conditions used in computing stroke risk score were done using International Classification of Disease (ICD) codes for these conditions. Studies that have assessed the validity of information recorded in VA administrative databases using the ICD codes compared to information abstracted from original medical record have reported very high levels of agreement.[5–7]

Stroke cases were identified with the use of ICD codes of hemorrhagic stroke (430.xx, 431.xx) or ischemic stroke (433.x1, 434.x1, 436) assigned as the primary diagnosis upon hospital discharge. A history of stroke was identified using the above stroke codes or the code of late effect of stroke (438.x) assigned at inpatient or outpatient settings.

Cases were identified by a new stroke in FY2008. Persons were excluded if they also had a history of stroke prior to FY2008, as such persons would have suffered a recurrent stroke in FY2008. Persons were further excluded if they did not have a primary care visit in this VA network in FY2007 (October 1, 2006 to September 30, 2007) because we wanted to evaluate

the stroke calculator among persons who could have been potentially enrolled in a hypothetical stroke risk reduction program.

A comparison group was composed of a random sample of all persons who had a primary care visit within the network in FY2007. Persons were excluded if they were assigned a history of stroke up to the end of FY2007. Persons were further excluded if they developed a new stroke during FY2008 because such persons are already included as cases.

Obtaining data for components of the Framingham calculators Stroke risk calculators

The data warehouse contained information for every component of the Framingham cardiovascular disease (CVD) calculator [8] and the Framingham stroke calculators, [9] but not for other stroke calculators identified.[10–13] Therefore, for both cases and controls, we obtained all Framingham measurements of age, sex, systolic blood pressure (SBP), blood pressure treatment, total cholesterol, high density lipoprotein (HDL) cholesterol, and smoking status during the 12 month period of FY2007. When more than one SBP was available, the average of the last two outpatient SBP levels was used. When more than one cholesterol value was available, we used the latest one. Persons were designated to be a smoker if they had smoked anytime in the past year, in accordance with the VA definition of smoking.

We then identified whether persons were diagnosed with atrial fibrillation, cardiovascular disease, left ventricular hypertrophy (LVH), or diabetes using ICD codes assigned from 2002 to the end of FY2007. In the original Framingham study, left ventricular hypertrophy was diagnosed by electrocardiograms, but because such reports are not included in the data warehouse, ICD codes for LVH were used instead. For diabetes ascertainment, prescription of diabetes medications was used in addition to ICD codes, in accordance with the VA method for identifying patients with diabetes.

In addition, all other available components from other identified stroke calculators were abstracted from the data warehouse: diastolic blood pressure, body mass index, low density lipoprotein, alcohol use, cardiomyopathy, creatinine, estimated glomerular filtration rate, and chronic renal disease.

Analysis

We performed bivariate analyses to compare the stroke cases and the comparison group for all components of all calculators, including ones not fully used in this study. The Framingham calculators can be used either by calculating a score based on assigning points for each component or by calculating an exact 10-year risk based on equations supplied in the original manuscripts. In both methods missing SBP and cholesterol data were imputed using the normal values as presented in the 2008 generalized CVD calculator study.[8] Mann-Whitney tests and student t-tests were used to compare Framingham scores and risks, and 95% confidence intervals (CI) were calculated.

The c-statistic was used to quantify the ability of the calculators to discriminate between persons who did and did not develop a first-time stroke. The c-statistic represents the area under the receiver operating characteristic curve and varies between 0.50 (no discrimination) to a maximum of 1.00 (perfect discrimination). In addition, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using different cutoffs of Framingham generalized CVD 10-year risk in our sample after weighting our control group to represent the population from which the random sample was selected. The Framingham calculators were also used among a subset with age >55 years and again with a subset with SBP >160 mm Hg, as these subsets concentrate persons at higher risk. Analyses were performed using SAS, version 9 (SAS Institute Inc., Cary, NC).[14]

Two sensitivity analyses were performed. First, all persons with hemorrhagic stroke were excluded, and then the primary analyses were repeated on persons who develop ischemic stroke. Second, ICD codes of medical conditions were restricted to only FY2007 instead of from the inception of the data warehouse, and then the primary analyses were repeated.

Results

In FY 2008, of the 909 persons discharged with a stroke, 403 (44.3%) were recurrent strokes. Of the remaining 506 persons with first-time stroke in FY2008, 313 persons were receiving primary care in the network in FY2007. Of these stroke cases, 69 (22%) were admitted to a non-VA hospital. For the comparison group, there were 221,371 persons who had a primary care visit in FY2007. Excluding persons who had a history of stroke or who developed a first-time stroke in FY2008 reduced the number to 218,876 persons. A random sample of 25, 361 persons (11.6% random sample) served as the comparison group (Table 1).

The stroke cases had a higher risk profile than the comparison group on many components of the Framingham calculators: older age, predominantly male, higher SBP, higher total cholesterol, and more likely to have diabetes, CVD, LVH and be on treatment for blood pressure (all $p<0.05$, see Table 1). Among non-Framingham components, they were also more likely to have chronic renal disease and cardiomyopathy. Among stroke cases, 8% did not have a recorded SBP and 21% did not have a recorded cholesterol value in FY2007; among controls, 16% did not have a recorded SBP and 27% did not have a recorded cholesterol value in FY2007 (data not shown).

In Table 2, the mean Framingham generalized CVD score (18.0 vs. 14.5) as well as the mean Framingham stroke specific score (13.2 vs. 10.2) was higher for stroke cases than controls (both $p<0.0001$). The c-statistic for the generalized CVD score was 0.68, 95% CI; 0.65–0.70 and for the stroke score was 0.64, 95% CI; 0.62–0.67. The calculated 10-year risk using the generalized CVD calculator was also higher among stroke cases than controls (40% vs. 28%, $p<0.0001$) and a c-statistic of 0.67, 95% CI; 0.64–0.70.

In a sensitivity analysis, we excluded all 101 persons with hemorrhagic stroke (32%) and reran analyses to identify the 212 persons with ischemic stroke (Table 3). The c-statistics were similar to the primary analysis. After restricting data on medical conditions to only FY2007, we found the same c-statistic of 0.67 (0.62–0.69) using the calculated 10-year risk using the generalized CVD calculator Test properties of the Framingham generalized CVD calculator among different thresholds is shown in Table 4. Because the one-year incidence of first-time stroke was low, the PPV remained low even at the highest Framingham risk thresholds and among older persons and persons with elevated SBP.

Discussion

The major finding of this study was that it is feasible to generate Framingham scores on large number of persons using administrative databases. The mean Framingham score was high for many persons in the control group, but it was still significantly higher for persons who would develop a first-time stroke in the next year. Therefore, in addition to its current use for individual patients in one-on-one encounters with a health care provider, Framingham calculators can also be used for population-wide assessments by healthcare administrators.

Although the c-statistics reported in our study are comparable to c-statistics of other tools used in stroke care such as the ABCD2 score and the CHADS2 score,[15, 16] our results also demonstrate a low PPV because the ratio of cases to controls is low. It is important to

emphasize that in this application, the Framingham calculators are not being used as a diagnostic tool that guide use of more definitive tests, but instead used as a clinical prediction tool where no “gold standard” tool for stroke prediction exists. Therefore, a lower PPV and specificity may be an acceptable tradeoff in order to obtain high sensitivity in detecting first-time stroke in the near future, so that resources can be targeted to persons at highest risk.

Differences in the study population, surveillance method, and outcome criteria are three established reasons why prognostic indexes tested in a different population perform less well compared to the original derivation study.[17] First, our study sample consists of veterans who use the VA, who are predominantly male and have lower socioeconomic status and health status compared to the general population.[18] Low socioeconomic status was shown to be a predictor in the QRISK cardiovascular disease risk algorithm.[12] Therefore, it is likely that the Framingham calculator underestimates the risk for stroke in our population because it is more disadvantaged compared to the general population.[18] Second, the original Framingham cohort studies minimized missing data by making concerted efforts to collect data at all time points. In contrast, persons in our administrative dataset did not undergo as complete surveillance for medical conditions and likely possessed undiagnosed conditions that would have been detected if they were enrolled in a cohort study such as Framingham. By imputing normal values when they were missing, our calculations underestimate the actual cardiovascular risk for all persons. Third, we used administrative codes to identify the outcome variable, development of a first-time stroke. While this approach maximizes the efficiency and applicability of using such risk prediction tools, it will not be as accurate as a skilled clinician in identifying persons at risk for stroke, as was done in Framingham.[5–7] In addition, the data warehouse captures some but not all admissions to non-VA hospitals. One study reported that 76% of dually eligible Medicare and VA patients obtained care for their initial stroke at non-VA hospitals, [19] as a result not all veterans admitted to non-VA hospitals may have their data recorded in the data warehouse.

The study has several limitations. We did not have longitudinal data to examine outcomes beyond one year. In addition, as with all studies conducted in veteran populations, studies should also be conducted in non-veteran populations before determining whether findings are generalizable to that population. Identified stroke cases and data obtained for the components of the Framingham calculator from the VA administrative database used in this study were not validated by chart abstraction. However, many studies have assessed the validity of information recorded in VA administrative databases using the ICD codes compared to information abstracted from original medical record and reported very high levels of agreement.[5–7]

Regarding recommendations to future applications of stroke tools using administrative data, the discriminating abilities of the Framingham calculators was similar using the last year of data versus using the prior five years of data. The stroke-specific calculator (that includes atrial fibrillation but not cholesterol) performed similarly to the newer CVD calculator, so we believe that either calculator could be used. We will be exploring whether the discrimination of the Framingham calculators can be improved using other clinical data available in VA databases. However, novel markers such as C - reactive protein have not been shown to substantially improve upon the already very good discriminating properties of existing Framingham calculators.[20, 21]

Conclusions

Persons who develop a first-time stroke do have a significantly higher Framingham risk than controls based on administrative data available in the year prior to their stroke. While our

study shows that the proportion of persons who develop a stroke in the following year may be too low to be easily identified, the c-statistics of administrative data-derived Framingham scores appear satisfactory enough to attempt predicting a more common outcome, such as stroke in the following 10 years. As clinical datasets become more available, administrative data-derived Framingham scores should be further validated to determine their suitability in studies of population health.

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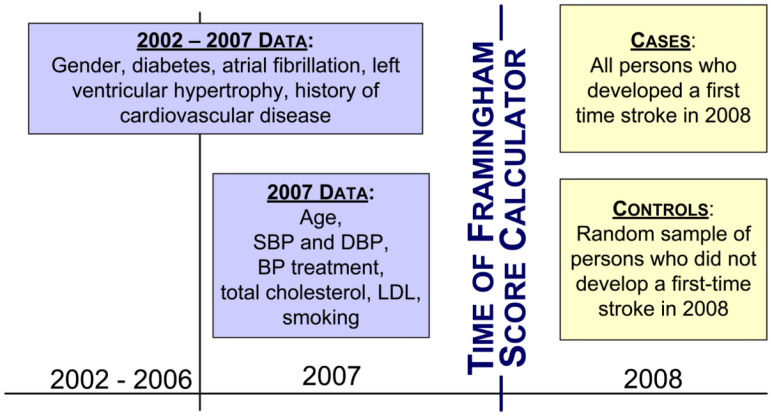

Figure.

Design of nested-case control study for analyzing how well Framingham calculators can identify patients who will develop first-time stroke in the following year.

In this study, all cases and controls have had a VA outpatient visit to a primary care provider in 2007.

TABLE 1

Characteristics of cases who developed a first-time stroke in 2008 and controls without a first-time stroke by 2008

	Developed first- time stroke (ischemic or hemorrhagic) in FY2008 N = 313	Did not develop first- time stroke by FY2008 N = 25,361*	p-value
Sociodemographics			
Age, Mean(SD)†	67.2 (11.8)	62.0 (14.9)	<0.0001
Male, %†	97.1	91.6	0.001
Smoking in the past year, % †	42.2	37.0	0.07
Physiologic measurements in 2007			
Systolic blood pressure, mean (SD), mm Hg †, §	138.1 (20.5)	129.8 (16.2)	<0.0001
Diastolic blood pressure, mean(SD), mm Hg §	13.2	10.9	<0.0001
Body mass index	29.0 (5.9)	29.3 (6.5)	0.38
Prescription of medication for BP, % †	76.7	61.0	<0.0001
Laboratory values in 2007			
Total cholesterol, mean (SD) mg/dL †	181.7 (48.9)	174.4 (42.4)	0.02
High-density lipoprotein, mean (SD), mg/dL †	41.4 (14.0)	42.3 (13.4)	0.21
Low-density lipoprotein cholesterol, mean (SD), mg/dL	111.6 (41.3)	103.9 (34.1)	0.005
Creatinine, mean (SD)	7.6 (31.7)	6.3 (29.8)	0.45
Glomerular filtration rate, mean (SD)	69.6 (26.7)	76.3 (24.6)	<0.0001
Diagnosis codes from 2002–2007			
Alcoholism, %	10.5	12.5	0.30
Atrial fibrillation, % †	10.5	8.7	0.25
Cardiomyopathy, %	4.8	2.5	0.01
Cardiovascular disease, % †	34.5	25.4	0.0002
Chronic renal disease, %	16.6	8.4	<0.0001
Diabetes, % †, ||	42.2	30.8	<0.0001
Left ventricular hypertrophy, % †	15.0	9.3	0.001

BP indicates, blood pressure; SD, standard deviation

*Weighted to represent 218,876 persons

†Component of the Framingham generalized cardiovascular disease or stroke calculator

§Average of the last two outpatient BP levels

||Diagnosis codes for diabetes or the use of diabetic medications

TABLE 2

Performance of Framingham calculators to identify first-time stroke

	Ischemic or hemorrhagic stroke in FY2008 N = 313	No Stroke FY2008 N = 25,361*	c-statistic (95% confidence interval)
Framingham generalized CVD calculator:			
Score, mean (SD)	18.0 (4.2)†	14.5 (5.9)	0.68 (0.65–0.70)
Estimated 10-year risk based on score§	>30%	21.6%	-
Calculated 10-year risk CVD, %	40.1%†	28.0%	0.67 (0.64–0.70)
Framingham stroke specific score, mean(SD)			
Score, mean (SD)	13.2 (6.1)†	10.2 (6.2)	0.64 (0.62–0.67)
Estimated 10-year stroke risk based on score§,‖	15.0%	10.0%	-

CVD indicates, cardiovascular disease; SD, standard deviation

*Weighted to represent 218,876 persons

†p<0.0001

§Based on information provided in the Framingham study[8,9]

‖Insufficient information to calculate the 10-year stroke risk[9]

TABLE 3

Performance of Framingham calculators to identify first-time ischemic stroke

	Ischemic stroke in FY2008 N = 212	No Stroke FY2008 N = 25,361*	c-statistic (95% confidence interval)
Framingham generalized CVD calculator:			
Score, mean (SD)	18.3 (4.2)†	14.5 (5.9)	0.69 (0.66–0.73)
Estimated 10-year risk based on score§	>30%	21.6%	-
Calculated 10-year risk CVD, %	41.4%†	28.0%	0.69 (0.65–0.72)
Framingham stroke specific score, mean(SD)			
Score, mean (SD)	13.6 (6.1)†	10.2 (6.2)	0.65 (0.63–0.69)
Estimated 10-year stroke risk based on score§, ‖	17.0%	10.0%	-

CVD indicates, cardiovascular disease; SD, standard deviation

*Weighted to represent 218,876 persons

†p<0.0001

§Based on information provided in the Framingham study[8,9]

‖Insufficient information to calculate the 10-year stroke risk[9]

TABLE 4

Performance of Framingham calculator among subsets of population

	Cases/weighted controls	c-statistic	Sensitivity	Specificity	PPV	NPV
Framingham generalized cardiovascular disease10-year risk, %						
>0	313/218,876	0.675	100.0	0.0	0.1	100.0
>10	297/178,486	0.628	94.9	18.5	0.2	100.0
>20	256/133,506	0.608	81.8	38.4	0.2	99.9
>30	196/90,265	0.617	62.6	58.8	0.2	99.9
>40	148/53,499	0.588	47.3	75.6	0.3	99.9
>50	97/29,352	0.572	31.0	86.6	0.3	99.9
Other cutoffs						
Age > 55 years	181/154,519	0.659	57.8	29.4	0.1	99.8
Systolic blood pressure > 160 mm Hg	29/6,982	0.540	9.3	96.8	0.4	99.9

BP indicates, blood pressure; NPV, negative predictive value; PPV, positive predictive value

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