Identifying Frail Older People Using Predictive Modeling

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Objectives: To determine whether a designation of frailty using the Adjusted Clinical Groups–diagnoses based computerized predictive model (ACG Dx-PM) can identify an elderly population who (1) have the clinical characteristics of frailty and (2) are frail as determined by the validated Vulnerable Elders Survey (VES), and to determine the ability of these tools to predict adverse outcomes.

Study Design: Secondary analysis of administrative and survey data.

Methods: Participants over age 65 years (n = 195) in an outpatient comprehensive geriatric assessment study at an Israeli health maintenance organization (HMO) were screened for frailty using the ACG Dx-PM and VES. Administrative and demographic data were also gathered.

Results: Compared with ACG nonfrail patients, ACG frail patients were older and less likely to be married; had a higher rate of falls, incontinence, and need for personal care; and had a poorer quality of life consistent with a clinical picture of frailty. The ACG frailty tag identified a frail population using the VES frailty determination as the accepted standard with moderate success (area under the curve 0.62). Adjusting for sex and functional status in backward logistic regression, the ACG frailty tag predicted hospitalizations (P <.032) and the VES frailty tool predicted emergency department visits (P <.016).

Conclusions: The ACG frailty tag identified an elderly population with clinical characteristics of frailty and performed with moderate success compared with the VES. Both tools predicted adverse outcomes in older HMO members. A combined screening approach for frailty using predictive modeling with a function-based survey deserves further study.

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For author information and disclosures, see end of text.

The growing population of older people living with multiple chronic conditions such as arthritis, hypertension, diabetes, and ischemic heart disease account for much of the American Medicare and Israeli healthcare budgets.[1,2] The Adjusted Clinical Groups–diagnoses based predictive model (ACG Dx-PM), which is part of the Johns Hopkins ACG Case Mix System, is a tool that analyzes health insurance enrollment records and diagnostic information from claims data to predict the intensity of a person's use of healthcare resources in the future. The ACG Dx-PM predictions for older people are based on age, sex, diagnostic codes, and pharmacy data if available. This tool is used by many organizations to efficiently identify older people with multiple chronic conditions (multimorbid patients) at high risk for substantial costs and use of healthcare resources in the future who are appropriate for care management programs.[3,4]

A major focus of geriatric care is the diagnosis, treatment, and prevention of frailty, rather than multimorbidity per se.[5] Frailty is a geriatric syndrome that overlaps with, but is distinct from, multimorbidity. Frail older people are at increased risk for adverse outcomes such as functional decline, falls, and incontinence, in addition to hospitalization and death.[6] While the ACG Dx-PM predictive tool can be used to identify older people with multimorbidity who are at risk for substantial future costs and use of healthcare resources, it is not known whether this predictive tool can also be used to identify older people who are appropriate for interventions that prevent, delay, or treat frailty.

To help identify this frail population, frailty diagnostic "clusters" have been introduced as a component of the ACG Dx-PM predictive modeling tool.[7] The elements of this frailty tag only partially encompass elements of existing and accepted frailty criteria.[8,9] In addition, most frailty definitions do not depend on the presence of only 1 cluster of diagnoses as in the ACG Dx-PM predictive modeling frailty tag, but describe a syndrome with multiple components and diagnoses.[10,11] The predictive ability of this frailty tag to identify a clinically frail population appropriate for interventions to prevent, delay, or reduce frailty and adverse outcomes has not been studied.

Using the database of an evaluative study of comprehensive geriatric assessment (CGA) clinics in Israel, the objective of the current study was to determine whether the ACG Dx-PM frailty tag (ACG frail) can identify elderly patients who (1) have the clinical characteristics of frailty and (2) are frail

as determined by a validated frailty survey. An additional objective was to determine the ability of these tools to predict adverse outcomes such as emergency department (ED) visits, hospitalization, and death.

Take-Away Points

Predictive modeling is an efficient method to identify frail older people appropriate for interventions to prevent adverse outcomes. Frailty, a focus of geriatric care, overlaps with but is a broader concept than multimorbidity.

- Frail older people are at increased risk for adverse outcomes such as hospitalization, death, and functional decline.
- Identifying frail older people appropriate for interventions to prevent or delay adverse outcomes is an important public health goal.
- Frailty determination using predictive modeling is an efficient method to identify this population. Combining this screening approach with a short functional survey merits further study.

METHODS

In the context of an ongoing study examining the processes and outcomes of CGA outpatient clinics in an Israeli health maintenance organization (HMO), data were collected prospectively on 221 consecutive older people who underwent CGA in any 1 of 5 geriatric clinics in 2008. All older people who received CGA were included in the study population. CGA, a multidisciplinary assessment and management intervention for older people, has been shown to prevent adverse outcomes such as functional decline in frail elderly persons.[12,13] The Myers Brookdale Institute and Maccabi Healthcare Services have recently completed an evaluative study of their CGA programs in Israel.[14] This study database provides a rich source of information on the demographic, medical, and functional characteristics of a population of elderly patients who underwent CGA in 2008. In addition, a frailty determination was made for each participant using the standardized Vulnerable Elders Survey (VES).[11] The study was approved by the institutional review board of Maccabi Healthcare Services. Data were collected from face-to-face interviews, medical record review, and the administrative databases of the HMO before and 1 year after CGA.

One study variable was a VES frailty score.[11] This survey is a 13-item function-based self-report questionnaire developed by the Rand Corporation and University of California–Los Angeles, and widely used to identify frail elderly people for quality improvement and disease management interventions. It asks older people to report their age, their ability to perform 6 physical and 5 functional activities, and their self-rated health. In the CGA study, the VES was administered by study personnel in face-to-face interviews; scores ranged from 0 (lowest risk) to 10 (highest risk), with scores of 3 and above indicating frailty (VES frail). The VES has been shown to predict functional decline, mortality, and healthcare services use.[15,16] Higher scores have been shown to reflect greater frailty.[17]

A second study variable was a frailty tag (ACG frail). This tag was assigned to participants who had a frailty diagnostic cluster by ACG-Dx-PM methodology.[7] Frailty diagnostic clusters included malnutrition, dementia, impaired vision, decubitus ulcer, incontinence of urine or feces, loss of weight, obesity, poverty, barriers to access of care, and difficulty walking. Having any one of the diagnostic clusters resulted in allocation of a frailty tag.

Health service utilization variables used to describe the study population were collected from the HMO administrative databases for 2008 (the year of CGA). These included number of physician visits in 3 months, number of ED visits in a year, and number of hospitalizations in the year. Health service utilization outcome variables collected from the HMO administrative databases for 2009 (the year after CGA) included number of ED visits in a year, number of hospitalizations, and mortality. These outcome variables were chosen in keeping with the existing literature and based on availability in the HMO database.[9,18] Data on functional status were not available in the HMO administrative databases and therefore could not be used as an outcome variable. Demographic, clinical, and social variables such as age, sex, chronic conditions, and marital status were also collected.

The study population consisted of 195 participants who had complete data on all variables.

Statistical Analyses

Demographic characteristics of the VES frail and ACG frail groups were described and compared using *t* tests for continuous variables and χ^2 tests for categorical variables. The nonparametric *t* test (Mann-Whitney) was used to determine whether older people identified as ACG frail (0 = no, 1 = yes) were also frail as defined by the VES tool (ordinal). We also created a dichotomous VES variable with 0 reflecting nonfrail status (score 0-2) and 1 reflecting frail status (score 3+). Pearson correlation was used to determine whether older people identified as ACG frail were also frail as defined by the VES dichotomous variable.

Receiver operator characteristic (ROC) methodology and an area under the curve (AUC) determination were also used to examine the relationships between ACG frail and VES frail status. We assessed the ability of the dichotomous ACG frail score to discriminate frailty defined according to the ordinal VES frail score. Finally, multiple logistic regression methodol-

Table 1. Demographic and Geriatric Syndrome Characteristics of the Study Population

Characteristic	Total Sample (N = 195)	VES Frail		ACG Frail	
		No (score 0-2; n = 33)	Yes (score 3+; n = 162)	No (n = 96)	Yes (n = 99)
Age, mean (SD), y	79.8 (6.8)	78.3 (5.2)	80.1 (7)	78.7[a] (7.6)	80.8 (5.7)
Female, %	55.9	66.7	53.7	50	61.6
Education, mean (SD), y	11.4 (4.7)	12.5 (4.3)	11.2 (4.8)	11.7 (5.4)	11.1 (3.4)
Married, %	48.7	39.4	50.6	55.9[a]	41.8
Holocaust survivor, %	68.7	62.5	70.1	61	75
Receiving income supplement, %	22.5	28.1	21.3	22	22.9
MMSE score, mean (SD)	22.5 (6.5)	26.2[b] (5.7)	21.7 (6.4)	22.8 (6.6)	22.2 (6.4)
ADL score, mean (SD)	81 (22)	99[b] (4)	76.7 (22.4)	83.9 (22.8)	78.6 (21.2)
GDS score, mean (SD)	6.3 (3.9)	4.9 (4.6)	6.6 (3.7)	5.6 (4.1)	6.6 (3.7)
Falls, %	46.7	26.7[b]	50.7	22.6[b]	67.3
Incontinent, %	44	12.1[b]	50.6	34.4[b]	53.1
Receiving personal care, %	43.6	3[b]	51.9	33.3[b]	53.5
Medications, mean (SD), n	7.85 (3.82)	7 (3.2)	8 (3.9)	7.6 (4)	8 (3.6)
SF total, mean (SD)	59.7 (17.6)	46.6[b] (14.9)	63 (16.7)	56.8[a] (18.9)	62.7 (15.7)

ADL indicates Barthel Activities of Daily Living scale; ACG frail, frail by the Adjusted Clinical Groups–diagnoses based computerized predictive model; GDS, Geriatric Depression Scale; MMSE, Mini Mental State Examination; SD, standard deviation; SF total, 12-Item Short Form Survey from the RAND Medical Outcomes Study; VES, frail by the Vulnerable Elders Survey.
[a] $P < .05$.
[b] $P < .01$.

ogy using the backward elimination method characterized the predictive ability of the 2 tools for the outcomes of ED visits, hospitalization, and death in 2009. The backward elimination method is based on the amount of unique variance a variable adds to a model. In this method, a model with all the variables is calculated first. Then, each variable is removed and the variable that causes the least reduction in accounted variance by its removal from the model is the first to be eliminated. The process continues until no more variables are removed. We applied this method with VES and ACG frail status as the unique independent variables. We assumed that both variables were predictive of ED visits, hospitalization, and death. If one of these variables was eliminated from the model, then that variable did not contribute to the prediction of the specific outcome. ACG-Dx PM version 8.21 was used for all determinations.

RESULTS

Demographic and Functional Characteristics

Demographic and functional characteristics were compared between nonfrail and frail participants in each of the categories: VES frail and ACG frail (Table 1). The VES frail group was more cognitively impaired and less functional than their nonfrail comparison group. In addition, compared with the nonfrail group, the VES frail group also had higher rates of falls, incontinence, and need for personal care, and a poorer quality of life. ACG frail persons compared with ACG nonfrail persons were older; were less likely to be married; had a higher rate of falls, incontinence, and need for personal care; and had a poorer quality of life. No significant differences were found between the nonfrail and frail groups in any of the categories when examining sex, education, Holocaust survivorship, and socioeconomic status.

Healthcare Utilization

Compared with the VES nonfrail group, the VES frail group were more likely to see a physician in 2008 and have an ED visit or to be hospitalized in the year after their CGA (2009). The ACG frail group was more likely to have an ED visit in 2008 and to be hospitalized in 2009 than the ACG nonfrail group (Table 2).

Frailty

We did not find a meaningful correlation between VES frail and ACG frail (Pearson correlation 0.103). Defining the VES frail as ordinal (0-10), we found that the mean rank of the VES score was significantly higher (indicating greater frailty) for those who were ACG frail compared with those who were not ACG frail, indicating that those frail by ACG criteria were also frail by VES criteria (2-tailed $P < .005$; $z = -2.79$).

Table 2. Healthcare Utilization in the Year of CGA (2008) and the Year After CGA (2009) by Frailty Tool Status

Variable	Total Sample (N = 195)	VES Frail		ACG Frail	
		No (score 0-2; n = 33)	Yes (score 3+; n = 162)	No (n = 96)	Yes (n = 99)
2008					
Hospitalizations, mean (SD), n	0.66 (1.9)	0.36 (0.71)	0.72 (2.07)	0.46 (0.9)	0.86 (2.5)
ED visits, mean (SD), n	0.45 (1.86)	0.24 (0.5)	0.49 (2.02)	0.12[a] (0.49)	0.7 (2.5)
Physician visits, mean (SD), n	4.2 (7.4)	2.06[b] (2.3)	4.6 (7.9)	3.9 (4.4)	4.5 (9.3)
2009					
Hospitalizations, mean (SD), n	4.36 (11.08)	2[a] (6.6)	4.8 (11.7)	2.74[a] (7.7)	5.9 (13.4)
ED visits, mean (SD), n	0.5 (0.98)	0.24[b] (0.43)	0.56 (1.04)	0.49 (0.95)	0.51 (1)
Mortality rate, mean (SD)	0.13 (0.33)	0.09 (0.29)	0.14 (0.34)	0.09 (0.29)	0.16 (0.37)

ACG frail indicates frail by The Adjusted Clinical Groups–diagnoses based computerized predictive model; CGA, comprehensive geriatric assessment; ED, emergency department; SD, standard deviation; VES frail, frail by the Vulnerable Elders Survey.
[a] $P < .05$.
[b] $P < .01$.

Defining the VES scale as ordinal (0-10) and the ACG tool as 0 for nonfrail and 1 for frail, the AUC of the ACG frail tool was 62% (**Figure**). An AUC of 0.5 represents a predictive ability no better than chance, whereas 1.0 indicates perfect predictive ability. The ROC curve analysis reveals that the AUC for the ACG frailty tool was moderate.

Logistic Regression

In order to examine the contribution of each of the tools under study to the prediction of the healthcare utilization variables of emergency department visits, hospitalization, and death, we performed an unadjusted backward logistic regression including only VES frail and ACG frail in the model. We found that VES frail predicted emergency department visits ($P < .023$), hospitalization ($P < .006$), and mortality ($P < .029$). ACG frail was eliminated from the model.

In order to clarify the contribution of each of the tools under study to the prediction of these healthcare utilization outcomes, we performed another backward logistic regression including VES frail, ACG frail, sex, and functional status. We found that after adjusting for these independent variables, VES frail predicted ED visits ($P < .016$), ACG frail predicted hospitalizations ($P < .032$), and gender predicted mortality ($P < .041$). Age and chronic conditions (congestive heart failure, ischemic heart disease, asthma, chronic obstructive pulmonary disease, and diabetes) were not included in the model because we found multicolinearity between these variables and the tools under study.

DISCUSSION

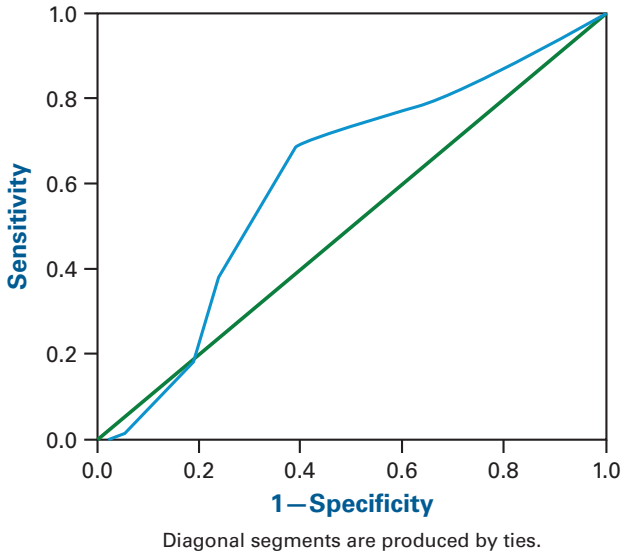
The frail groups identified by the VES frailty tool and ACG frailty tag had clinical characteristics consistent with frailty compared with their corresponding nonfrail groups. The ACG frailty tag did identify a frail population with moderate success using the VES frailty determination as the accepted standard. In unadjusted analyses comparing the VES frailty tool and ACG frailty tag, the VES frailty tool was the best predictor of health service utilization (ie, ED visits, hospitalization, and death in the year following CGA). Although our predictive model is not a comprehensive model to predict healthcare utilization outcomes, we have demonstrated that in adjusted analyses, the ACG frailty tag best predicted hospitalizations while the VES frailty tool predicted ED visits.

Predictive modeling is widely used by many healthcare organizations for risk stratification and identification of case mix. Our data have shown that predictive modeling can also be used to identify a frail population at risk for adverse outcomes and likely to benefit from clinical interventions. This study extends the work of Sylvia et al,[19] who have shown that older people identified as at risk for generating high medical expenditures in the future by ACG-PM methodology had medical conditions and functional limitations suggesting that they were good candidates for case and disease management. Sylvia et al did not examine the predictive ability of the frailty cluster within the ACG system. Our study contributes to the literature not only by describing clinical characteristics of older people identified by the frailty cluster, but also by comparing the predictive ability of this tool with that of the VES, an accepted frailty screening tool.

Our study also supports the findings of McGee et al,[16] who showed that frail older people identified by the VES were more likely to use healthcare services than nonfrail older people.

In a study validating the ACG System in Sweden, Halling et al[20] showed that the ability of the prediction model to

Figure. ROC Curve for ACG Frail and VES Frail



ACG frail indicates frail by the Adjusted Clinical Groups–diagnoses based computerized predictive model; ROC, receiver operator characteristic; VES frail, frail by the Vulnerable Elders Survey.

correctly predict an older person's use of resources could be improved by adding covariates such as functional status and health perception gleaned from short surveys. Others have advocated a similar approach to frailty screening.[19] Although we did not directly examine a combined screening strategy, our study results also point to the benefits of using a predictive model combined with survey data on functional status and health perceptions.

Strengths and Limitations

The strengths of our study are the extensive database of clinical characteristics and frailty measurement in combination with healthcare utilization data drawn from the administrative databases of the HMO.

A limitation of our study is its small sample size (N = 195) drawn from a survey of CGA. This small sample size might make it difficult to generalize from our findings. In addition, our study sample was a group of selected older people referred for CGA with a frailty rate of 83.1% (162/195). This rate is higher than the 32.1% in an Irish elderly sample (N = 2033)[16] and 32.3% in a US elderly sample (N = 6205).[11] Although this narrow range of frailty can limit the application of logistic regression modeling, it does reflect the real-world clinical setting of CGA. Finally, while the VES is an accepted, widely used, and evidence-based definition of frailty and hence is a legitimate gold standard for comparison, consensus on the definition of frailty has not been reached.[21,22] The VES is a function-based tool, whereas other accepted definitions of frailty are based on physical performance or on a count of accumulated deficits.[10,23]

CONCLUSIONS

Screening for frailty using the simple VES frailty tool is an effective method of identifying older people appropriate for interventions to prevent, delay, or treat frailty. While effective, this method is survey based and therefore time and labor intensive if implemented on a large population of community-dwelling elderly people. ACG frailty tag determination using information readily available from administrative databases is an efficient method of identifying elders who are appropriate for these interventions.

Frailty screening using predictive modeling combined with short, easy surveys to gather functional and health perception data merits further study.

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REFERENCES

1. Yancik R, Ershler W, Satariano W, Hazzard W, Cohen HJ, Ferrucci L. Report of the national institute on aging task force on comorbidity. *J Gerontol A Biol Sci Med Sci.* 2007;62(3):275-280.

2. Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. *Arch Intern Med.* 2002;162(20):2269-2276.

3. Boult C, Green AF, Boult L, Pacala JT, Snyder C, Leff B. Successful models of comprehensive care for older adults with chronic conditions: evidence for the Institute of Medicine's "retooling for an aging America" report. *J Am Geriatr Soc.* 2009;57(12):2328-2337.

4. Bodenheimer T, Berry-Millett R. *Care Management for Patients With Complex Healthcare Needs.* The Synthesis Project, issue 19. Princeton, NJ: Robert Wood Johnson Foundation. http://www.rwjf.org/pr/product.jsp?id=52372. Published December 16, 2009. Accessed September 12, 2012.

5. Strandberg TE, Pitkälä KH. Frailty in elderly people [published correction appears in *Lancet.* 2007;369(9576):1860]. *Lancet.* 2007;369(9570):1328-1329.

6. Hogan DB, MacKnight C, Bergman H; Steering Committee, Canadian Initiative on Frailty and Aging. Models, definitions, and criteria of frailty. *Aging Clin Exp Res.* 2003;15(3)(suppl):1-29.

7. Weiner JP. *Development and Evaluation of the Johns Hopkins University Risk Adjustment Models for Medicare+Choice Plan Payment.* Final report to Centers for Medicare & Medicaid Services, US Department of Health and Human Services. Baltimore, MD: Johns Hopkins University; 2003.

8. Abellan van Kan G, Rolland Y, Houles M, Gillette-Guyonnet S, Soto M, Vellas B. The assessment of frailty in older adults. *Clin Geriatr Med.* 2010;26(2):275-286.

9. Sternberg SA, Wershof Schwartz A, Karunananthan S, Bergman H, Mark Clarfield A. The identification of frailty: a systematic literature review. *J Am Geriatr Soc.* 2011;59(11):2129-2138.

10. Fried LP, Tangen CM, Walston J, et al; Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci.* 2001;56(3):M146-M156.

11. Saliba D, Elliott M, Rubenstein LZ, et al. The Vulnerable Elders Survey: a tool for identifying vulnerable older people in the community. *J Am Geriatr Soc.* 2001;49(12):1691-1699.

12. Stuck AE, Beck JC, Egger M. Preventing disability in elderly people. *Lancet.* 2004;364(9446):1641-1642.

13. Cohen HJ, Feussner JR, Weinberger M, et al. A controlled trial of inpatient and outpatient geriatric evaluation and management. *N Engl J Med.* 2002;346(12):905-912.

14. Bentur N, Sternberg SA, Lemberger J, Spalter T, Sharon A. *Comprehensve Geriatric Assessment Clinics in Israel.* Research report. Jerusalem, Israel: Myers-JDC-Brookdale Institute; 2011.

15. Min L, Yoon W, Mariano J, et al. The vulnerable elders-13 survey predicts 5-year functional decline and mortality outcomes in older ambulatory care patients. *J Am Geriatr Soc.* 2009;57(11):2070-2076.

16. McGee HM, O'Hanlon A, Barker M, et al. Vulnerable older people in the community: relationship between the Vulnerable Elders Survey and health service use. *J Am Geriatr Soc.* 2008;56(1):8-15.

17. Min L, Elliott MN, Wenger NS, Saliba D. Higher vulnerable elders survey scores predict death and functional decline in vulnerable older people. *J Am Geriatr Soc.* 2006;54(3):507-511.

18. Pel-Littel RE, Schuurmans MJ, Emmelot-Vonk MH, Verhaar HJ. Frailty: defining and measuring of a concept. *J Nutr Health Aging.* 2009; 13(4):390-394.

19. Sylvia ML, Shadmi E, Hsiao CJ, Boyd CM, Schuster AB, Boult C. Clinical features of high-risk older persons identified by predictive modeling. *Dis Manag.* 2006;9(1):56-62.

20. Halling A, Fridh G, Ovhed I. Validating the Johns Hopkins ACG Case-Mix System of the elderly in Swedish primary health care. *BMC Public Health.* 2006;6:171.

21. Hubbard RE, O'Mahony MS, Woodhouse KW. Characterising frailty in the clinical setting—a comparison of different approaches. *Age Ageing.* 2009;38(1):115-119.

22. Rodriguez-Manas L, Féart C, Mann G, et al; on behalf of the FOD-CC group (Appendix 1). Searching for an operational definition of frailty: a Delphi method based consensus statement: the Frailty Operative Definition-Consensus Conference Project [published online ahead of print, 2012]. *J Gerontol A Biol Sci Med Sci.*

23. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ.* 2005;173(5):489-495. ■