



Effect of frailty on resource use and cost for Medicare patients

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Aim: The effects of frailty and multiple chronic conditions (MCCs) on cost of care are rarely disentangled in archival data studies. We identify the marginal contribution of frailty to medical care cost estimates using Medicare data. **Materials & methods:** Use of the Fautot frailty score to identify differences in acute medical events and cost of care for patients, controlling for MCCs and medication use. **Results:** Estimated marginal cost of frailty was US\$10,690 after controlling for demographics, comorbid conditions, polypharmacy and use of potentially inappropriate medications. **Conclusion:** Frailty contributes greatly to cost of care, but while often correlated, is not synonymous with MCCs. Thus, it is important to control separately for frailty in studies that compare medical care use and cost.

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As the size of the US population over age 65 increases, Medicare has focused much effort on targeting patients with multiple complex chronic conditions for interventions to control preventable spending. Patients with multiple chronic conditions, such as combinations of diabetes, heart failure, hypertension or chronic obstructive pulmonary disease are targeted for special interventions to maximize their health and minimize cost of care [1,2]. It is well recognized that patients with multiple chronic conditions are at high risk for medical events. The risks of debilitation and of costly events are affected by clinical, behavioral health and social risk factors [3], and may vary greatly by neighborhood socio-economic position [4]. One important clinical/functional risk factor is frailty [3,5,6]. Frailty, defined as being weak or delicate, can be considered as 'a state of vulnerability to adverse outcomes resulting from the accumulation of deficits associated with clinical effects' [7]. Frailty indicators used in the proposed conceptual model of a starter taxonomy for high-need patients published by the National Academy of Medicine in 2017 [3] are gait abnormality, malnutrition, failure to thrive, cachexia, debility, difficulty in walking, history of fall, muscle wasting, muscle weakness, decubitus ulcer, senility or durable medical equipment use. However, it is difficult to measure frailty [8,9], particularly in research involving electronic health record (EHR) or archival billing data [10]. Therefore, proxy measures related to comorbid disease and activities of daily living have been developed to approximate frailty [11].

Indeed, some frailty measures designed for use with archival data are mainly based on the presence of a set of chronic disease diagnoses for conditions known to be highly associated with frailty [11,12]. However, not all frail elderly have multiple chronic conditions, so our understanding of the effects of frailty on risk of medical events and cost of care may be biased if frailty is solely measured by a constellation of chronic condition diagnoses. Indeed, observational studies of disease risk or cost of illness may be biased if frailty is not measured well and included in analytical models as a risk adjustor or a predictor.

This study examines the impact of a proxy-frailty measure on differences in acute medical events and cost of care for patients. We defined our proxy for frailty based on work done by Fautot *et al.* [13], which is a validated frailty score (FS) for use in archival data. The Fautot FS, that defines frailty based on 19 variables that predict dependency

in activities of daily living, contains few chronic disease codes in its definition. We chose this measure of frailty in order to separate the frailty as much as possible from measures of comorbid conditions because it is important to understand their distinct contributions to use and cost of medical care, and commonly accepted indexes for comorbid disease can be included as separate risk adjustors. As a mechanism to illustrate the impact of frailty on outcomes assessment in older populations, we describe the marginal difference in costs and events for a large cohort of Medicare patients classified at baseline as having robust, pre-frail and frail levels of health [14].

Population & data

We used 2013 data for Medicare patients with supplementary commercial health insurance from the MarketScan[®] (Truven Analytics) database. All patients aged 65 and above with insurance coverage for at least the first 3 months of 2013 were extracted from the insurance eligibility data table. Inpatient, outpatient and pharmacy records for this cohort were also extracted. Records for services received through 31 March 2013 were separated and used for the construction of baseline measures. Records from 1st April and later were used for constructing the follow-up (FU) cost and event measures. All risk measures, resource use and cost variables were aggregated at the patient level. We excluded all patients under age 65 and patients with diagnoses at baseline of cancer, paraplegia or late effects of stroke since they would more than likely carry a different risk profile. All patient records for a 3-month baseline period were used to construct measures of frailty and morbidity to be used for the baseline description. All outpatient records were used to construct the Elixhauser comorbidity score [15]; all inpatient records were used to construct the Quan version of the Charlson score, which is calculated as the weighted sum of 12 chronic disease variable identified by examining all ICD-9 codes on patients hospital discharge records, with a possible range from 0 to 28 [1,8]. The Faurot frailty index [13] was used to identify frailty at baseline. The score uses 24 variables defined based on ICD-9 diagnosis codes and procedure, and durable medical equipment billing codes present in inpatient, outpatient and durable medical equipment billing files. The codes measure use of preventive services, which are indicators of robustness and are weighted with a minus weight because they were protective against frailty in the prediction model. Other codes capture symptoms, chronic disease diagnoses, functional limitations and use of medical equipment, which are all weighted positively as indicators of increasing levels of frailty. The scores are summed and used to classify patients at baseline into three groups described as frail (score >5), prefrail (score 1–4.9) and robust (score <1) [14]. Polypharmacy was defined by a record of five or more prescriptions filled for different medications (defined by generic name) for each month during the baseline period [16,17], and a record of one or more dispensed prescriptions that met the 2012 Beers Criteria list [18,19] of potentially inappropriate medications (PIMs) and classes to avoid in older adults, was used as a measure of PIM use. A binary indicator of any hospital admission during baseline, and patient data on age, sex, region and residence in a nonmetropolitan area (rural) were used to define their demographic characteristics. Patient race was not used because this variable is not available in the data source. Only patients with at least 90 days of insurance coverage were retained in the analytical dataset.

Outcomes

Outcomes of interest included cost, defined from the perspective of an insurer, and measured as the aggregated total insurance payments recorded for each patient for the remaining 9 months in 2013 after the baseline period (TotCost). Payments by type of resource used were also examined for inpatient hospital payments (IPCost), outpatient services (OPCost) and prescription medications (RxCost). Other outcomes measured were a dichotomous measure of any hospital admission (AnyADM), number of hospital admissions (NumADM), total days in the hospital (IPDays) and number of recorded days in a skilled nursing facility (SNFDays). Death in the hospital was also recorded (Died), although this variable is not a reliable indicator of mortality, because only deaths that occur while in a hospital are recorded.

Statistical analysis

Descriptive statistics and crude outcome estimates were compared between the groups defined by frailty level using χ^2 tests for categorical variables and *t*-tests (normally distributed) or Mann–Whitney U/Wilcoxon tests (non-normally distributed) for continuous variables. P-values for descriptive statistics are not shown as sample sizes are so large as to result in statistically significant differences even when not clinically relevant.

Outcomes analysis for total payments and payment by frailty groups were compared using γ -distributed generalized linear log-linked multivariable regression models, adjusting for baseline covariates. The use of a γ -distributed

Table 1. Description of Medicare beneficiaries baseline characteristics by frailty category[†].

Variable name	Frail, n = 202,528 (5.57%)	Prefrail, n = 738,462 (19.73%)	Robust, n = 2,795,550 (74.70%)
Age mean (SD)	79.9 (6.7)	76.0 (7.2)	73.2 (6.7)
Study days mean (SD)	340 (62.6)	350.7 (47.7)	353.6 (42.4)
Charlson score mean (SD)	0.56 (1.26)	0.19 (0.81)	0.02 (0.31)
Females (%)	122,736 (58.9)	433,097 (58.7)	1,483,561 (53.1)
Any hospital admission (%)	47,041 (22.6)	55,758 (7.6)	28,598 (1.0)
Polypharmacy (%)	63,119 (30.2)	150,886 (20.4)	248,329 (8.9)
Any Beers Rx (%)	119,612 (57.4)	366,414 (49.6)	961,734 (34.4)
Geographic distribution:			
– Rural (%)	32,987 (15.8)	114,667 (15.3)	432,086 (15.5)
– North-east (%)	39,499 (4.5)	170,945 (19.2)	677,934 (76.3)
– North-central (%)	89,052 (8.5)	223,752 (21.4)	734,061 (70.1)
– South (%)	50,492 (5.2)	184,458 (19.1)	730,145 (75.7)
– West (%)	26,891 (3.5)	147,394 (19.0)	600,224 (77.5)
– Unknown (%)	2594 (3.8)	11,913 (17.6)	53,186 (78.6)
10 Most frequent Elixhauser index conditions:			
– Hypertension (%)	130,532 (62.6)	337,038 (45.6)	807,377 (28.9)
– Diabetes (%)	64,561 (31.0)	154,679 (21.0)	374,612 (13.4)
– Cardiac arrhythmia (%)	60,331 (28.9)	126,431 (17.1)	201,347 (7.2)
– Diabetic complications (%)	37,029 (17.8)	86,101 (11.7)	147,082 (5.3)
– COPD (%)	51,291 (24.6)	103,086 (14.0)	111,555 (4.0)
– Senility (%)	–	–	–
– Congestive heart failure (%)	56,045 (26.9)	14,445 (10.1)	20,297 (0.7)
– Chronic renal failure (%)	26,948 (12.9)	48,698 (6.6)	72,711 (2.6)
– Cardiac valve (%)	15,513 (7.4)	47,292 (6.4)	85,128 (3.1)
– Asthma (%)	9,835 (4.7)	30,937 (4.2)	56,465 (2.0)

[†] p-value for differences between groups are not shown because the sample size is so large that all differences are significant at < 0.05 even if differences are of no substantive importance.

COPD: Chronic obstructive pulmonary disease; Rx: Prescription; SD: Standard deviation.

generalized linear model with a log-transformed link function has been shown to be a good method to estimate healthcare cost distributions that are generally right-skewed, especially when the log-transformed-dependent variables do not have heavy tails or excessive heteroscedasticity [20]. Adjustors considered for inclusion in each outcome model were demographic characteristics, chronic conditions, Charlson comorbidity index score, polypharmacy, any Beers PIM, any Elixhauser condition and number of days in the FU period. Variables removed from the final models included only those with little to no predictive/confounding effect and no influence on model fit (akaike information criteria) or primary estimate (β), which resulted in final models including all covariates [21]. Multivariable generalized linear regression models (logistic and negative binomial) were used to examine risk of events and number of resources used.

Results

A total of 3,742,540 Medicare patients with supplementary private insurance coverage, for a mean of 352 days (standard deviation [SD] 44.9) in 2013, were included in the final dataset (Table 1). Their mean cost for the FU period was US\$10,139 (SD 29,398), mean age was 74.1 years (SD 7.0) with 54.5% females. Overall, 14.4% of patients in the cohort had one or more emergency department (ED) visits, 11.4% had at least one hospital admission and 3.8% had an admission to a SNF during the FU period. Of the patients in the cohort, 208,528 (5.6%) met the criteria for being frail, 738,462 (19.7%) were prefrail and 2,795,550 (74.7%) were classified as robust based on baseline observations. There was a slightly higher representation of females in the frail and prefrail groups, and also higher mean age. Overall, 3.5% of patients had one or more hospital admissions during the baseline period, with large differences for frail patients (22.6%), compared with prefrail (7.5%) and robust patients (1.0%). Overall, 12.4% of patients had polypharmacy recorded during the baseline period, with greater rates observed for

Table 2. Description of Medicare beneficiaries unadjusted resource use and cost during the 9-month follow-up period by frailty category[†].

Variable name	Frail, n = 202,528 (5.57%)	Prefrail, n = 738,462 (19.73%)	Robust, n = 2,795,550 (74.70%)
Any hospital admission, n (%)	34,143 (32.1)	126,442 (19.6)	238,448 (8.7)
Death in hospital, n (%)	1955 (1.8)	4567 (0.7)	6565 (0.2)
Any ED visit, n (%)	34,953 (32.9)	139,488 (21.7)	327,743 (12.0)
Any SNF admission, n (%)	31,404 (29.6)	51,317 (8.0)	50,813 (1.9)
Patients with any use:			
– Hospital days mean (SD)	8.91 (12.74)	6.59 (9.53)	5.62 (8.13)
– ED visits mean (SD)	1.86 (1.69)	1.57 (1.23)	1.36 (0.84)
– SNF days mean (SD)	38.40 (41.10)	29.68 (35.31)	25.07 (31.30)
– Total cost mean (SD)	25,320 (53,066)	16,305 (38,058)	8100 (25,082)
– Inpatients cost mean (SD)	9196 (33,348)	5475 (23,984)	2393 (16,503)
– Outpatient cost mean (SD)	13,549 (34,257)	8524 (24,204)	4361 (15,114)
– Rx cost mean (SD)	2576 (7109)	2306 (5536)	1346 (3849)

[†] All differences between robust and prefrail, and between prefrail and frail have $p < 0.05$.
ED: Emergency department; Rx: Prescription; SD: Standard deviation; SNF: Skilled nursing facility.

Table 3. Adjusted total costs (95% CI) observed during the 9-month follow-up period.

Variables in model	Frail	Prefrail	Robust	Significance
Model 1. Demographics: Age, sex, study days, rural, region	US\$33,374 (33,163–33,586)	US\$20,635 (20,558–20,712)	US\$10,257 (10,257–10,311)	All variables <0.05
Model 2. Demographics: Charlson score, hospital admission	US\$27,860 (27,683–28,038)	US\$19,367 (19,295–19,439)	US\$10,389 (10,362–10,416)	All variables <0.05
Model 3. Demographics: Charlson score, hospital admission, polypharmacy, any Beers	US\$25,712 (25,551–25,873)	US\$18,168 (18,102–18,235)	US\$10,545 (10,518–10,572)	All variables <0.05
Model 4. Demographics: Charlson score, hospital admission, Elixhauser Dx	US\$22,075 (21,911–22,241)	US\$16,670 (16,608–16,733)	US\$10,249 (10,222–10,276)	All variables <0.05
Model 5. Demographics: Charlson score, hospital admission, Elixhauser Dx, polypharmacy, any Beers	US\$21,066 (20,911–21,222)	US\$15,895 (15,836–15,953)	US\$10,376 (10,349–10,402)	All variables <0.05

Dx: Diagnosis codes.

frail and prefrail patients, and 38.7% patients received one or more prescriptions for drugs on Beers list during the baseline period. The mean Charlson comorbidity score was 0.087 (SD 0.558) and ranged from 0 to 15 at baseline, with higher values in frail and prefrail patients. The ten most common diagnoses measured by the Elixhauser index during the baseline period in order of prevalence include hypertension, diabetes, cardiac arrhythmia, diabetic complications, chronic obstructive pulmonary disease, senility, congestive heart failure, chronic renal failure, cardiac valve problems and asthma, with consistently higher rates observed by frailty status. The majority of patients resided in a metropolitan area (84.5%), with 24% from the north-east, 28% from a north-central state, 26% from the south, 21% from the west and 2% lacking state information (Table 1).

In unadjusted analyses the risk of hospital admissions, ED visits and admission to SNF during the 9-month FU period, as well as the amount of resources used (hospital days, ED visits and SNF days) was examined for the patient cohorts classified by baseline frailty. Robust patients had consistently lower risk of medical care use and cost, followed by prefrail patients, with frail patients having the highest use of medical care and highest cost (Table 2).

We estimated the marginal cost of being frail or prefrail compared with being robust using five multivariable models (Table 3), which used increasingly comprehensive measures to control for the effect of baseline variables on cost. In Model 1 we only controlled for the effects demographics (age and sex) and geographic characteristics (region and rural residence). In Model 2 we added any baseline hospital use (yes/no) and the Charlson comorbidity score, which are common control variables used in adjusted cost analyses. In Model 3 we added controls for baseline polypharmacy and use of drugs included on Beers list to the control variables included in Model 2. Model 4 contains the same variables as Model 2, except we added 26 individual binary indicators of the comorbid conditions in the

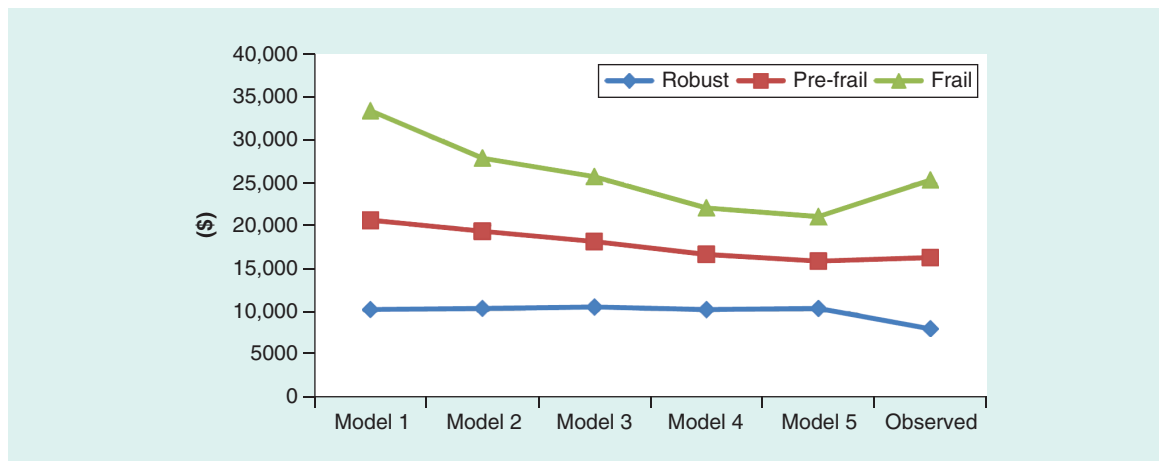


Figure 1. Effect of control variables included in the model on differences between robust, prefrail and frail cost estimates compared with unadjusted costs. The models contain the following variables; Model 1: demographics; Model 2: demographics, Charlson score, hospital admission; Model 3: demographics, Charlson score, hospital admission, polypharmacy, any Beers; Model 4: demographics, Charlson score, hospital admission, Elixhauser Dx; Model 5: demographics, Charlson score, hospital admission, Elixhauser Dx, polypharmacy, any Beers; observed are the unadjusted values. Dx: Diagnosis codes.

Elixhauser index. Finally, in Model 5 we included all the baseline control variables. The model cost estimates for robust patients varied little as a result of adding baseline control variables. However, the marginal cost difference between robust, prefrail and frail patients moderated substantially as we added controls for baseline differences in comorbid conditions and medication patterns. The estimated cost difference between robust and frail patients decreased from US\$23,117 in Model 1 to US\$10,690 in Model 5. The cost difference between the estimates for pre-frail and frail was US\$12,739 in Model 1 and US\$5,171 in Model 5. The trends in cost estimates for the models and the unadjusted costs are displayed in Figure 1.

Similar findings were observed for other outcomes of interest. We examined the differences between robust, prefrail and frail patients on risk of hospital admissions, SNF admissions and ED visits, and found statistically significant and clinically meaningful differences between robust, pre-frail and frail patients (Table 4). The same pattern was observed for medical resource use for robust, prefrail and frail patients on mean use of hospital days, number of emergency department visits and days in an SNF for patients with use of these services (Table 4). We also observed increased risk of death during a hospital stay by frailty level (total death rates could not be measured because no information on out-of-hospital deaths is included in the dataset).

The estimates for the models that controlled for all available baseline variables (Model 5) demonstrated a consistently smaller difference between frail, prefrail and robust cohorts than those estimated by Model 1 where we only controlled for age, sex, region, rural location and study days. The estimated adjusted odds ratios of hospital admission and SNF admission had the largest differences between Model 1 and Model 5, as would be expected because Model 1 did not control for the presence of comorbid conditions. The differences between Model 1 and Model 5 were much smaller when resource use differences were estimated for only those patients who used the specific type of care.

Discussion

We examined differences in acute medical events and cost of care for Medicare patients in 2013 using the Fautot [13] frailty index derived from data over a 3-month baseline period. We also used the baseline data to assign two other comorbidity measures: the Charlson score [22] and the Elizhouser index [15], which are commonly used to control for comorbid conditions in studies using archival billing data. We controlled for hospital use, polypharmacy and the use of any drugs on Beers list of PIMs [19]. The proxy FS classified patients at baseline into: robust, prefrail or frail groups. The mean cost of care for the 9-month FU period for Frail patients was US\$25,320, compared with US\$16,305 for the prefrail, and US\$8,099 for robust patients. Our cost estimate for the frail group is slightly lower than the 2012 Medicare cost derived from the report of cost for frail patients provided by Figueroa *et al.* [23]

Table 4. Multivariable results for Models 1 and 5 for assessing follow-up risk of one or more hospital admission; number of hospital days for those admitted, number of ED visits, risk of one or more skilled nursing facility admissions and number of skilled nursing facility days during the follow-up time.

	Model 1: OR (95% CI)	Model 5: OR (95% CI)	Estimate difference: Model 1 - Model 5
Any hospital admission			
Robust	Reference	Reference	NA
Prefrail	2.36 (2.337–2.372)	1.75 (1.731–1.761)	0.609
Frail	3.92 (3.87–3.98)	2.28 (2.24–2.32)	1.643
Number of days in hospital			
Robust	5.53 (5.50–5.56)	5.77 (5.74–5.81)	-0.24
Prefrail	6.41 (6.36–6.45)	6.13 (6.09–6.18)	0.28
Frail	8.51 (8.42–8.60)	7.39 (7.30–7.47)	2.38
Any ED visit			
Robust	Reference	Reference	
Prefrail	1.91 (1.90–1.92)	1.51 (1.50–1.52)	0.396
Frail	3.20 (3.16–3.25)	1.95 (1.912–1.979)	1.259
Number of ED visits			
Robust	1.38 (1.37–1.38)	1.41 (1.40–1.41)	-0.03
Prefrail	1.58 (1.57–1.59)	1.54 (1.53–1.55)	0.04
Frail	1.85 (1.84–1.87)	1.70 (1.68–1.72)	0.15
Any SNF admission			
Robust	Reference	Reference	NA
Prefrail	3.69 (3.64–3.74)	2.66 (2.63–2.70)	1.024
Frail	13.74 (13.51–13.97)	6.03 (5.90–6.17)	7.708
Number of SNF days			
Robust	24.62 (24.26–24.98)	25.47 (25.08–25.87)	-0.85
Prefrail	29.51 (29.09–29.94)	29.11 (28.70–29.54)	0.40
Frail	38.73 (38.10–39.37)	36.49 (35.82–37.16)	2.24

CI: Confidence interval; ED: Emergency department; NA: Not applicable; OR: Odds ratio; SNF: Skilled nursing facility.

in their Appendix Table 3. These authors report that the US\$3836 mean Medicare preventable spending for frail beneficiaries constitutes 9.3% of total cost. Thus, their frail cohort would have an estimated 9-months cost of US\$30,935 in 2012 compared with our estimate of US\$25,230 for 2013. However, Figuerosa *et al.* [23] classified frailty using a hierarchical ‘waterfall approach’, so their estimates include the marginal cost of comorbid conditions, and would therefore be higher than ours. Their frailty measure classified 8.6% of their cohort as frail. We observed a slightly lower rate of 5.56% in our cohort, which is similar to the 6.4% of patients with five to six difficulties in activities of daily living reported by Kautter [24] in the study of Medicare risk adjustment for the frail elderly. We observed a difference of US\$17,220 in FU cost between frail and robust patients, and a difference of US\$8205 between prefrail and robust individuals. This is a 213% higher FU cost for frail patients and 101% for prefrail patients compared with those who are robust. This difference between frail and robust patient in FU cost narrowed to US\$10,690 (103%) in the fully controlled model (Model 5). A reduction of similar magnitude (US\$5,519; 53%) was observed for the FU costs for the prefrail and robust comparison.

The importance of using a comprehensive set of baseline variables, including risk adjusters, constructed from the information imbedded in the International Classification of Disease (ICD), Current Procedural Terminology (CPT), Healthcare Common Procedure Coding System (HCPCS) and the National Drug Code (NDC) codes in baseline data can be fully appreciated by reviewing the very large differences in the odds of events (admission, ED visit and SNF risk) that we observed for Model 1 (unadjusted) and Model 5 (fully adjusted, Table 4). Two-stage modeling approaches are often needed for comparing costs of important resources, such as days in hospital when many patients have no use of this type of resource (many 0 values). We observed a very large difference in the adjusted odds ratio estimates across all types of resource use for Models 1 and 5 for patients classified by frailty. This finding demonstrates the importance of the baseline control variables for the comparison of utilization of specific resources and their cost using two-part regression models.

We increasingly use archival billing data to evaluate the effects of intervention to improve outcomes and decrease costs for Medicare patients. These studies depend on careful matching of treatment and control populations at baseline to avoid selection bias. It is clear from the findings in this study that we need to include frailty, prefrailty and robust status, as well as several comprehensive measures of comorbidities and medication use in our baseline control measures because they noticeably have the ability to contribute independently to bias in our estimates if they are unbalanced in a population. The use of archival data for assessment of quality improvement and policy evaluation holds great promise for reaching the goal of a 'learning health system'. However, the sparse amount of clinical measures that are available in billing data require that we are diligent in using the information imbedded in the ICD, CPT, HCPCS and NDC codes in baseline data to construct and validate proxy measures for medical conditions that may inject selection bias in our estimates. We found that patient frailty at baseline is an important predictor of medical resource use and cost for Medicare patients, independent of patient demographics, comorbidity burden and medication use patterns. Thus, frailty should be included as a baseline control and/or matching variable in comparative effectiveness and program evaluation studies that compare resource use and cost for Medicare beneficiaries.

The study has several limitations. All studies that use archival billing data to compare cost and outcomes for groups of patients are at risk of potential misclassification bias due to errors in ICD-9 diagnosis codes and CPT/HCPCS billing codes. This is especially the case with a score, such as frailty, which depends on the identification of billing codes for durable medical equipment during a short baseline period, because some frail patients may have received the equipment before the baseline period and may still be using it. This issue will tend to underidentify frailty and bias costs toward the null for frail patients. The fact that we limited the baseline period to 3 months could induce ascertainment bias for both frailty and comorbidity measurements. When designing archival studies, trade-offs must be made between using the available data for the baseline period, which may limit the data available for the FU time period, and potentially make the baseline measures less relevant due to differential effects of aging across population strata. Further, billing data contain errors and may have entries that are adjustment records for disallowed payments. Most of these records are removed during the data cleaning and dataset construction. However, our study used >285 million records to construct the analytical dataset, thus it is likely that we missed some adjustment records. Our mean cost per patient in the study was US\$10,139 over 9-months FU, or approximately US\$13,519 when annualized. This amount includes 2013 payments by Medicare, plus payments by a commercial insurer who provided supplementary Medicare insurance. The Kaiser Family Foundation reports that mean Medicare expenditure per beneficiary in 2013 was US\$10,827, or US\$2,692 less than our estimate. This relatively small cost difference increases our confidence in these cost estimates.

Conclusion

Frailty, even when identified in an imperfect manner through the use of diagnosis and procedure codes, increases the estimated mean cost of medical care by as much as US\$17,220 over a 9-month time period. However, because frailty increases with age and often co-occurs with comorbid conditions, polypharmacy and use of PIMs medications, it is important to differentiate the effects of frailty (and prefrailty) on cost from effects imposed by comorbidities and medication burdens. We found that once we controlled for patient demographics, comorbidities and medication use patterns, the cost contribution of frailty remained, but was much smaller. Thus, it is important that researchers differentiate between effects of frailty, and effect of disease and medication burden in their studies. Each factor contributes to cost, but while often correlated, are not synonymous. Further, our findings highlight the importance of using a comprehensive approach to identify control variable for cost comparisons. The conceptual framework proposed by the National Academy of Medicine [3] provides a good start. It captures demographic, geographic, behavioral, physiologic and disease-related variables, which should all be considered for inclusion as control variables in cost comparisons. The change from ICD-9 to ICD-10 codes with the latter's greater ability to capture social determinants of health, combined with the work to identify demographic factors [4] and develop a common taxonomy that segments individuals in a health system's population based on the care they need as well as how often they need it [3] should be used to guide the selection of control variables used in future cost comparison studies.

Summary points

- Medicare and other payers have focused much effort on targeting patients with multiple chronic conditions (MMCs) for interventions to control preventable spending. However, studies that compare use and cost of medical care using archival billing data rarely consider the effect that patient frailty may have on cost of care.
- Patients with MMCs are at high risk for medical events and that many of them are frail, defined as being weak or delicate, and proxy measures based on the presence of comorbid disease and have been developed to approximate frailty.
- However, not all frail elderly have MMCs, so our understanding of the effects of frailty on risk of medical events and cost of care may be biased if frailty is solely measured by a constellation of chronic condition diagnoses.
- Observational studies of disease risk or cost of illness may be biased if frailty is not measured well and included in analytical models as a risk adjustor or a predictor.
- This study examines the ability of an ICD9-code-based frailty measure that classifies patients as robust, prefrail and frail to identify differences in acute medical events and cost of care for Medicare patients using archival billing data.
- We used five multivariable models with increasingly comprehensive measures to control for the effect of baseline variables on cost to estimate the marginal cost of frailty, controlling for other patient characteristics.
- The estimated cost differences between robust and frail patients were US\$23,117 without control for patient characteristics, and US\$10,690 in models that controlled for age, sex, region, rural location, study days, Charlson score, Elixhauser index, hospital admission, polypharmacy and use of medications from Beers list during a 3-month baseline period.
- Frailty, even when identified in an imperfect manner through the use of diagnosis and procedure codes, increases the estimated mean cost of medical care by as much as US\$17,220 over a 9-month time period.
- It is important that researchers differentiate between effects of frailty, and effect of disease and medication burden in their studies. Each factor contributes to cost, but while often correlated, are not synonymous.

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Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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