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Development of a Predictive Model for Frailty Utilizing Electronic Health Records

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A Thesis Presented by

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ABSTRACT

Development of a Predictive Model for Frailty Utilizing Electronic Health Records

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Frailty is a multifaceted, geriatric syndrome that is associated with age-related declines in functional reserves resulting in increased risks of in-hospital death, readmissions and discharge to nursing homes. The risks associated with frailty highlights the need for providers to be able to quickly, and accurately, assess someone's frailty level. Previous studies have shown that bedside clinician assessment is not a reliable or valid way to determine frailty, meaning that a more reliable, valid and concise method is needed. We developed a prediction model using discharge ICD-9/ICD-10 diagnostic codes and other demographic variables to predict Reported Edmonton Frail Scale scores. Participants were from the Baystate Frailty Study, a prospective cohort design study among elderly patients greater than 65 years old who were admitted to a single academic medical center between 2014 and 2016. Three different predictive models were completed utilizing the LASSO approach. The adjusted r-square increased across the three models indicating an increase in the predictive ability of the models. In this study of 762 hospitalized patients over the age of 65 years old, we found that a frailty prediction model that included ICD codes only had a poor prediction ability (adjusted r-square=0.10). The prediction ability improved 2-fold after adding demographic information, a comorbidity score and interaction terms (adjusted r-square=0.26). This study provided additional insights into the development of an automatic frailty assessment, something which is currently missing from clinical care.

Keywords: frailty, prediction model, ICD codes, electronic health record, Edmonton Frail Scale

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CHAPTER 1

INTRODUCTION

1.1 Public Health Impact of Frailty

In 2014, over 12 million hospitalizations were reported for patients over the age of 65 years, accounting for 35% of all hospitalizations.[1] For some older people, hospital admission is associated with an increased risk of harm over and above the presenting condition.[2] Several attempts have been made to identify people at high risk of poor outcomes, many focusing on frailty and multimorbidity.[3] Frailty can be defined as "a clinical state characterized by an increased vulnerability of an organism to stressors, exposing individuals to negative health-related outcomes".[4] As such, frailty is a multifaceted, geriatric syndrome that is associated with age-related declines in functional reserves resulting in increased risks of in-hospital death, readmissions and discharge to nursing homes.[4] The risks associated with frailty highlights the need for providers to be able to quickly, and accurately, assess someone's frailty level. In addition, with the aging of the United States population and increasing longevity of older adults, frailty is expected to increase in prevalence. Previous studies have shown that bedside clinician assessment is not a reliable or valid way to determine frailty[5], meaning that a more reliable, valid and concise method is needed. The ability to predict frailty is crucial for providing meaningful interventions for patients, keeping them out of the hospital and reducing mortality and morbidity, however operationally defining, and ultimately measuring frailty has been shown to be difficult.

There are five widely accepted physical traits that indicate frailty: weight loss of more than 10 pounds over 1-year, frequent exhaustion, low levels of activity, slow gait,

and poor grip strength.[6,7] While assessing physical traits can predict frailty[6,7], it is not always feasible to collect this data from patients, which again underscores the need for other types of assessments. While previous assessment tools have reported high validity and reliability in assessing frailty[8], many of these tools are time-consuming and require providers or other healthcare personnel to complete the interviews in-person with patients and/or caretakers. Due to these different constraints, most hospitalized elderly patients are not adequately assessed for frailty. While limitations in physiological reserves are generally not modifiable, the ability to identify frail patients quickly and accurately could allow providers to use targeted interventions that can positively influence the patient's outcome, again, for example, lowering the risk of readmission to the hospital and/or mortality. Such frailty-appropriate interventions could include geriatric or palliative consultations, admissions to geriatric wards, early interventions to increase mobilization, medication reconciliation by a geriatric pharmacist, delirium prevention, discussions regarding goals of care, and early planning for discharge.[9,10] Overall, there is a need for a way to predict which patients accurately and quickly are at risk of being categorized as frail so appropriate interventions can be implemented.

1.2 Previous predictive models and assessments of frailty

Previous research studies have been able to use clinical data to predict different scores on clinical assessment tools, for example, predicting impaired glucose tolerance for those with a diagnosis of diabetes[11], cardiac risk[12], and neurosurgical outcomes.[13] The ability to predict different outcomes and risks utilizing clinical data would allow providers to be able to give more appropriate care, and would also save time and resources, giving providers and other healthcare personnel the time to give target interventions. Previous predictive models of frailty have used ICD-9/ICD-10CM

diagnostic codes[7,10,14–16]; however, these models included outpatient settings and/or were not validated against a reference measure of frailty such as in-person assessments and did not include patients hospitalized in the United States. Being able to predict a validated assessment could add validity and reliability to these prediction models, potentially making them more valuable and useful. In addition, the lack of studies in the United States demonstrates the need for this sort of prediction model to be applied to this population, as healthcare in the United States may differ from the other countries in which these projects were previously completed.

As noted above, previous work supports the notion that electronic health record (EHR) data can be utilized to predict the outcome of frailty[7,10,16], however, these models could be strengthened by utilizing a validated measure of frailty as the outcome.[7,8,10,14–20] Further, tools that are used to measure frailty vary widely across their individual measurements of frailty, making the tools less useful because the operational definition of frailty can change from tool to tool.[21] The variables in and of themselves can be valid measures of frailty, however, when combined into singular tools, consistency could lead to a more reliable and valid measure. In addition, one scoping review found that only a few of these assessments were reliable[22], highlighting the need for a better method in which to predict frailty.[14]

1.3 Study objectives, significance, and innovation

This project aimed to develop a model that utilizes ICD-9/ICD-10 diagnostics codes to predict a validated, in-person assessment of frailty, the Reported Edmonton Frailty Scale (REFS). As noted previously, other studies have examined outpatient populations from outside the United States and did not utilize a validated in-person assessment of frailty. This project addresses some of those gaps by utilizing an inpatient

population, in the United States, and is using the REFS, which is a validated measure, as the outcome. The REFS is a scale that can be completed at the bedside by any individual and measures frailty across domains that are generally found in all geriatric assessments.[23]

Specific Aim: To develop a predictive model that combines demographic and administrative variables to predict frailty.

Hypothesis: The variables available from the EHR, specifically ICDs from discharge, will predict frailty.

In this project, we leveraged the information from a unique database from the Baystate Frailty Study (BFS) of 1100 hospitalized elders with frailty determined by in-person assessment using the REFS. For this study, frailty was defined using the subjects' score on the REFS, with a higher score indicating higher levels of frailty. We utilized demographic and administrative variables available from the subject's admission/discharge visit and from the BFS database to develop a prediction model for frailty assessed by the REFS. The overall aim of the project is to ascertain if ICD-9/ICD-10 codes and other clinical variables can be utilized to accurately predict frailty scores on the REFS.

CHAPTER 2

METHODS

2.1 The Baystate Frailty Study

We developed a prediction model using discharge ICD-9/ICD-10 diagnostic codes and other demographic variables to predict REFS scores in participants of the BFS. The BFS was a prospective cohort design study among 1100 elderly patients greater than 65 years old who were admitted to Baystate Medical Center (BMC) in Springfield, Massachusetts between January 1, 2014, through April 30, 2016, for urgent surgeries, trauma, elective orthopedic surgeries, and for treatment of congestive heart failure (CHF), pneumonia (PNA) and/or chronic obstructive pulmonary disease (COPD) or other medical conditions.

2.2 Study Population

Eligible patients for the BFS were individuals over the age of 65 who presented to BMC for: 1) an urgent noncardiac surgical procedure that required an in-patient stay and that was sufficiently complex to result in postoperative complications (e.g., hip fractures, small bowel obstruction, acute cholecystitis, vascular procedures, amputations); or 2) those with trauma, elective orthopedic surgeries (hip and knee replacement) and 3) non-surgical patients with the 3 most common medical conditions: CHF, PNA, and COPD. The BFS excluded individuals who had cardiac surgeries, emergent surgeries (patients with an acute life-threatening condition necessitating immediate surgery), patients who did not speak English (difficult to obtain consent, administer the questionnaire and evaluate daily mental status) and patients with advanced dementia. Individuals who were

transferred from other acute care facilities, those patients admitted to observation or to the intensive care unit were also excluded.

A total of 1100 patients were initially enrolled into the BFS. Of these, 317 patients were excluded for missing age data (n=5), place of residence data (n=2), BMI data (n=22), missing complete REFS (n=178), or missing both BMI and REFS (n=110). Of the 288 patients missing REFS data, 272 of them met exclusion criteria. Twenty-one patients had been enrolled twice, so only their first visit/admission was included, which left a total of 762 subjects for analysis.

2.3 Assessment of Frailty

Frailty was assessed using the REFS which was administered before the surgery or within 24 hours after admission for non-surgical patients. It was administered by trained research staff in an in-person, bedside interview with the patient. The REFS assesses frailty across multiple domains including cognition, self-evaluation of general health status, functional independence, presence of social support, medication use and adherence, nutrition, mood, incontinence, and self-reported performance. Each item is scored 0 points (frailty absent/normal health), 1 point (minor errors or mild/moderate impairment) or 2 points (important errors or severely impaired). The maximum REFS score is 18 and higher scores have been shown to reflect greater frailty.[24]

2.4 Validity of Frailty Assessment

The REFS has been validated in other studies for use by non-geriatricians[15–17] and has been shown to have reliability measure frailty.[16,18] In a previous validation study, patients who were at least 65 years old and referred for a comprehensive geriatric assessment were given the REFS. The REFS was administered to these patients by

research assistants who did not have previous formal training relating to the REFS. A random sample of these same patients was selected to do the REFS again to assess interrater reliability.[18] The REFS was shown to have a normal distribution with a high interrater reliability (kappa= 0.77-0.84) over multiple interviewers. [16,18] The REFS also has high internal consistency, with analyses showing a Cronbach's alpha of 0.62.[18]

2.5 Predictor Variables

The main predictor variables were ICD-9/ICD-10 codes from the subject's discharge records after the date of enrollment. These discharge ICD-9/ICD-10 codes were then manually categorized into 14 different frailty domains consisting of (1) debility problems, (2) fatigue issues, (3) swallowing issues, (4) nutrition issues, (5) cognitive issues, (6) acute confusional states, (7) incontinence, (8) chronic skin ulcers, (9) sensory impairment, (10) impaired mobility, (11) depression problems, (12) falls, (13) fractures, and (14) anemia, due to their clinical relevance to the outcome of frailty. This data was collected retrospectively from the EHR and the Baystate Frailty Study (BFS) database. These domains were identified as potential explanatory categories by the principal investigators of the BFS through their previous analyses of the already collected data and based on consultation with 4 geriatrician researchers. These domains were treated as dichotomous variables (yes or no to having the ICD code present in the discharge information) and were created by manually reviewing and assigning all collected ICD-9/ICD-10 diagnosis codes into the frailty domains as necessary (Appendix A). Utilizing these variables as dichotomous variables allowed for the collapsing of the ICD codes from individual codes into the frailty domains allowing for ease of analysis. As there were hundreds of ICD codes present from the discharge information, sorting into

frailty domains and dichotomous variables made the data more concise. This review and assignment were completed by two study staff members, one of whom is a hospitalist at BMC. Any ICD-9/ICD-10 code that did not fit into one of the categories above were removed from the analysis. Demographic variables that were assessed were age, gender, residence at time of admission and BMI. These variables were obtained from patient records. Finally, we also assessed the extent of comorbidity using the Gagne Comorbidity Score. The Gagne score combines the Charlson and Elixhauser scores, both of which have been shown to be associated with short- and long-term mortality.[25]

2.6 Statistical Analyses

2.6.1 Preliminary analyses

For preliminary descriptive analyses, means and standard deviations were computed for continuous factors and frequencies distributions have been estimated for categorical variables. To facilitate examination of factors related to the REFS, the sample was divided into frail and non-frail patients, based on the REFS score. (This dichotomy was only for the purposes of the data shown in Table 1. The REFS was used as a continuous outcome variable for the predictive models.) Frail and non-frail patients were compared using two-sample t-tests for continuous variables and Fisher's exact test for categorical variables.

2.6.2 Development of Predictive Model

In developing the prediction model, we followed best practices for prediction model building by splitting the data intro a training and a validation data set.[26,27] To train the predictive model, a training dataset was created by randomly selecting 75% the patient sample. The remaining 25% formed the validation dataset. This approach was used for

several reasons. First, this approach minimized overly optimistic estimates in developing (i.e., training) the prediction model. Although a stepwise linear regression approach may be used to select a subset of predictor variables. Harrell (2012) advises against its use because the final model can overfit the data. As a consequence, the resulting beta coefficients will likely be poor out-of-sample predictors.[28] To address these concerns, a Least Absolute Shrinkage and Selection Operator (LASSO) approach was utilized to train, validate, and test the model utilizing a linear regression. A LASSO approach allows for the inclusion of all potential predictors into a single model. The LASSO will then compute all possible models utilizing all the predictors and then select the model which has the best outcome, dropping predictors that seem to have no statistical relation to the outcome. Employing the LASSO approach minimizes bias arising from optimistic estimation by minimizing estimates of the out-of-sample prediction error.[29] Thus, the LASSO approach not only can yield a more simplified, unbiased model (by removing unnecessary variables), but also can control for collinearity among the variables. The LASSO approach allows for the development of a more parsimonious model, it does not report statistics commonly seen in regression models. In addition, the LASSO approach may also remove variables that could be of interest in favor of parsimony and collinearity concerns meaning an interact term may stay in the model while the individual predictor may be removed.

For this project a LASSO was applied as a linear regression model since the outcome was continuous and approximately normally distributed. In total, three LASSO models were completed, Model 1 consisted only of the frailty domains (based on ICD-9/10 CM codes), Model 2 consisted of frailty domains and demographics, and then the final model,

Model 3, included the frailty domains, demographics, the Gagne score for prediction of comorbidities and interaction terms. A secondary, more standard linear regression model was run utilizing the predictors identified in Model 3, the strongest LASSO model, to assess each individual predictor in a more conventional approach. Model beta coefficients from the training dataset were applied to the validation dataset and calibration was assessed (i.e., model performance was measured on how accurately the model could predict the REFS score and as such, frailty). Our primary analysis utilized the REFS modeled as a continuous variable, however in general, a patient can be classified as frail, using the REFS, if he or she scores at or above a cut point of 8 and as not frail if the patient scored at or below a score of 7.

CHAPTER 3

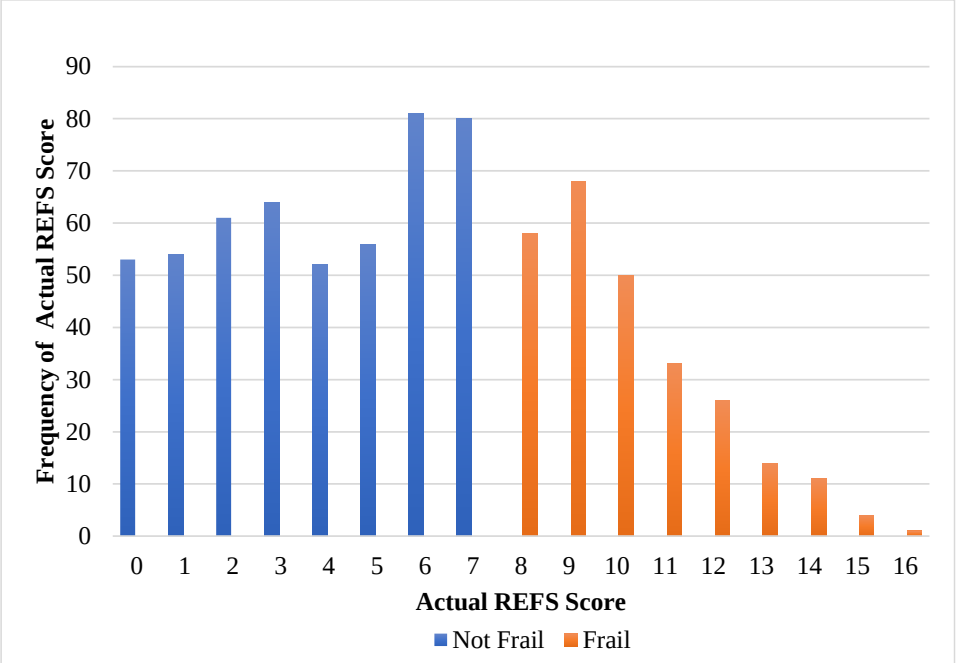
RESULTS

Cohort characteristics

A total of 1100 patients were initially enrolled into the BFS. Of these, 331 patients were excluded for missing BMI data (n=22), missing complete REFS (n=178) and a few missing both BMI and REFS (n=110). Of the 288 patients missing REFS data, 272 of them met our exclusion criteria. We also had 21 patients who had been enrolled twice, and we chose only included their first visit. Five individuals did not have an age recorded, and another 2 were missing residence data which left a total of 762 subjects for analysis.

To describe the study population and evaluated characteristics associated with frailty, For the purposes of Table 1, subjects were divided into non-frail and frail categories, though for analysis the REFS was used as a continuous variable. The average REFS score was 5.9 for the population, with non-frail individuals having an average score of 3.8 and frail individuals having an average score of 10.1 (Figure 1).

Figure 1. Histogram of Actual REFS Score



The overall study population had an average age of 78.6 years, with frail individuals being slightly older (80.2 years) than non-frail individuals (77.8 years). Gender was almost equally distributed across both groups, and most of the study population were white (670 participants). As illustrated in Table 1, most of the sample were on Medicare, which was consistent across both the frail and non-frail groups. Those in the frail category were more likely be readmitted within 30-days and were also more likely to be dead within 1 year of their visit when compared to those in the non-frail category. T-test analyses showed several significant relationships between the clinical variables of interest and the dichotomized REFS score (Table 1). Most clinical characteristics were significantly associated with the REFS except for BMI when utilized as a continuous variable, however when BMI was used ca a categorical variable (normal, overweight, etc.), there was statistical significance. Similarly, almost all the frailty domains, except for debility (p=0.45) were also significantly associated with the REFS.

Table 1. Patient's characteristics by frailty categories

Clinical Characteristic	Total	Not Frail (0-7)	Frail (8-16)	
	(n = 762)	*(n=501)*	*(n=261)*	*p-value*
Age (years), *mean (SD)*	78.6 (7.8)	77.8 (8.1)	80.2 (7.3)	< 0.001
BMI kg/m2, *mean (SD)*	28.3 (7.0)	28.4 (6.9)	28.2 (7.4)	0.8
REFS score, *mean (SD)*	5.9 (3.7)	3.8 (2.3)	10.1 (1.8)	
	n (%)	***n (%)***	***n (%)***	
Patient Type				< 0.0001
Urgent Surgery	191 (25.1)	159 (31.7)	32 (12.3)	
Medical	473 (62.2)	250 (49.9)	223 (85.8)	
Elective Surgery	97 (12.8)	92 (18.4)	5 (1.9)	
Gender				0.06
Female	441 (57.9)	288 (57.5)	153 (58.6)	
Male	321 (42.1)	213 (42.5)	108 (41.4)	
Race/Ethnicity				< 0.0001
Asian	3 (0.4)	1 (0.2)	2 (0.8)	
Black	44 (5.8)	19 (3.8)	25 (9.6)	
Hispanic	34 (4.5)	17 (3.4)	17 (6.5)	
Other	3 (0.4)	3 (0.6)	0 (0)	
Unknown	8 (1.1)	8 (1.6)	0 (0)	
White	670 (87.9)	453 (90.4)	217 (83.1)	
BMI Categories				0.0026
< 18.5	25 (3.3)	13 (2.6)	12 (4.6)	
>=18.5 to < 25	239 (31.4)	153 (30.5)	86 (33.0)	
>= 25	498 (65.4)	335 (66.9)	163 (62.5)	
Residence				< 0.0001
Home	682 (89.5)	468 (93.4)	214 (82)	
Assisted Living	47 (6.1)	23 (4.6)	24 (9.2)	
Nursing Home	33 (4.3)	10 (2)	23 (8.8)	
Discharge Disposition				< 0.0001
Home or Home with Services	410 (53.8)	289 (57.3)	126 (47.6)	
Nursing Home	313 (41.1)	186 (36.9)	128 (48.3)	
Rehabilitation	27 (3.5)	20 (4.0)	8 (3.0)	
Expired or Hospice	12 (1.6)	9 (1.8)	3 (1.1)	
Death				< 0.0001
No	465 (61)	345 (68.9)	120 (46)	
Yes	297 (39)	156 (31.1)	141 (54)	
Readmitted w/in 30 Days				< 0.0001
No	662 (86.9)	456 (91)	206 (78.9)	
Yes	100 (13.1)	45 (9)	55 (21.1)	
Insurance				0.0046
Other	50 (6.6)	41 (8.2)	9 (3.5)	
Medicare	712 (93.4)	460 (91.8)	252 (96.6)	

Table 1. (cont.) Patient's characteristics by frailty categories

Frailty Categories	Total	Not Frail (0-7)	Frail (8-16)	
	(n = 762)	*(n=501)*	*(n=261)*	*p-value*
	n (%)	*n (%)*	*n (%)*	
Debility				0.45
No	760 (99.7)	500 (99.8)	260 (99.6)	
Yes	2 (0.3)	1 (0.2)	1 (0.4)	
Fatigue				0.0032
No	731 (95.9)	488 (97.4)	243 (93.1)	
Yes	31 (4.1)	13 (2.6)	18 (6.9)	
Swallowing Issues				0.02
No	535 (70.2)	361 (72)	174 (66.7)	
Yes	227 (29.8)	140 (27.9)	87 (33.3)	
Nutrition Issues				0.01
No	226 (29.7)	159 (31.7)	67 (25.7)	
Yes	536 (70.3)	342 (68.3)	194 (74.3)	
Cognitive Issues				0.01
No	701 (91.9)	468 (93.4)	233 (89.3)	
Yes	61 (8)	33 (6.6)	28 (10.7)	
Acute Confusion				0.0061
No	705 (92.5)	472 (94.2)	233 (89.3)	
Yes	57 (7.5)	29 (5.8)	28 (10.7)	
Incontinence				0.04
No	688 (90.3)	457 (91.2)	231 (88.5)	
Yes	74 (9.7)	44 (8.8)	30 (11.5)	
Chronic Skin Ulcers				0.001
No	713 (93.6)	479 (95.6)	234 (89.6)	
Yes	49 (6.3)	22 (4.4)	27 (10.3)	
Sensory Impairment				0.05
No	621 (81.5)	413 (82.4)	208 (79.7)	
Yes	141 (18.5)	88 (17.6)	53 (20.3)	
Impaired Mobility				0.04
No	343 (45)	231 (46.1)	112 (42.9)	
Yes	419 (55)	270 (53.9)	149 (57.1)	
Depression Problems				<0.0001
No	491 (64.4)	360 (71.9)	131 (50.2)	
Yes	271 (35.6)	141 (28.1)	130 (49.8)	
Falls				0.0005
No	626 (82.2)	396 (79)	230 (88.1)	
Yes	136 (17.8)	105 (21)	31 (11.9)	
Fractures				<0.0001
No	605 (79.4)	374 (74.7)	231 (88.5)	
Yes	157 (20.6)	127 (25.3)	30 (11.5)	
Anemia				0.0007
No	510 (66.9)	354 (70.7)	156 (59.8)	
Yes	252 (33.1)	147 (29.3)	105 (40.2)	

Predictive models

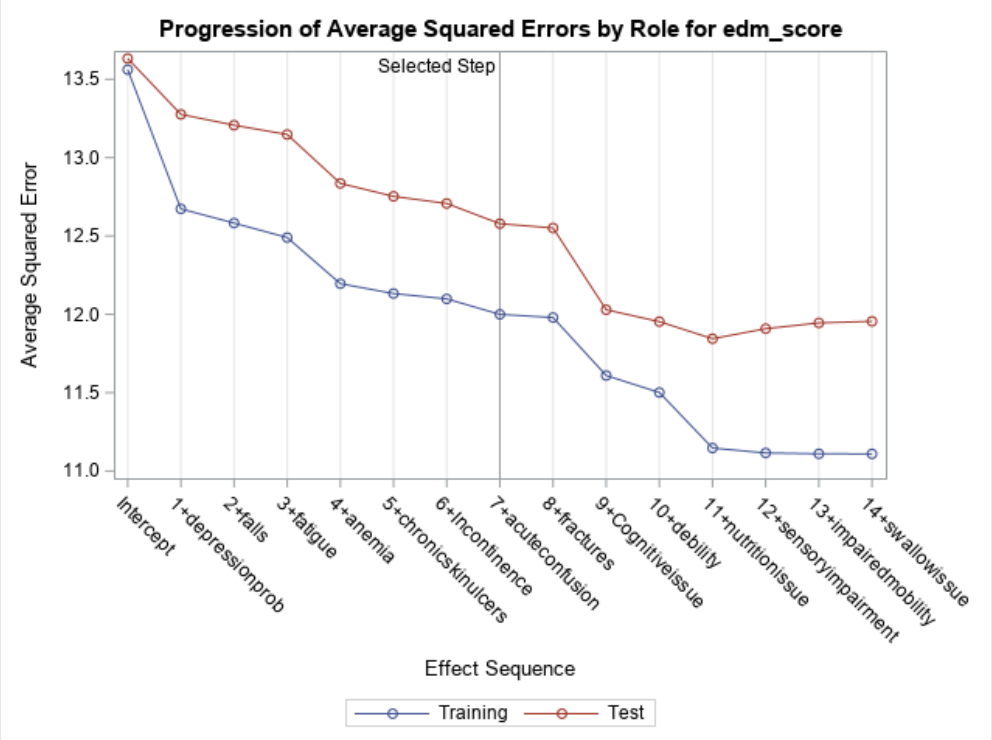
Three different models were completed utilizing the LASSO approach (Table 2). The adjust r-square increased across the three models indicating an increase in the predictive ability of the model. Falls and debility were negatively associated with the REFS score across the models. Table 2 shows the results of the variable selection for the three models. Each variable that was included in the model has the coefficient and rank included in the table, such that the higher the rank, the more strongly associated with the REFS the variable is. The coefficient also demonstrates the strength of the association with the REFS score.

Table 2. LASSO Models

	Model 1		**Model 2**		**Model 3**	
Adjusted R-Square	0.10		0.25		0.26	
MSE	12.17		10.19		10.09	
Variable Name	**Coefficient**	**Rank**	**Coefficient**	**Rank**	**Coefficient**	**Rank**
Acute Confusion	0.08	7	0.48	10	0.62	11
Anemia	0.29	4	0.50	8	0.57	8
Chronic Skin Ulcers	0.18	5	0.29	11	0.42	12
Cognitive Issues	-	-	-	-	-	-
Debility	-	-	-1.49	12	-2.61	13
Depression Problems	1.53	1	1.80	2		
Falls	-0.60	2	-0.88	4	-0.98	4
Fatigue	0.77	3	1.42	6	1.63	6
Fractures	-	-	-0.40	7	-0.40	7
Impaired Mobility	-	-	-	-	0.02	14
Incontinence	0.07	6	-	-	-	-
Nutrition Issues	-	-	0.36	9	0.43	9
Sensory Impairment	-	-	-	-	-	-
Swallowing Issues	-	-	-	-	-	-
Age			0.11	1	0.11	2
BMI			-	-	-	-
Gender			-	-	-	-
Residence			0.76	3	0.77	3
Gagne Score			0.14	5	0.15	5
Age*Depression					0.02	1
Age*Falls					-	-
Gender*Depression					0.49	10

Model 1. Model 1 included only the Frailty Domains to predict the REFS. The analysis kept 7 of 14 domains in the final model including fatigue, acute confusion, incontinence, chronic skin ulcers, depression problems, falls and anemia, but excluding fractures, cognitive issues, debility, nutritional issues, sensory impairment, impaired mobility, and swallowing issues (Figure 2). The overall adjusted r-square for model 1 was 0.10. In Figure 2, the selected cut-off for the predictors to be included is demonstrated by the "Selected Step" line drawn at "acute confusion". All predictors up to that line were selected by the LASSO to remain in the model, while the predictors after the line were not selected by the LASSO analysis.

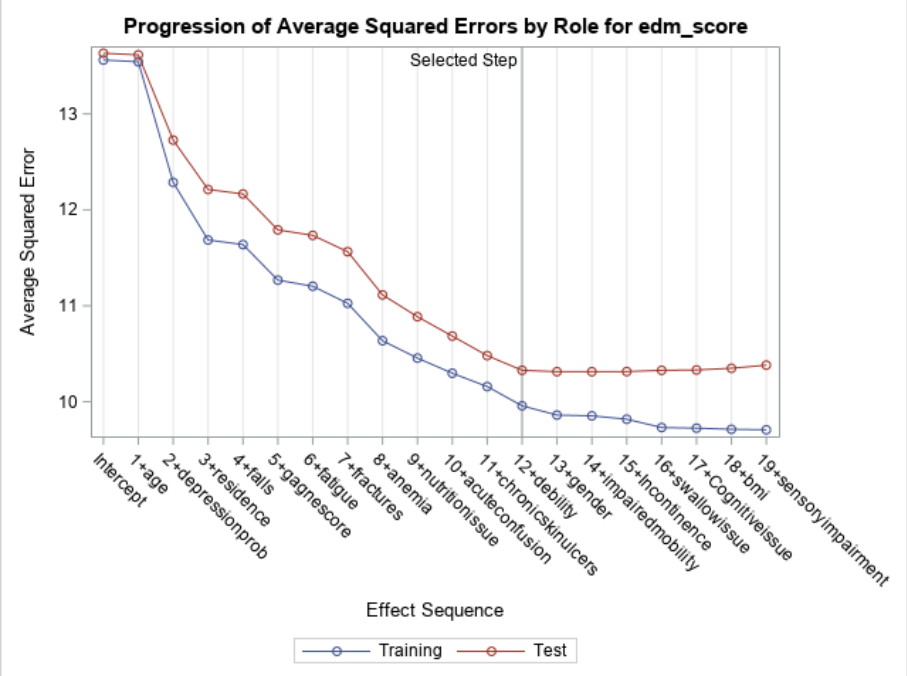
Figure 2. LASSO Model 1- Frailty Domains Only



Model 2. The second model included demographic data, age, gender, residence, BMI, the 14 frailty domains, and the Gagne Comorbidity Score. In the second model, the LASSO approach excluded 7 of the variables (gender, impaired mobility,

incontinence, swallowing issues, cognitive issues, BMI, and sensory impairment), while retaining the following variables: age, residence, depression problems, falls, fatigue, fractures, anemia, nutritional issues, acute confusion, chronic skin ulcers and debility problems. The adjusted r-square for this model was notably higher at 0.25. (Figure 3). In Figure 3, the selected cut-off for the predictors to be included is demonstrated by the "Selected Step" line drawn at "debility". All predictors up to that line were selected by the LASSO to remain in the model, while the predictors after the line were not selected by the LASSO analysis.

Figure 3. LASSO Model 2- Frailty Domains and Demographics



Model 3. The final model included all demographic variables, 14 frailty domains, the Gagne Comorbidity Score, and included the following interaction terms: depression by age, falls by age, and depression by gender. These interaction terms have been shown in previous literature to be correlated with frailty and as such were included as interactions in the final model. In this model, 12 variables and 2 interaction terms met the

criteria for inclusion, age, residence, debility, fatigue, nutritional issues, acute confusion, chronic skin ulcers, impaired mobility, falls, fractures, anemia, and the Gagne score, along with the interactions between gender and depression problems and age and depression problems (Figure 4).

Figure 4. LASSO Model 3- Frailty Domains, Demographics, and Interaction Terms

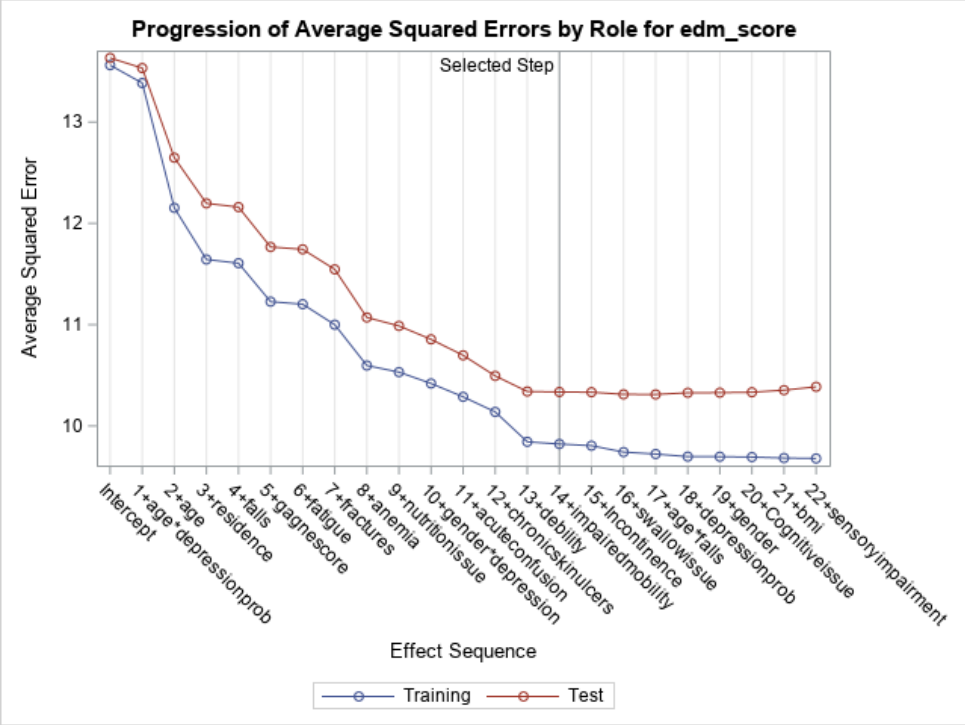


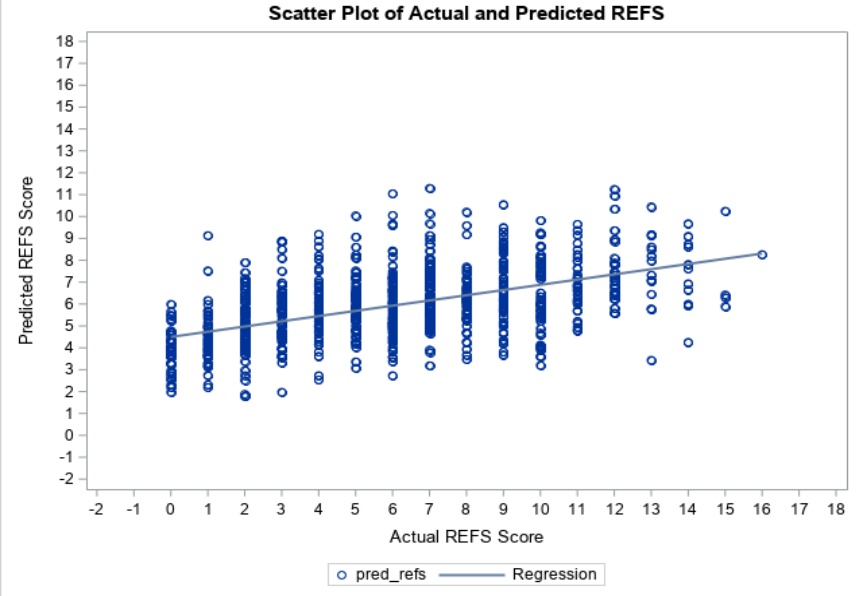
Figure 4 demonstrates the final model selected by the LASSO. Predictors that are listed before the "Selected Step" line were included in the final model, while the others were excluded. The blue and red lines demonstrate the training (75% of the sample) and test (25% of the sample) datasets and the impact that adding in each predictor has at each step. The figure demonstrates that including the variables listed after the "Selected Step" do not add to the overall significance of the model. The overall adjusted r-square for the third model was the highest at 0.257. A linear regression model utilizing the variables that were selected in the LASSO model 3 was completed to gain insight into the individual predictors (Table 3).

Table 3. Linear Regression Analysis Summary for LASSO Model 3

Variable	Estimate	95% CI	t	p-value
Age	0.12	(0.09, 0.15)	8.06	<.0001
Acute Confusion	0.88	(0.02, 1.75)	2.01	0.045
Anemia	0.90	(0.41, 1.40)	3.59	0.0003
Chronic Skin Ulcers	0.92	(-0.02, 1.86)	1.92	0.0553
Debility	0.94	(-3.48, 5.36)	0.42	0.6753
Falls	-0.86	(-1.73, 0.01)	-1.95	0.0517
Fatigue	1.89	(0.74, 3.04)	3.23	0.0013
Fractures	-0.88	(-1.70, -0.06)	-2.11	0.0352
Gagne Score	0.19	(0.08, 0.30)	3.28	0.0011
Impaired Mobility	0.27	(-0.20, 0.73)	1.14	0.2555
Nutrition Issues	0.81	(0.30, 1.31)	3.15	0.0017
Residence	0.96	(0.45, 1.46)	3.70	0.0002
Age*Depression Problems	0.02	(0.01, 0.03)	5.68	<.0001
Gender*Depression Problems	0.50	(-0.28, 1.28)	1.25	0.2128

The relationship between the predicted REFS score and the actual REFS score can be seen in the scatterplot in Figure 5. There is a slight positive correlation between the predicted REFS score (as created by the LASSO model) and the actual REFS that was measured in the BFS, however this is not statistically significant as indicated by the final adjusted r-square (0.26).

Figure 5. Scatter plot of actual and predicted REFS



CHAPTER 4

DISCUSSION

In this study of 762 hospitalized patients over the age of 65 years old, we found that a frailty prediction model that included ICD codes only had a poor prediction ability (r-square = 0.10). The prediction ability improved 2-fold after adding demographic information, a comorbidity score and interaction terms (r-square = 0.26). This study provided additional insights into the development of an automatic frailty assessment, something which is currently missing from clinical care.

4.1 Comparison with prior literature

Several previous studies attempted to develop frailty prediction models, however most often they focused on outcomes that are related to frailty (e.g., mortality or readmission) but did not utilize a validated, in-person assessment of frailty, such as the REFS, and instead utilized other claims data to define frailty outcomes[7,10,16]. This research was also completed outside of the United States[7,16] highlighting a gap in generalizability that is addressed by the current project. Only one prior study developed a claims-based frailty indicator anchored to a well-established frailty phenotype (Fried frailty phenotype measured in the cardiovascular health study).[7] However, this study included only Medicare patients and utilized outpatient claims data.[7] The only other study that developed a hospital frailty risk score using data from EHR was done in UK and may not reflect accurately the US population characteristics.[16]

We attempted to predict an actual, validated measure of frailty utilizing data available in the EHR. Utilizing only data that is already available in the EHR and would not require additional questionnaires or other clinical measures, would make it easier to

complete risk assessments for frail individuals. These clinical risk assessments could then lead to targeted intervention and care to frail patients, ultimately lowering readmissions, hospitalizations, and deaths.

4.2 Strengths and limitations

The major strength of this study compared to others is the large population size and utilizing an in-person, validated assessment of frailty as the outcome. Further, this study utilized rigorous methodology using LASSO regression for model development and validation. Some limitations of the study include that it only included a population from a single, large academic medical center. In addition, non-English speaking individuals were also excluded. While this study was completed at a single, academic institution, we anticipate that the results would still be generalizable due to the large sample size and rigorous methodology.

4.3 Future directions

While these prediction models were shown to be weak, it still provides critical information for the development of a clinical frailty tool. The results showed that there were strong relationships between depression and age, both separately and combined, relating to frailty. Knowing that depression has a strong relationship to frailty provides insight into a potential area for intervention. This project supports the notion older individuals have higher rates of depression and this was associated with frailty. Providers and healthcare personnel may be able to provide early interventions to help quell the development of depression in older populations and as such, potentially have an impact on an individual's frailty, which could then lead to less admissions to the hospital and even lower mortality rates as a function of frailty. Additionally, future research may look

to utilize other clinically available variables, such as laboratory values, vital signs, home medications, prescriptions, etc. and not just ICD codes in prediction models. It could also to be important to look at variables outside of those available in the EHR to define frailty. Our study looked at clinical variables and comorbid conditions, and perhaps frailty is more than the sum of those variables. Future research could also aim to assess relationships of non-clinical variables to the outcome of frailty.

APPENDICES

APPENDIX A: ICD Codes in Frailty Domains

Frailty Domain	ICD-9/ICD 10 Code and Description
Debility Problems	799.3 DEBILITY NOS
	R54 Age-related physical debility
Fatigue Issues	780.79 MALAISE AND FATIGUE NEC
	R53.1 Weakness
	R53.81 Other malaise
	M62.81 Muscle weakness (generalized)
	728.87 MUSCLE WEAKNESS-GENERAL
	729.1 MYALGIA AND MYOSITIS NOS
Swallowing Issues	787.20 DYSPHAGIA NOS
	787.22 DYSPHAGIA, OROPHARYNGEAL
	R13.10 Dysphagia, unspecified
	R13.13 Dysphagia, pharyngeal phase
	527.7 SALIVARY SECRETION DIS
	530.0 ACHALASIA & CARDIOSPASM
	530.10 ESOPHAGITIS, UNSPECIFIED
	530.11 REFLUX ESOPHAGITIS
	530.19 OTHER ESOPHAGITIS
	530.3 ESOPHAGEAL STRICTURE
	530.5 DYSKINESIA OF ESOPHAGUS
	530.81 ESOPHAGEAL REFLUX
	530.85 BARRETT'S ESOPHAGUS
	530.89 OTHER DSRDERS ESOPHAGUS
	J69.0 Pneumonitis due to inhalation of food and vomit
Nutrition Issues	261 NUTRITIONAL MARASMUS
	262 OTH SEVERE MALNUTRITION
	263.0 MALNUTRITION MOD DEGREE
	263.9 PROTEIN-CAL MALNUTR NOS
	265.1 THIAMINE DEFIC NEC/NOS
	266.2 B-COMPLEX DEFIC NEC
	268.9 VITAMIN D DEFICIENCY NOS
	270.6 DIS UREA CYCLE METABOL
	271.3 DISACCHARIDASE DEF/MALAB
	272.0 PURE HYPERCHOLESTEROLEM
	272.1 PURE HYPERGLYCERIDEMIA
	272.2 MIXED HYPERLIPIDEMIA
	272.4 HYPERLIPIDEMIA NEC/NOS
	273.1 MONOCLON PARAPROTEINEMIA
	E11.9 Type 2 diabetes mellitus without complications
	579.0 CELIAC DISEASE

	249.00 SEC DM WO CMP NT ST UNCN
	250.00 DMII WO CMP NT ST UNCNTR
	250.02 DMII WO CMP UNCNTRLD
	250.03 DMI WO CMP UNCNTRLD
	250.13 DMI KETOACD UNCONTROLD
	250.20 DMII HPRSM NT ST UNCNTRL
	250.40 DMII RENL NT ST UNCNTRLD
	250.42 DMII RENAL UNCNTRLD
	250.43 DMI RENAL UNCNTRLD
	250.50 DMII OPHTH NT ST UNCNTRL
	250.51 DMI OPHTH NT ST UNCNTRLD
	250.52 DMII OPHTH UNCNTRLD
	250.60 DMII NEURO NT ST UNCNTRL
	250.62 DMII NEURO UNCNTRLD
	250.70 DMII CIRC NT ST UNCNTRLD
	250.72 DMII CIRC UNCNTRLD
	250.80 DMII OTH NT ST UNCNTRLD
	250.81 DMI OTH NT ST UNCNTRLD
	250.82 DMII OTH UNCNTRLD
	251.2 HYPOGLYCEMIA NOS
	783.21 ABNORMAL LOSS OF WEIGHT
	783.22 UNDERWEIGHT
	Z79.4 Long term (current) use of insulin
	Z68.1 Body mass index [BMI] 19.9 or less, adult
	V85.0 BMI LESS THAN 19,ADULT
	R68.81 Early satiety
	R73.01 Impaired fasting glucose
	R73.03 Prediabetes
	R73.9 Hyperglycemia, unspecified
	R63.0 Anorexia
	R63.1 Polydipsia
	R63.4 Abnormal weight loss
	R64 Cachexia
	E43 Unspecified severe protein-calorie malnutrition
	E44.0 Moderate protein-calorie malnutrition
	E44.1 Mild protein-calorie malnutrition
	E46 Unspecified protein-calorie malnutrition
	E53.8 Deficiency of other specified B group vitamins
	E53.9 Vitamin B deficiency, unspecified
	E55.9 Vitamin D deficiency, unspecified
	E10.21 Type 1 diabetes mellitus with diabetic nephropathy
	E10.22 Type 1 diabetes mellitus w diabetic chronic kidney disease

	E10.319 Type 1 diabetes w unsp diabetic rtnop w/o macular edema
	E10.43 Type 1 diabetes w diabetic autonomic (poly)neuropathy
	E10.51 Type 1 diabetes w diabetic peripheral angiopath w/o gangrene
	E10.649 Type 1 diabetes mellitus with hypoglycemia without coma
	E10.65 Type 1 diabetes mellitus with hyperglycemia
	E11.21 Type 2 diabetes mellitus with diabetic nephropathy
	E11.22 Type 2 diabetes mellitus w diabetic chronic kidney disease
	E11.29 Type 2 diabetes mellitus w oth diabetic kidney complication
	E11.319 Type 2 diabetes w unsp diabetic rtnop w/o macular edema
	E11.329 Type 2 diab w mild nonprlf diabetic rtnop w/o macular edema
	E11.3299 Type 2 diab with mild nonp rtnop without macular edema, unsp
	E11.39 Type 2 diabetes w oth diabetic ophthalmic complication
	E11.40 Type 2 diabetes mellitus with diabetic neuropathy, unsp
	E11.42 Type 2 diabetes mellitus with diabetic polyneuropathy
	E11.51 Type 2 diabetes w diabetic peripheral angiopath w/o gangrene
	E11.52 Type 2 diabetes w diabetic peripheral angiopathy w gangrene
	E11.610 Type 2 diabetes mellitus w diabetic neuropathic arthropathy
	E11.628 Type 2 diabetes mellitus with other skin complications
	E11.649 Type 2 diabetes mellitus with hypoglycemia without coma
	E11.65 Type 2 diabetes mellitus with hyperglycemia
	E11.69 Type 2 diabetes mellitus with other specified complication
	E11.8 Type 2 diabetes mellitus with unspecified complications
	E13.10 Oth diabetes mellitus with ketoacidosis without coma
	E13.628 Oth diabetes mellitus with other skin complications
	E13.69 Oth diabetes mellitus with other specified complication
	E16.2 Hypoglycemia, unspecified
	783.0 ANOREXIA
	783.5 POLYDIPSIA

	783.6 POLYPHAGIA
	R62.7 Adult failure to thrive
Cognitive Issues	F01.50 Vascular dementia without behavioral disturbance
	F01.51 Vascular dementia with behavioral disturbance
	F02.80 Dementia in oth diseases classd elswhr w/o behavrl disturb
	F02.81 Dementia in oth diseases classd elswhr w behavioral disturb
	F03.90 Unspecified dementia without behavioral disturbance
	F03.91 Unspecified dementia with behavioral disturbance
	F05 Delirium due to known physiological condition
	F09 Unsp mental disorder due to known physiological condition
	G30.9 Alzheimer's disease, unspecified
	G31.83 Dementia with Lewy bodies
	G31.84 Mild cognitive impairment, so stated
	I69.320 Aphasia following cerebral infarction
	I69.31 Cognitive deficits following cerebral infarction
	I69.920 Aphasia following unspecified cerebrovascular disease
	797 SENILITY W/O PSYCHOSIS
	R47.01 Aphasia
	331.0 ALZHEIMER'S DISEASE
	331.19 FRONTOTEMP DEMENTIA NEC
	331.4 OBSTRUCTIV HYDROCEPHALUS
	331.82 DEMENTIA W LEWY BODIES
	331.83 MILD COGNITIVE IMPAIREMT
	784.3 APHASIA
	780.93 MEMORY LOSS
Acute Confusion States	F19.939 Other psychoactive substance use, unsp with withdrawal, unsp
	F22 Delusional disorders
	F23 Brief psychotic disorder
	F31.2 Bipolar disord, crnt episode manic severe w psych features
	R41.0 Disorientation, unspecified
	R41.82 Altered mental status, unspecified
	850.0 CONCUSSION W/O COMA
	850.11 CONCUS-BRIEF COMA <31 MN
	850.5 CONCUSSION W COMA NOS
	850.9 CONCUSSION NOS
	780.97 ALTERED MENTAL STATUS
	780.09 OTHER ALTER CONSCIOUSNES
	780.1 HALLUCINATIONS
	780.2 SYNCOPE AND COLLAPSE

	780.4 DIZZINESS AND GIDDINESS
Incontinence	N39.3 Stress incontinence (female) (male)
	N39.41 Urge incontinence
	N39.46 Mixed incontinence
	N39.498 Other specified urinary incontinence
	R32 Unspecified urinary incontinence
	R15.9 Full incontinence of feces
	N39.0 Urinary tract infection, site not specified
	N39.3 Stress incontinence (female) (male)
	N39.41 Urge incontinence
	N39.46 Mixed incontinence
	N39.498 Other specified urinary incontinence
	788.30 URINARY INCONTINENCE NOS
	788.31 URGE INCONTINENCE
	788.41 URINARY FREQUENCY
	788.42 POLYURIA
	788.43 NOCTURIA
	788.63 URGENCY OF URINATION
	788.69 OTH ABNORMALT URINATION
	787.60 FULL INCONTINENCE-FECES
Chronic Skin Ulcers	E10.622 Type 1 diabetes mellitus with other skin ulcer
	E11.621 Type 2 diabetes mellitus with foot ulcer
	I70.245 Athscl native arteries of left leg w ulceration oth prt foot
	I83.019 Varicose veins of right lower extremity w ulcer of unsp site
	I83.208 Varicos vn unsp low extrm w ulc oth prt low extrm and inflam
	K25.4 Chronic or unspecified gastric ulcer with hemorrhage
	K25.9 Gastric ulcer, unsp as acute or chronic, w/o hemor or perf
	K26.0 Acute duodenal ulcer with hemorrhage
	K26.4 Chronic or unspecified duodenal ulcer with hemorrhage
	K26.9 Duodenal ulcer, unsp as acute or chronic, w/o hemor or perf
	K27.7 Chronic peptic ulcer, site unsp, w/o hemorrhage or perf
	K27.9 Peptic ulc, site unsp, unsp as ac or chr, w/o hemor or perf
	L89.110 Pressure ulcer of right upper back, unstageable
	L89.152 Pressure ulcer of sacral region, stage 2
	L89.153 Pressure ulcer of sacral region, stage 3
	L89.154 Pressure ulcer of sacral region, stage 4
	L89.324 Pressure ulcer of left buttock, stage 4
	L89.611 Pressure ulcer of right heel, stage 1

	L89.890 Pressure ulcer of other site, unstageable
	L97.411 Non-prs chr ulcer of right heel and midft lmt to brkdwn skin
	L97.422 Non-prs chr ulcer of left heel and midfoot w fat layer expos
	L97.519 Non-prs chronic ulcer oth prt right foot w unsp severity
	L97.521 Non-prs chronic ulcer oth prt l foot limited to brkdwn skin
	L97.529 Non-pressure chronic ulcer oth prt left foot w unsp severity
	L97.819 Non-pressure chronic ulcer oth prt r low leg w unsp severity
	L97.829 Non-pressure chronic ulcer oth prt l low leg w unsp severity
	L97.919 Non-prs chronic ulc unsp prt of r low leg w unsp severity
	L97.929 Non-prs chronic ulc unsp prt of l low leg w unsp severity
	Z87.11 Personal history of peptic ulcer disease
	707.24 PRESSURE ULCER, STAGE IV
	707.22 PRESSURE ULCER, STAGE II
	707.21 PRESSURE ULCER, STAGE I
	707.20 PRESSURE ULCER,STAGE NOS
	707.10 ULCER OF LOWER LIMB NOS
	707.09 PRESSURE ULCER, SITE NEC
	707.00 PRESSURE ULCER, SITE NOS
	707.03 PRESSURE ULCER, LOW BACK
	707.05 PRESSURE ULCER, BUTTOCK
	707.07 PRESSURE ULCER, HEEL
	707.12 ULCER OF CALF
	707.13 ULCER OF ANKLE
	707.14 ULCER OF HEEL & MIDFOOT
	707.15 ULCER OTHER PART OF FOOT
	707.19 ULCER OTH PART LOW LIMB
	707.23 PRESSURE ULCER,STAGE III
	707.8 CHRONIC SKIN ULCER NEC
	707.9 CHRONIC SKIN ULCER NOS
Sensory Impairment	359.9 MYOPATHY NOS
	362.01 DIABETIC RETINOPATHY NOS
	362.03 NONPROLF DB RETNOPH NOS
	362.50 MACULAR DEGENERATION NOS
	362.57 DRUSEN (DEGENERATIVE)
	362.60 PERIPH RETINA DEGEN NOS

	365.10 OPEN-ANGLE GLAUCOMA NOS
	365.70 GLAUCOMA STAGE NOS
	365.89 GLAUCOMA NEC
	365.9 GLAUCOMA NOS
	366.9 CATARACT NOS
	368.16 PSYCHOPHYSIC VISUAL DIST
	368.8 VISUAL DISTURBANCES NEC
	369.00 BOTH EYES BLIND-WHO DEF
	369.4 LEGAL BLINDNESS-USA DEF
	369.60 BLINDNESS, ONE EYE
	369.8 VISUAL LOSS, ONE EYE NOS
	369.9 VISUAL LOSS NOS
	373.11 HORDEOLUM EXTERNUM
	376.33 ORBITAL EDEMA
	377.41 ISCHEMIC OPTIC NEUROPTHY
	378.53 FOURTH NERVE PALSY
	378.54 SIXTH NERVE PALSY
	379.50 NYSTAGMUS NOS
	382.9 OTITIS MEDIA NOS
	383.00 AC MASTOIDITIS W/O COMPL
	383.9 MASTOIDITIS NOS
	386.00 MENIERE'S DISEASE NOS
	386.10 PERIPHERAL VERTIGO NOS
	388.01 PRESBYACUSIS
	389.10 SENSORNEUR HEAR LOSS NOS
	389.8 HEARING LOSS NEC
	389.9 HEARING LOSS NOS
	Z98.41 Cataract extraction status, right eye
	Z98.42 Cataract extraction status, left eye
	Z98.49 Cataract extraction status, unspecified eye
	Z97.0 Presence of artificial eye
	H26.9 Unspecified cataract
	H35.30 Unspecified macular degeneration
	H40.20X0 Unsp primary angle-closure glaucoma, stage unspecified
	H40.9 Unspecified glaucoma
	H47.20 Unspecified optic atrophy
	H53.2 Diplopia
	H53.421 Scotoma of blind spot area, right eye
	H54.0 Blindness, both eyes
	H54.41 Blindness, right eye, normal vision left eye
	H54.42 Blindness, left eye, normal vision right eye
	H54.8 Legal blindness, as defined in USA

	H57.12 Ocular pain, left eye
	H57.8 Other specified disorders of eye and adnexa
	H59.312 Postproc hemor of left eye and adnexa fol an opth procedure
	R42 Dizziness and giddiness
	R44.1 Visual hallucinations
	H90.5 Unspecified sensorineural hearing loss
	H91.90 Unspecified hearing loss, unspecified ear
	H91.91 Unspecified hearing loss, right ear
	H91.93 Unspecified hearing loss, bilateral
	H05.20 Unspecified exophthalmos
	H61.22 Impacted cerumen, left ear
	H81.09 Meniere's disease, unspecified ear
	H81.10 Benign paroxysmal vertigo, unspecified ear
Impaired Mobility	Z99.3 Dependence on wheelchair
	Z96.611 Presence of right artificial shoulder joint
	Z96.641 Presence of right artificial hip joint
	Z96.642 Presence of left artificial hip joint
	Z96.643 Presence of artificial hip joint, bilateral
	Z96.649 Presence of unspecified artificial hip joint
	Z96.651 Presence of right artificial knee joint
	Z96.652 Presence of left artificial knee joint
	Z96.653 Presence of artificial knee joint, bilateral
	Z96.659 Presence of unspecified artificial knee joint
	Z96.89 Presence of other specified functional implants
	G20 Parkinson's disease
	G25.0 Essential tremor
	G25.81 Restless legs syndrome
	M13.822 Other specified arthritis, left elbow
	M13.871 Other specified arthritis, right ankle and foot
	M13.872 Other specified arthritis, left ankle and foot
	M13.88 Other specified arthritis, other site
	M16.0 Bilateral primary osteoarthritis of hip
	M16.10 Unilateral primary osteoarthritis, unspecified hip
	M17.0 Bilateral primary osteoarthritis of knee
	M17.11 Unilateral primary osteoarthritis, right knee
	M17.12 Unilateral primary osteoarthritis, left knee
	M17.9 Osteoarthritis of knee, unspecified
	M19.011 Primary osteoarthritis, right shoulder
	M19.039 Primary osteoarthritis, unspecified wrist
	M19.041 Primary osteoarthritis, right hand
	M19.042 Primary osteoarthritis, left hand
	M19.049 Primary osteoarthritis, unspecified hand

	M19.079 Primary osteoarthritis, unspecified ankle and foot
	M19.90 Unspecified osteoarthritis, unspecified site
	R26.89 Other abnormalities of gait and mobility
	214.8 LIPOMA NEC
	357.2 NEUROPATHY IN DIABETES
	278.00 OBESITY NOS
	278.01 MORBID OBESITY
	278.02 OVERWEIGHT
	278.03 OBESITY HYPOVENT SYND
	356.1 PERONEAL MUSCLE ATROPHY
	443.9 PERIPH VASCULAR DIS NOS
	Z99.81 Dependence on supplemental oxygen
	Z74.01 Bed confinement status
	Z68.26 Body mass index [BMI] 26.0-26.9, adult
	Z68.27 Body mass index [BMI] 27.0-27.9, adult
	Z68.28 Body mass index [BMI] 28.0-28.9, adult
	Z68.29 Body mass index [BMI] 29.0-29.9, adult
	Z68.30 Body mass index [BMI]30.0-30.9, adult
	Z68.31 Body mass index [BMI] 31.0-31.9, adult
	Z68.32 Body mass index [BMI] 32.0-32.9, adult
	Z68.33 Body mass index [BMI] 33.0-33.9, adult
	Z68.34 Body mass index [BMI] 34.0-34.9, adult
	Z68.35 Body mass index [BMI] 35.0-35.9, adult
	Z68.36 Body mass index [BMI] 36.0-36.9, adult
	Z68.37 Body mass index [BMI] 37.0-37.9, adult
	Z68.38 Body mass index [BMI] 38.0-38.9, adult
	Z68.39 Body mass index [BMI] 39.0-39.9, adult
	Z68.41 Body mass index [BMI]40.0-44.9, adult
	Z68.42 Body mass index [BMI] 45.0-49.9, adult
	Z68.43 Body mass index [BMI] 50.0-59.9, adult
	Z68.44 Body mass index [BMI] 60.0-69.9, adult
	V85.23 BMI 27.0-27.9,ADULT
	V85.24 BMI 28.0-28.9,ADULT
	V85.25 BMI 29.0-29.9,ADULT
	V85.30 BMI 30.0-30.9,ADULT
	V85.31 BMI 31.0-31.9,ADULT
	V85.32 BMI 32.0-32.9,ADULT
	V85.33 BMI 33.0-33.9,ADULT
	V85.34 BMI 34.0-34.9,ADULT
	V85.35 BMI 35.0-35.9,ADULT
	V85.36 BMI 36.0-36.9,ADULT
	V85.37 BMI 37.0-37.9,ADULT
	V85.38 BMI 38.0-38.9,ADULT

	V85.39 BMI 39.0-39.9,ADULT
	V85.41 BMI 40.0-44.9, ADULT
	V85.42 BMI 45.0-49.9, ADULT
	V85.43 BMI 50.0-59.9, ADULT
	V85.45 BMI 70 AND OVER, ADULT
	V46.11 RESPIRATOR DEPEND STATUS
	V46.2 DEPEND-SUPPLEMENT OXYGEN
	V46.3 WHEELCHAIR DEPENDENCE
	V49.71 STATUS AMPUT GREAT TOE
	V49.72 STATUS AMPUT OTHR TOE(S)
	V49.73 STATUS AMPUT FOOT
	V49.75 STATUS AMPUT BELOW KNEE
	V49.76 STATUS AMPUT ABOVE KNEE
	V49.84 BED CONFINEMENT STATUS
	R26.2 Difficulty in walking, not elsewhere classified
	R26.81 Unsteadiness on feet
	R27.0 Ataxia, unspecified
	I73.89 Other specified peripheral vascular diseases
	I73.9 Peripheral vascular disease, unspecified
	G82.20 Paraplegia, unspecified
	E66.01 Morbid (severe) obesity due to excess calories
	E66.2 Morbid (severe) obesity with alveolar hypoventilation
	E66.3 Overweight
	E66.9 Obesity, unspecified
	781.2 ABNORMALITY OF GAIT
	781.3 LACK OF COORDINATION
	714.0 RHEUMATOID ARTHRITIS
	714.9 INFLAMM POLYARTHROP NOS
	715.15 LOC PRIM OSTEOART-PELVIS
	715.31 LOC OSTEOARTH NOS-SHLDER
	715.32 LOC OSTEOARTH NOS-UP/ARM
	715.34 LOC OSTEOARTH NOS-HAND
	715.35 LOC OSTEOARTH NOS-PELVIS
	715.36 LOC OSTEOARTH NOS-L/LEG
	715.38 LOC OSTEOAR NOS-SITE NEC
	715.90 OSTEOARTHROS NOS-UNSPEC
	715.91 OSTEOARTHROS NOS-SHLDER
	715.95 OSTEOARTHROS NOS-PELVIS
	715.96 OSTEOARTHROS NOS-L/LEG
	344.1 PARAPLEGIA NOS
Depression Problems	290.0 SENILE DEMENTIA UNCOMP
	290.40 VASCULAR DEMENTIA,UNCOMP
	290.41 VASC DEMENTIA W DELIRIUM

	291.0 DELIRIUM TREMENS
	291.2 ALCOHOL PERSIST DEMENTIA
	292.81 DRUG-INDUCED DELIRIUM
	293.0 DELIRIUM D/T OTHER COND
	293.83 MOOD DISORDER OTHER DIS
	293.9 TRANSIENT MENTAL DIS NOS
	294.10 DEMENTIA W/O BEHAV DIST
	294.11 DEMENTIA W BEHAVIOR DIST
	294.20 DEMEN NOS W/O BEHV DSTRB
	294.21 DEMEN NOS W BEHAV DISTRB
	295.90 SCHIZOPHRENIA NOS-UNSPEC
	296.20 DEPRESS PSYCHOSIS-UNSPEC
	296.24 DEPR PSYCHOS-SEV W PSYCH
	296.30 RECURR DEPR PSYCHOS-UNSP
	296.44 BIPOL I MANIC-SEV W PSY
	296.80 BIPOLAR DISORDER NOS
	296.89 BIPOLAR DISORDER NEC
	296.90 EPISODIC MOOD DISORD NOS
	297.1 DELUSIONAL DISORDER
	298.9 PSYCHOSIS NOS
	300.00 ANXIETY STATE NOS
	300.01 PANIC DIS W/O AGORPHOBIA
	300.02 GENERALIZED ANXIETY DIS
	300.22 AGORAPHOBIA W/O PANIC
	300.3 OBSESSIVE-COMPULSIVE DIS
	300.4 DYSTHYMIC DISORDER
	301.83 BORDERLINE PERSONALITY
	303.90 ALCOH DEP NEC/NOS-UNSPEC
	309.0 ADJUSTMNT DIS W DEPRESSN
	309.81 POSTTRAUMATIC STRESS DIS
	311 DEPRESSIVE DISORDER NEC
	F31.9 Bipolar disorder, unspecified
	F32.9 Major depressive disorder, single episode, unspecified
	F33.1 Major depressive disorder, recurrent, moderate
	F33.41 Major depressive disorder, recurrent, in partial remission
	F39 Unspecified mood [affective] disorder
	F41.0 Panic disorder [episodic paroxysmal anxiety]
	F41.1 Generalized anxiety disorder
	F41.8 Other specified anxiety disorders
	F41.9 Anxiety disorder, unspecified
	F43.10 Post-traumatic stress disorder, unspecified
	F43.21 Adjustment disorder with depressed mood

	F43.22 Adjustment disorder with anxiety
Falls	E880.9 FALL ON STAIR/STEP NEC
	E881.0 FALL FROM LADDER
	E884.2 FALL FROM CHAIR
	E884.3 FALL FROM WHEELCHAIR
	E884.4 FALL FROM BED
	E884.6 FALL FROM COMMODE
	E884.9 FALL-1 LEVEL TO OTH NEC
	E885.9 FALL FROM SLIPPING NEC
	E888.1 FALL STRIKING OBJECT NEC
	E888.8 FALL NEC
	E888.9 FALL NOS
	E917.9 OBJ W-W/O SUB FALL NEC
	E918 CAUGHT BETWEEN OBJECTS
	E929.3 LATE EFF ACCIDENTAL FALL
	Z91.81 History of falling
	R29.6 Repeated falls
	W01.0XXA Fall same lev from slip/trip w/o strike against object, init
	W05.0XXA Fall from non-moving wheelchair, initial encounter
	W06.XXXA Fall from bed, initial encounter
	W06.XXXD Fall from bed, subsequent encounter
	W18.09XA Striking against oth object w subsequent fall, init encntr
	W18.11XA Fall from or off toilet w/o strike against object, init
	W18.30XA Fall on same level, unspecified, initial encounter
	W18.39XA Other fall on same level, initial encounter
	W19.XXXA Unspecified fall, initial encounter
	W19.XXXD Unspecified fall, subsequent encounter
Fractures	S22.000A Wedge compression fracture of unsp thoracic vertebra, init
	S22.079A Unsp fracture of T9-T10 vertebra, init for clos fx
	S22.31XA Fracture of one rib, right side, init for clos fx
	S22.41XA Multiple fractures of ribs, right side, init for clos fx
	S32.018A Oth fracture of first lumbar vertebra, init for clos fx
	S32.019A Unsp fracture of first lumbar vertebra, init for clos fx
	S32.028A Oth fracture of second lumbar vertebra, init for clos fx
	S42.009A Fracture of unsp part of unsp clavicle, init for clos fx
	S42.309D Unsp fx shaft of humerus, unsp arm, subs for fx w routn heal

	S52.502A Unsp fracture of the lower end of left radius, init
	S72.011A Unsp intracapsular fracture of right femur, init for clos fx
	S72.22XA Displaced subtrochanteric fracture of left femur, init
	S72.91XD Unsp fracture of right femur, subs for clos fx w routn heal
	S92.312A Disp fx of first metatarsal bone, left foot, init
	S92.322A Disp fx of second metatarsal bone, left foot, init
	S92.332A Disp fx of third metatarsal bone, left foot, init
	S92.342A Disp fx of fourth metatarsal bone, left foot, init
	S92.902A Unsp fracture of left foot, init encntr for closed fracture
	V13.51 HX PATHOLOGICAL FRACTURE
	V15.51 HX TRAUMATIC FRACTURE
	733.81 MALUNION OF FRACTURE
	733.82 NONUNION OF FRACTURE
	733.94 STRESS FX METATARSALS
	733.12 PATH FX DSTL RADIUS ULNA
	733.13 PATH FX VERTEBRAE
	733.14 PATH FX NECK OF FEMUR
	733.16 PATH FX TIBIA FIBULA
	733.19 PATH FX OTH SPECIF SITE
	802.0 NASAL BONE FX-CLOSED
	805.00 FX CERVICAL VERT NOS-CL
	805.02 FX C2 VERTEBRA-CLOSED
	805.2 FX DORSAL VERTEBRA-CLOSE
	805.4 FX LUMBAR VERTEBRA-CLOSE
	807.00 FRACTURE RIB NOS-CLOSED
	807.01 FRACTURE ONE RIB-CLOSED
	807.03 FRACTURE THREE RIBS-CLOS
	807.04 FRACTURE FOUR RIBS-CLOSE
	807.05 FRACTURE FIVE RIBS-CLOSE
	807.06 FRACTURE SIX RIBS-CLOSED
	807.07 FRACTURE SEVEN RIBS-CLOS
	807.09 FX MULT RIBS NOS-CLOSED
	807.2 FRACTURE OF STERNUM-CLOS
	808.0 FRACTURE ACETABULUM-CLOS
	808.2 FRACTURE OF PUBIS-CLOSED
	808.44 PELV FX-CL W/O PLV DISRP
	808.8 PELVIC FRACTURE NOS-CLOS
	811.03 FX SCAP, GLEN CAV/NCK-CL
	812.00 FX UP END HUMERUS NOS-CL
	812.01 FX SURG NCK HUMERUS-CLOS

	812.03 FX GR TUBEROS HUMERUS-CL
	812.20 FX HUMERUS NOS-CLOSED
	812.21 FX HUMERUS SHAFT-CLOSED
	812.40 FX LOWER HUMERUS NOS-CL
	813.01 FX OLECRAN PROC ULNA-CL
	813.13 MONTEGGIA'S FX-OPEN
	813.42 FX DISTAL RADIUS NEC-CL
	813.44 FX LOW RADIUS W ULNA-CL
	813.83 FX RADIUS W ULNA NOS-CL
	815.01 FX 1ST METACARP BASE-CL
	816.02 FX DIST PHALANX, HAND-CL
	820.00 FX FEMUR INTRCAPS NOS-CL
	820.03 FX BASE FEMORAL NCK-CLOS
	820.09 FX FEMUR INTRCAPS NEC-CL
	820.20 TROCHANTERIC FX NOS-CLOS
	820.21 INTERTROCHANTERIC FX-CL
	820.22 SUBTROCHANTERIC FX-CLOSE
	820.8 FX NECK OF FEMUR NOS-CL
	821.00 FX FEMUR NOS-CLOSED
	821.01 FX FEMUR SHAFT-CLOSED
	821.20 FX LOW END FEMUR NOS-CL
	821.22 FX LOW FEMUR EPIPHY-CLOS
	821.23 SUPRACONDYL FX FEMUR-CL
	821.29 FX LOW END FEMUR NEC-CL
	822.0 FRACTURE PATELLA-CLOSED
	823.00 FX UPPER END TIBIA-CLOSE
	823.01 FX UPPER END FIBULA-CLOS
	823.02 FX UP TIBIA W FIBULA-CL
	823.20 FX SHAFT TIBIA-CLOSED
	823.22 FX SHAFT FIB W TIB-CLOS
	823.80 FX TIBIA NOS-CLOSED
	824.4 FX BIMALLEOLAR-CLOSED
	824.5 FX BIMALLEOLAR-OPEN
	824.6 FX TRIMALLEOLAR-CLOSED
	824.8 FX ANKLE NOS-CLOSED
	825.21 FX ASTRAGALUS-CLOSED
	825.25 FX METATARSAL-CLOSED
	825.31 FX ASTRAGALUS-OPEN
	829.0 FRACTURE NOS-CLOSED
	E887 FRACTURE, CAUSE NOS
	M80.08XA Age-rel osteopor w current path fracture, vertebra(e), init
	M80.88XA Oth osteopor w current path fracture, vertebra(e), init

	M81.0 Age-related osteoporosis w/o current pathological fracture
	M84.40XA Pathological fracture, unsp site, init encntr for fracture
	M84.444A Pathological fracture, right finger(s), init for fx
	M84.48XA Pathological fracture, other site, init encntr for fracture
	M84.58XA Pathological fracture in neoplastic disease, oth site, init
	V54.12 AFTRCRE TRAUM FX LOW ARM
	905.2 LATE EFFECT ARM FX
	905.4 LATE EFFECT LEG FX
	996.44 PERIPROSTHETC FX-PROS JT
Anemia	280.0 CHR BLOOD LOSS ANEMIA
	280.8 IRON DEFIC ANEMIA NEC
	280.9 IRON DEFIC ANEMIA NOS
	281.0 PERNICIOUS ANEMIA
	281.1 B12 DEFIC ANEMIA NEC
	281.9 DEFICIENCY ANEMIA NOS
	283.0 AUTOIMMUN HEMOLYTIC ANEM
	285.1 AC POSTHEMORRHAG ANEMIA
	285.21 ANEMIA IN CHR KIDNEY DIS
	285.22 ANEMIA IN NEOPLASTIC DIS
	285.29 ANEMIA-OTHER CHRONIC DIS
	285.3 ANEMIA D/T ANTINEO CHEMO
	285.8 ANEMIA NEC
	285.9 ANEMIA NOS
	D46.21 Refractory anemia with excess of blasts 1
	D50.0 Iron deficiency anemia secondary to blood loss (chronic)
	D50.9 Iron deficiency anemia, unspecified
	D51.0 Vitamin B12 defic anemia due to intrinsic factor deficiency
	D53.8 Other specified nutritional anemias
	D53.9 Nutritional anemia, unspecified
	D58.9 Hereditary hemolytic anemia, unspecified
	D62 Acute posthemorrhagic anemia
	D63.1 Anemia in chronic kidney disease
	D63.8 Anemia in other chronic diseases classified elsewhere
	D64.81 Anemia due to antineoplastic chemotherapy
	D64.9 Anemia, unspecified

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