

THE LANCET

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

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APPENDICES

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APPENDIX 1 - List of ICD-10 codes selected *a priori* as markers of frailty

A list of ICD-10 codes was put together as candidate markers of frailty following consultation with primary care, public health and geriatric medicine physicians and clinical coding staff in one acute hospital trust. This was used to identify hospitalised older adults (75 years+) who might be frail. The proportion with any one of the following ICD-10 codes in their hospital records was calculated for each of the six clusters.

Table A1 ICD-10 codes relevant to frailty

ICD-10 code	ICD Description
E46	Unspecified protein-energy malnutrition
F00, F01, F02, F03, F05	F00* Dementia in Alzheimer's disease
	F00.0* Dementia in Alzheimer's disease with early onset (G30.0+)
	F00.1* Dementia in Alzheimer's disease with late onset
	F00.2* Dementia in Alzheimer's disease, atypical or mixed type
	F00.9* Dementia in Alzheimer's disease, unspecified
	F01 Vascular dementia
	F01.0 Vascular dementia of acute onset
	F01.1 Multi-infarct dementia
	F01.2 Subcortical vascular dementia
	F01.3 Mixed cortical and subcortical vascular dementia
	F01.8 Other vascular dementia
	F01.9 Vascular dementia, unspecified
	F02* Dementia in other diseases classified elsewhere
	F02.0* Dementia in Pick's disease A
	F02.1* Dementia in Creutzfeldt-Jakob disease
	F02.2* Dementia in Huntington's disease
	F02.3* Dementia in Parkinson's disease
	F02.4* Dementia in human immunodeficiency virus [HIV] disease
	F02.8* Dementia in other specified diseases classified elsewhere
	F03 Unspecified dementia
	F05 Delirium, not induced by alcohol and other psychoactive substances
	Excludes: delirium tremens, alcohol-induced or unspecified (F10.4)
	F05.0 Delirium not superimposed on dementia, so described

	F05.1 Delirium superimposed on dementia
	F05.8 Other delirium
	F05.9 Delirium, unspecified
R15	Faecal incontinence
R26.2 & R26.8	R26.2 Difficulty in walking, not elsewhere classified
	R26.8 Other and unspecified abnormalities of gait and mobility
R32	Unspecified urinary incontinence
R40	Somnolence, stupor and coma
	Excludes: coma:
	· diabetic
	· hepatic
	· hypoglycaemic (nondiabetic)
	· neonatal
	· uraemic

Table A1 continued - ICD-10 codes relevant to frailty

ICD-10 code	ICD Description
R41	Other symptoms and signs involving cognitive functions and awareness
	R41.0 Disorientation, unspecified
	R41.1 Anterograde amnesia
	R41.2 Retrograde amnesia
	R41.3 Other amnesia
	R41.8 Other and unspecified symptoms and signs
R46.0	Very low level of personal hygiene
R54	Senility
W00-W19	Falls
Z73.9	Problem related to life-management difficulty, unspecified
Z74	Problems related to care-provider dependency
	Z74.0 Reduced mobility, bedfast, chairfast
	Z74.1 Need for assistance with personal care
	Z74.2 Need for assistance at home and no other household member able to render care
	Z74.3 Need for continuous supervision
	Z74.8 Other problems related to care-provider dependency
	Z74.9 Problem related to care-provider dependency, unspecified
Z99.3	Dependence on wheelchair

APPENDIX 2 - Model used to develop Hospital Frailty Risk Score

We used the results of the cluster analysis to develop a hospital frailty risk score. In a development cohort of 22,139 people aged 75 years+, one out of the six clusters was identified as having characteristics of frailty. We derived a hospital frailty risk score based on the broad set of 109 ICD-10 codes that were at least twice as prevalent in this frail group compared with the rest of the cohort, not restricted to pre-defined frailty syndromes.

Because many of the ICD-10 codes were correlated, we created a score that was a weighted sum of these ICD codes rather than a count, awarding a certain number of points for each code that was present in a patient's records over two years. To calculate the points, we fitted a logistic regression model that included membership of the frail group as the binary dependent variable (frail vs. non-frail) and the set of ICD-10 codes as binary predictor variables (1 = present, 0 = absent for each code). We incorporated a penalty when fitting the model to shrink coefficients on individual predictor variables within correlated groups.^{1,2} This was estimated using the 'glmnet' package for ridge (penalised) regression in R (version 3.3.0), with the penalty selected through cross-validation to maximize the area under the receiver operating curve (c-statistic). The c-statistic summarises how well the model discriminates individual membership of the frail group.² A value of 0.5 indicates that the model classifies patient no better than chance and 1.0 indicates perfect discrimination.

To simplify the calculation and interpretation of the score, we multiplied regression coefficients by five to create a points system, so that a certain number of points are awarded for each ICD-10 code and added together to create the final frailty risk score.

Table A2 shows the list of ICD-10 codes that contribute to the hospital frailty risk score, their prevalence (over two years) in the development cohort overall and in the frail cluster, and the number of points awarded for each code to create final score. The SAS code to calculate the score using patient-level HES data is also provided as a macro.

References

1. Barker L, Brown C. Logistic regression when binary predictor variables are highly correlated. *Statist. Med* 2001; 20: 1431-1442.
2. Harrell FE. *Regression modelling strategies: with applications to linear models, logistic and ordinal regression and survival analysis*. 2nd Edition Springer: New York 2015.

Table A2 List of 109 ICD-10 codes included in logistic regression model and number of points awarded for each to create the hospital frailty risk score

ICD Code	ICD Description	Number with code in devt cohort (n = 22,139)	%	Number with code in frail group (n = 4,907)	%	Points awarded
F00	Dementia in Alzheimer's disease	664	3.0%	564	11.5%	7.1
G81	Hemiplegia	332	1.5%	240	4.9%	4.4
G30	Alzheimer's disease	1,107	5.0%	751	15.3%	4.0
I69	Sequelae of cerebrovascular disease (secondary codes)	509	2.3%	343	7.0%	3.7
R29	Other symptoms and signs involving the nervous and musculoskeletal systems (R29.6 Tendency to fall)	4,140	18.7%	2,429	49.5%	3.6
N39	Other disorders of urinary system (includes urinary tract infection and urinary incontinence)	3,852	17.4%	2,233	45.5%	3.2
F05	Delirium, not induced by alcohol and other psychoactive substances	1,328	6.0%	923	18.8%	3.2
W19	Unspecified fall	2,568	11.6%	1,462	29.8%	3.2
S00	Superficial injury of head	886	4.0%	569	11.6%	3.2
R31	Unspecified haematuria	708	3.2%	309	6.3%	3.0
B96	Other bacterial agents as the cause of diseases classified to other chapters (secondary code)	1,395	6.3%	918	18.7%	2.9
R41	Other symptoms and signs involving cognitive functions and awareness	2,037	9.2%	1,222	24.9%	2.7
R26	Abnormalities of gait and mobility	1,882	8.5%	1,114	22.7%	2.6
I67	Other cerebrovascular diseases	1,838	8.3%	1,050	21.4%	2.6
R56	Convulsions, not elsewhere classified	332	1.5%	206	4.2%	2.6
R40	Somnolence, stupor and coma	266	1.2%	177	3.6%	2.5
T83	Complications of genitourinary prosthetic devices, implants and grafts	244	1.1%	147	3.0%	2.4
S06	Intracranial injury	221	1.0%	128	2.6%	2.4

S42	Fracture of shoulder and upper arm	266	1.2%	142	2.9%	2.3
E87	Other disorders of fluid, electrolyte and acid-base balance	2,546	11.5%	1,251	25.5%	2.3
M25	Other joint disorders, not elsewhere classified	1,262	5.7%	648	13.2%	2.3
E86	Volume depletion	1,550	7.0%	893	18.2%	2.3
R54	Senility	332	1.5%	211	4.3%	2.2
Z50	Care involving use of rehabilitation procedures	354	1.6%	196	4.0%	2.1
F03	Unspecified dementia	2,701	12.2%	1,433	29.2%	2.1
W18	Other fall on same level	642	2.9%	363	7.4%	2.1
Z75	Problems related to medical facilities and other health care	642	2.9%	437	8.9%	2.0
F01	Vascular dementia	863	3.9%	491	10.0%	2.0
S80	Superficial injury of lower leg	244	1.1%	152	3.1%	2.0
L03	Cellulitis	863	3.9%	422	8.6%	2.0
H54	Blindness and low vision	642	2.9%	314	6.4%	1.9
E53	Deficiency of other B group vitamins	244	1.1%	123	2.5%	1.9
Z60	Problems related to social environment	487	2.2%	240	4.9%	1.8
G20	Parkinson's disease	487	2.2%	240	4.9%	1.8
R55	Syncope and collapse	1439	6.5%	633	12.9%	1.8
S22	Fracture of rib(s), sternum and thoracic spine	221	1.0%	113	2.3%	1.8
K59	Other functional intestinal disorders	2,590	11.7%	1,305	26.6%	1.8
N17	Acute renal failure	3,454	15.6%	1,713	34.9%	1.8
L89	Decubitus ulcer	775	3.5%	461	9.4%	1.7
Z22	Carrier of infectious disease	221	1.0%	132	2.7%	1.7
B95	Streptococcus and staphylococcus as the cause of diseases classified to other chapters	332	1.5%	182	3.7%	1.7
L97	Ulcer of lower limb, not elsewhere classified	797	3.6%	407	8.3%	1.6
R44	Other symptoms and signs involving general sensations and perceptions	221	1.0%	128	2.6%	1.6
K26	Duodenal ulcer	244	1.1%	98	2.0%	1.6
I95	Hypotension	1,727	7.8%	844	17.2%	1.6

N19	Unspecified renal failure	221	1.0%	93	1.9%	1.6
A41	Other septicaemia	952	4.3%	515	10.5%	1.6
Z87	Personal history of other diseases and conditions	2,790	12.6%	1,197	24.4%	1.5
J96	Respiratory failure, not elsewhere classified	886	4.0%	353	7.2%	1.5
X59	Exposure to unspecified factor	354	1.6%	196	4.0%	1.5
M19	Other arthrosis	2,635	11.9%	1,040	21.2%	1.5
G40	Epilepsy	443	2.0%	211	4.3%	1.5
M81	Osteoporosis without pathological fracture	1,660	7.5%	682	13.9%	1.4
S72	Fracture of femur	1,107	5.0%	530	10.8%	1.4
S32	Fracture of lumbar spine and pelvis	266	1.2%	128	2.6%	1.4
E16	Other disorders of pancreatic internal secretion	421	1.9%	211	4.3%	1.4
R94	Abnormal results of function studies	531	2.4%	236	4.8%	1.4
N18	Chronic renal failure	3,564	16.1%	1,354	27.6%	1.4
R33	Retention of urine	1,705	7.7%	824	16.8%	1.3
R69	Unknown and unspecified causes of morbidity	177	0.8%	103	2.1%	1.3
N28	Other disorders of kidney and ureter, not elsewhere classified	399	1.8%	172	3.5%	1.3
R32	Unspecified urinary incontinence	841	3.8%	461	9.4%	1.2
G31	Other degenerative diseases of nervous system, not elsewhere classified	686	3.1%	417	8.5%	1.2
Y95	Nosocomial condition	753	3.4%	447	9.1%	1.2
S09	Other and unspecified injuries of head	288	1.3%	157	3.2%	1.2
R45	Symptoms and signs involving emotional state	443	2.0%	260	5.3%	1.2
G45	Transient cerebral ischaemic attacks and related syndromes	244	1.1%	88	1.8%	1.2
Z74	Problems related to care-provider dependency	332	1.5%	201	4.1%	1.1
M79	Other soft tissue disorders, not elsewhere classified	930	4.2%	402	8.2%	1.1
W06	Fall involving bed	310	1.4%	186	3.8%	1.1

S01	Open wound of head	753	3.4%	407	8.3%	1.1
A04	Other bacterial intestinal infections	221	1.0%	108	2.2%	1.1
A09	Diarrhoea and gastroenteritis of presumed infectious origin	1,417	6.4%	618	12.6%	1.1
J18	Pneumonia, organism unspecified	3,830	17.3%	1,644	33.5%	1.1
J69	Pneumonitis due to solids and liquids	487	2.2%	250	5.1%	1.0
R47	Speech disturbances, not elsewhere classified	421	1.9%	236	4.8%	1.0
E55	Vitamin D deficiency	310	1.4%	157	3.2%	1.0
Z93	Artificial opening status	443	2.0%	162	3.3%	1.0
R02	Gangrene, not elsewhere classified	155	0.7%	83	1.7%	1.0
R63	Symptoms and signs concerning food and fluid intake	1,328	6.0%	564	11.5%	0.9
H91	Other hearing loss	1,151	5.2%	466	9.5%	0.9
W10	Fall on and from stairs and steps	266	1.2%	103	2.1%	0.9
W01	Fall on same level from slipping, tripping and stumbling	686	3.1%	270	5.5%	0.9
E05	Thyrotoxicosis [hyperthyroidism]	199	0.9%	74	1.5%	0.9
M41	Scoliosis	288	1.3%	123	2.5%	0.9
R13	Dysphagia	731	3.3%	324	6.6%	0.8
Z99	Dependence on enabling machines and devices	399	1.8%	167	3.4%	0.8
U80	Agent resistant to penicillin and related antibiotics	288	1.3%	177	3.6%	0.8
M80	Osteoporosis with pathological fracture	177	0.8%	83	1.7%	0.8
K92	Other diseases of digestive system	1,018	4.6%	388	7.9%	0.8
I63	Cerebral Infarction	863	3.9%	324	6.6%	0.8
N20	Calculus of kidney and ureter	133	0.6%	54	1.1%	0.7
F10	Mental and behavioural disorders due to use of alcohol	221	1.0%	93	1.9%	0.7
Y84	Other medical procedures as the cause of abnormal reaction of the patient	332	1.5%	147	3.0%	0.7
R00	Abnormalities of heart beat	1,284	5.8%	481	9.8%	0.7

J22	Unspecified acute lower respiratory infection	2,059	9.3%	878	17.9%	0.7
Z73	Problems related to life-management difficulty	421	1.9%	250	5.1%	0.6
R79	Other abnormal findings of blood chemistry	819	3.7%	324	6.6%	0.6
Z91	Personal history of risk-factors, not elsewhere classified	443	2.0%	182	3.7%	0.5
S51	Open wound of forearm	177	0.8%	103	2.1%	0.5
F32	Depressive episode	1395	6.3%	613	12.5%	0.5
M48	Spinal stenosis (secondary code only)	487	2.2%	177	3.6%	0.5
E83	Disorders of mineral metabolism	288	1.3%	132	2.7%	0.4
M15	Polyarthrosis	288	1.3%	113	2.3%	0.4
D64	Other anaemias	2,125	9.6%	829	16.9%	0.4
L08	Other local infections of skin and subcutaneous tissue	155	0.7%	83	1.7%	0.4
R11	Nausea and vomiting	1,196	5.4%	451	9.2%	0.3
K52	Other noninfective gastroenteritis and colitis	244	1.1%	93	1.9%	0.3
R50	Fever of unknown origin	354	1.6%	147	3.0%	0.1

Appendix 2 continued – SAS codes used to create the frailty algorithm

```

/*-----*/
/*          FRAILTY RISK SCORE MACRO          */
/*          frailtyriskscore.sas              */
/*          Version 1.0 01/07/2017           */
/*          Created by Jenny Neuberger and Eilis Keeble, Nuffield Trust */
/*          Contact: eilis.keeble@nuffieldtrust.org.uk */
/*-----*/
/* This macro is to be used to calculate frailty risk scores using patient */
/* -level historic data from the HES inpatient dataset over two years. */
/* */
/* The macro requires two inputs: */
/* 1. A CSV file which contains ICD10 codes and points to create the score, */
/*    the information for this can be found in Table A2. The selection of */
/*    these ICD10 codes and points is outlined in the methods section of the */
/*    paper. */
/* 2. A SAS data file containing episode level information of the patients */
/*    admission history with an index date of the most recent admission. */
/*    The score to be produced can be determined by specifying how much */
/*    history to read in on the "indat" command. For example to get only */
/*    history and not current admission, only admission dates less than */
/*    the index date should be imported. */
/* */
/* The resulting dataset, produced by the macro and named as the users sees */
/* fit, contains the id of the patients along with their frailty risk score. */
/* */
/* The syntax for calling the macro is: */
/* */
/* %create_score(csvfile = , indata = , outdat = , score = ) */
/* where */
/* "csvfile" * Specifies the CSV file with the ICD10 codes and points */
/* "indat"   * Specifies the dataset to be used and any conditions on how */
/*           much of the patients history to use for the score */
/* "outdat"  * Specifies the name of the resulting dataset containing the */
/*           score */
/* "score"   * Specifies the name of the score variable created */
/* */
/*-----*/

```

%macro create_score(Csvfile , Indat , Outdat , Score) ;

```

/*Imports the csv file containing ICD-codes and associated points to calculate */
/*the frailty risk score */

```

```

DATA Frailty_Score1;
  %let _EFIERR_ = 0;
  infile &Csvfile. delimiter = ',' MISSOVER DSD lrecl=32767 firstobs=2 obs=110;
  informat icd_code $3. ;
  informat icd_description $100. ;
  informat deficit_category $52. ;
  informat perc_in_devt_cohort $6. ;
  informat perc_in_frail_group $6. ;
  informat points $3. ;
  format icd_code $3. ;
  format icd_description $100. ;
  format deficit_category $52. ;
  format perc_in_devt_cohort $6. ;

```

```

format perc_in_frail_group $6. ;
format points $3. ;
input
icd_code
icd_description
deficit_category
perc_in_devt_cohort
perc_in_frail_group
points
;
if _ERROR_ then call symputx('_EFIERR_',1);
run;

DATA Frailty_score2 ;
set Frailty_score1 ;
rowid = _n_ ;
name = cats("dxs_",ICD_code,"") ;
diag = cats("","ICD_code,"") ;
ICDCode = cats("","ICD_code,"") ;
run ;

PROC sort data = Frailty_score2 ;
by ICDCode ;
run ;

/* Total number of diagnoses included in score is contained in macro variable */
/* &total. */

PROC sql noprint;
select count(*) into: total
from Frailty_score2
;
quit;

/* Assigns individual diagnoses to numbered set of macro variables */
/* (&diag1 to &diag109) and assigns points (based on model coefficients) to */
/* corresponding set of numbered macro variables (&points1 to &points109) */

%do i=1 %to &total ;

%global diag&i. ;
%global dstr&i. ;
%global points&i. ;

DATA _null_ ;
set Frailty_score2 ;
if &i. = _n_ ;
call symput("dstr&i.",diag) ;
call symput("diag&i.",name) ;
call symput("points&i.",points) ;
run ;

%end ;

/* Uses the HES episode-level extract &indat. to create a patient-level dataset*/
/* with variables indicating presence or absence of ICD-10 codes in frailty */
/* score over relevant time period (2 years recommended) */

DATA Dataset1 ;
set &Indat. ;

```

```

diagstr = catx(" ", of diag_01 diag_02 diag_03 diag_04 diag_05 diag_06
               diag_07 diag_08 diag_09 diag_10 diag_11 diag_12
               diag_13 diag_14 diag_15 diag_16 diag_17 diag_18
               diag_19 diag_20);
%do j = 1 %to &total. ;
  if find(diagstr,&&dstr&j,1) ge 1 then &&diag&j. = 1 ;
  else &&diag&j. = 0 ;
%end ;
run ;

PROC sql ;
create table Dataset2 as
select xhesid
      %do j = 1 %to &total. ;
      , max(&&diag&j.) as &&diag&j.
%end ;
from Dataset1
group by xhesid
;
quit ;

PROC sort data = Dataset2 nodup out = Dataset3 ;
by xhesid ;
run ;

/* Creates dataset with extra set of variables containing points for each */
/* diagnosis */
DATA Dataset4 ;
set Dataset3 ;
%do j = 1 %to &total. ;
  if &&diag&j. = 1 then points&j. = &&points&j. ;
  else points&j. = 0 ;
%end ;
run ;

/* Sums the points to create the frailty risk score */
PROC sql ;
create table Dataset5 as
select xhesid ,
      %do j = 1 %to &Total. ;
      + points&j.
%end ;
as &Score.
from Dataset4
;
quit ;

/* Creates output dataset with a variable which assigns the score to */
/* three categories */
DATA &Outdat ;
set Dataset5 ;
if &Score. < 5 then score_grp = 1 ;
else if (&Score. le 15 and &Score. ge 5) then score_grp = 2 ;
else if &Score. > 15 then score_grp = 3 ;
run ;

%mend create_score ;

/* %create_score(Csvfile = , Indata = , Outdat = , Score = ) */

```

Appendix 3 - Models used to estimate associations of hospital frailty risk score to outcomes

A hospital frailty risk score was calculated for each of 1,013,590 patients aged 75 years or older with an emergency admission to an NHS hospital in England. This score was based on their ICD-10 diagnoses documented in their index emergency admission and in their hospital records going back two years.

We fitted logistic regression models to estimate the association of frailty risk to three binary outcomes: 30-day mortality, long length of stay (>10 days in hospital) and emergency readmission within 30 days of discharge. The third model excluded patients who died in hospital. We tested different ways of including the HES frailty risk score as a categorical variable, using three categories of “low risk”, “intermediate risk” and “high risk”. Thresholds to categorise patients were selected to maximise discrimination in outcomes using the average hospital-specific c-statistic.

We estimated models with and without adjusting for the effects of patients’ age and sex and other characteristics on outcomes. Socioeconomic status was measured using the English Index of Multiple Deprivation (IMD) of a patient’s residential area, group into five categories based on a national ranking. The number of past admissions (0, 1, 2 or 3+) and Charlson comorbidity index (0, 1, 2 or 3+) were included as categorical variables. Hospital variation was captured by including hospital random effects, estimated as a hierarchical model using the ‘nlmixed’ procedure in SAS version 9.4. Associations between frailty risk categories and each outcome are presented using odds ratios (ORs) with their 95% confidence intervals (CIs).

Table A3.1 Characteristics of patients by HES frailty risk category in national validation cohort with an emergency admission between 1st April 2014 and 31st March 2015 (n = 1,023,337*)

	HES frailty risk category (score range)		
	Low risk (< 5)	Intermediate (5-15)	High risk (> 15)
Number of patients	434,952	383,871	204,514
% of patients	42.5%	37.5%	20.0%
HES frailty risk score, mean (SD)	2.1 (1.5)	9.2 (2.8)	23.3 (7.4)
Age, mean (SD)	82.6 (5.6)	84.8 (5.9)	86.1 (5.9)
Female	54.0%	59.0%	61.5%
Charlson comorbidity index, mean (SD)	1.9 (2.1)	3.0 (2.5)	4.5 (2.7)
Living in deprived area (IMD quintile 5)	16.7%	18.2%	19.7%
Number with missing IMD score [†]	5,210	3,162	1,375
No. of past admissions*, mean (SD)	1.3 (2.7)	1.9 (3.2)	3.3 (3.6)
0	50.9%	36.5%	13.9%
1	22.0%	23.5%	18.6%
2	12.4%	15.1%	18.3%
≥ 3	14.7%	25.0%	49.2%
At least one frailty syndrome [‡]	22.9%	66.8%	94.5%
Anxiety/Depression	5.1%	9.5%	17.2%
Functional dependence	0.4%	2.9%	12.6%
Falls and fractures	12.5%	34.7%	58.4%
Incontinence	0.7%	3.9%	13.5%
Mobility problems	1.1%	9.3%	29.6%
Pressure ulcers	0.6%	4.7%	15.9%
Cognitive impairment [‡]	4.7%	29.1%	66.2%

* Final models were estimated for 1,013,590 who were not missing an IMD score

[†] Past admissions to hospital over two years, including elective and emergency admissions.

[‡] Frailty syndromes based on ICD-10 codes defined in Soong et al. (2015). Cognitive impairment covers delirium (ICD-10 code F05), dementia (F00-F04, R41) and senility (R54).

Table A3.2 Relationship between HES frailty risk category and outcomes among patients in national validation cohort (n = 1,013,590†)

Outcome, HES frailty risk	%	Crude OR	Adjusted OR (95% CI) §
30-day mortality			
<i>Low risk (<5)</i>	5.8%	1.00	1.00
<i>Intermediate risk (5-15)</i>	11.4%	2.09	1.65 (1.62–1.68)
<i>High risk (>15)</i>	13.6%	2.56	1.71 (1.68-1.75)
Length of stay > 10 days			
<i>Low risk (<5)</i>	11.7%	1.00	1.00
<i>Intermediate risk (5-15)</i>	30.8%	3.36	3.29 (3.25-3.30)
<i>High risk (>15)</i>	44.4%	6.03	6.01 (5.92-6.10)
Emergency readmission within 30 days ‡			
<i>Low risk (<5)</i>	13.9%	1.00	1.00
<i>Intermediate risk (5-15)</i>	17.5%	1.32	1.23 (1.22-1.25)
<i>High risk (>15)</i>	21.4%	1.69	1.48 (1.46-1.50)

† Excludes patients with missing IMD score

‡ Emergency readmission within 30 days of discharge excluding patients who died in hospital (n = 920,629)

§ Adjusted for patients' age, sex, socioeconomic status, admission history and Charlson comorbidity index and hospital variation.

APPENDIX 4 - Construction of clinical frailty scales using

Linked clinical data were used to compare the hospital frailty risk score to established clinical frailty scales. Clinical data were collected from a cohort admitted to an Acute Medical Unit at Queen's Medical Centre in Nottingham or Leicester Royal Infirmary.^{1,2} This cohort represented a typical population of older people with an acute hospital admission and expectation of a relatively short treatment episode before discharge (<72 hours).

The Fried Phenotype model defines frailty as a clinical syndrome, where three or more of a set of criteria diagnoses an individual as frail. These are unintentional weight loss, self-reported exhaustion, grip strength, slow walking speed and low physical activity. The Leicester /Nottingham data included measures of weight loss, grip strength, self-reported energy levels, gait speed and self-reported physical activity (Table A4.1). The Rockwood deficit index is constructed from a list of 35 deficits; including some of the same individual variables that contribute to the Fried score. To calculate the score, an individual's total number of deficits is divided by the total possible deficits to obtain a continuous score between 0 and 1. The variables used to construct the Rockwood Index are listed in Table A4.2.

References

1. Edmans J, Bradshaw L, Gladman JRF, et al. The Identification of Seniors at Risk (ISAR) score to predict clinical outcomes and health service costs in older people discharged from UK acute medical units. *Age and Ageing* 2013; 42: 747-53.
2. Wou F, Gladman JRF, Bradshaw L, Franklin M, Edmans J, Conroy SP. The predictive properties of frailty-rating scales in the acute medical unit. *Age and Ageing* 2013; 42: 776-81.

Table A4.1 Variables used to construct Fried score

ITEM	DETAILS	Rules
Nutritional status	Weight loss > 5kg in preceding year	"Yes" - weight_loss_gt5_12mths = 1
Strength	Grip strength, lowest 20% in this population	Max grip strength value from left and right grip strength values. Lowest 20% of values from population stratified by gender and BMI = 1. Male BMI <=24, 24.1-26, 26.1-28, 28+. Female BMI <=23, 23.1-26, 26.1-29, 29+.
Energy	Do you feel full of energy? "no"	"No" – energy
Mobility	Gait speed 2.4m walk, lowest 20%	Slowest 20% of values stratified by gender and height = 1. Male Height <=173,>173. Female Height <=159,>159. If not able to walk 2.4m then given value of 1.
Physical activity	EuroQol-5D questions mobility, self-care, usual activities	Sum EQ5D values for self-care, mobility and usual activities. Score >=7/9 = 1.

Table A4.2 Variables used to construct Rockwood Index

ITEM	AMOS Construction
COPD	"Yes" - chronic_pulmonary_disease = 1
Cerebrovascular disease	"Yes" - cerebrovascular_disease = 1
Congestive heart failure	"Ye" - congestive_heart_failure = 1
Diabetes	"Yes" - diabetes = 1
Dementia	"Yes" - dementia = 1
Liver Disease	3 - liver_disease = 1
Myocardial infarction	"Yes" - myocardial_infarct = 1
Renal disease	"Yes" - rel_disease = 1
Tumour	"Yes" - tumour = 1
Ulcer disease	"Yes" - ulcer_disease = 1
Peripheral vascular disease	"Yes" - peripheral_vascular_disease = 1
Recent falls	"Yes" - fall = 1
Pressure sore	"Ye" - current_pressure_sores = 1
Polypharmacy (>3 meds every day)	"Yes" - polypharmacy = 1
Do you see well	"Yes" - sight = 1
Do you have serious problems with memory	"Yes" - memory = 1
Do you feel full of energy	"No" - energy = 1
Weight loss >5kg in past 12 months	"Yes" - weight_loss_gt5_12mths
MMSE<24/30	Total of mmse1-11 <24 = 1
Gait speed	Slowest 20% of values stratified by gender and height . Male Height <=173,>173. Female Height <=159,>159. - ability_to_walk_time = 1 If not able to walk 2.4m then given value of 1.
Grip strength	Lowest 20% of values stratified by gender and BMI = 1. Male BMI <=24, 24.1-26, 26.1-28, 28+. Female BMI <=23, 23.1-26, 26.1-29, 29+. - nt_max_grip = 1
Calf circumference	Lowest 20% of values - nt_max_calf = 1
Mid arm circumference	Lowest 20% of values - nt_max_muac = 1
Difficulty with concentration	0 = 0 / 1,2 = 0.5 / 3 = 1 - nt_concentration

Sleep loss over worry	$0 = 0 / 1 = 0.5 / 2/3 = 1 - nt_sleep$
Feel depressed	$0 = 0 / 1,2 = 0.5 / 3 = 1 - nt_depressed$
Help feeding	$0,1 - feed_bi = 1$
Help dressing	$0,1 - dressing_i = 1$
Help bathing	$0 - bath_bi = 1$
Help grooming	$0 - groom_bi = 1$
Bladder incontinence	$0,1 - incontu_bi = 1$
Bowel incontinence	$0,1 - incontb_bi = 1$
Help transferring	$0,1,2 - transfer_i = 1$
Help up/down stairs	$0,1 - stairs_i = 1$
Help with mobility	$0,1,2 - mob_bi = 1$

APPENDIX 5 Models used to estimate associations of hospital frailty risk score to outcomes – sensitivity analysis

The national validation cohort used in the original analysis presented in the main paper included 1,013,590 patients aged 75 years or older with an emergency admission to an NHS hospital in England in 2014/15. This cohort was used to estimate the association of frailty risk to 30-day mortality, long length of stay (>10 days in hospital) and emergency readmission within 30 days of discharge. This cohort included 10,256 patients who were previously included in the development cohort used to develop the hospital frailty risk score (see Table S1 below). Because this group only represented 1.0% of the national validation cohort, they were not dropped from the original analysis. Below are the results for a sensitivity analysis for a national validation cohort of 1,003,334 patients excluding people included in the development cohort. This confirms that the results of the analysis are not sensitive to the inclusion or exclusion of people included in the development cohort.

Table S1 Characteristics of three cohorts of hospitalised older people used in development and validation work, Hospital Episode Statistics (HES)

	Development cohort ^a (n = 22,139)	National validation cohort ^b (n = 1,013,590)	National validation cohort – EXCLUDING PEOPLE INCLUDED IN DEVELOPMENT COHORT ^c (n = 1,003,334)
Age in years	82.5 (5.6)	84.1 (5.9)	84.1 (5.9)
Gender			
Male	57.8%	57.4%	57.4%
Female	42.2%	42.6%	42.6%
HES frailty risk score	8.9 (9.8)	9.0 (8.7)	9.0 (8.7)
HES frailty risk category:			
Low risk (< 5)	66.0%	42.4%	42.5%
Intermediate risk (5-15)	20.3%	37.6%	37.5%
High risk (>15)	13.7%	20.0%	20.0%
Charlson comorbidity index	2.8 (2.9)	2.9 (2.6)	2.9 (2.6)
No of admissions over 2 years, including current admission:			
1	45.3%	37.9%	37.9%
2	24.0%	22.0%	22.0%
≥ 3	30.7%	40.1%	40.1%

Values are means (SDs) for continuous variables, and percentages for binary variables.

a The development cohort included older people aged 75 years+ living in one of three local authorities with *at least one hospital admission* over the period 1st April 2013 and 31st March 2015.

b The national validation cohort included all older people aged 75 years+ who had an *emergency hospital admission* in England between 1st April 2014 and 31st March 2015.

c The national validation cohort included 1,003,334 older people aged 75 years+ who had an *emergency hospital admission* in England between 1st April 2014 and 31st March 2015, excluding 10,256 people who were included in the development cohort.

Table S2 Characteristics of patients by HES frailty risk category in national validation cohort with an emergency admission between 1st April 2014 and 31st March 2015 (n = 1,003,334*)

	HES frailty risk category (score range)		
	Low risk (< 5)	Intermediate (5-15)	High risk (> 15)
Number of patients	425,940	376,591	200,804
% of patients	42.5%	37.5%	20.0%
HES frailty risk score, mean (SD)	2.1 (1.5)	9.1 (2.8)	23.3 (7.4)
Age, mean (SD)	82.6 (5.5)	84.8 (5.9)	86.1 (5.9)
Female	54.1%	59.0%	61.5%
Charlson comorbidity index, mean (SD)	1.9 (2.1)	3.0 (2.5)	4.5 (2.7)
Living in deprived area (IMD quintile 5)	16.5%	18.1%	19.5%
No. of past admissions†, mean (SD)	1.3 (2.7)	1.9 (3.2)	3.3 (3.6)
0	50.6%	36.3%	13.9%
1	22.1%	23.5%	18.6%
2	12.5%	15.2%	18.3%
≥ 3	14.8%	25.1%	49.2%
At least one frailty syndrome‡	22.9%	66.8%	94.5%
Anxiety/Depression	5.1%	9.5%	17.1%
Functional dependence	0.4%	2.9%	12.5%
Falls and fractures	12.5%	34.7%	58.3%
Incontinence	0.7%	3.9%	13.5%
Mobility problems	1.0%	9.3%	29.7%
Pressure ulcers	0.6%	4.7%	16.0%
Cognitive impairment‡	4.7%	29.2%	66.2%

* Final models were estimated for 1,003,334 who were not missing an IMD score and excluding 10,256 people who were included in the development cohort.

† Past admissions to hospital over two years, including elective and emergency admissions.

‡ Frailty syndromes based on ICD-10 codes defined in Soong et al. (2015). Cognitive impairment covers delirium (ICD-10 code F05), dementia (F00-F04, R41) and senility (R54).

Table S3 Relationship between HES frailty risk category and outcomes among patients in national validation cohort (n = 1,003,334†)

Outcome, HES frailty risk	%	Crude OR	Adjusted OR (95% CI) §
30-day mortality			
<i>Low risk (<5)</i>	5.8%	1.00	1.00
<i>Intermediate risk (5-15)</i>	11.4%	2.09	1.65 (1.62–1.68)
<i>High risk (>15)</i>	13.6%	2.56	1.71 (1.68-1.75)
Length of stay > 10 days			
<i>Low risk (<5)</i>	11.7%	1.00	1.00
<i>Intermediate risk (5-15)</i>	30.8%	3.36	3.30 (3.27-3.34)
<i>High risk (>15)</i>	44.4%	6.03	6.03 (5.94-6.11)
Emergency readmission within 30 days ‡			
<i>Low risk (<5)</i>	13.9%	1.00	1.00
<i>Intermediate risk (5-15)</i>	17.5%	1.32	1.23 (1.22-1.25)
<i>High risk (>15)</i>	21.4%	1.69	1.48 (1.46-1.50)

† Excludes patients with missing IMD score and 10,256 people who were included in the development cohort.

‡ Emergency readmission within 30 days of discharge excluding patients who died in hospital (n = 826,495)

§ Adjusted for patients' age, sex, socioeconomic status, admission history and Charlson comorbidity index and hospital variation.