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Development of a frailty index from routine hospital data in perioperative and critical care

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Abstract

Background: Frailty is common in surgical and intensive care unit (ICU) populations, yet is not routinely measured. Frailty indices are able to quantify this across a range of health deficits. We aimed to develop a frailty index (FI) from routinely collected hospital data in a surgical and ICU population.

Design: Prospective, observational single centre cohort study

Setting: A tertiary referral metropolitan Australian hospital.

Participants: 336 patients aged ≥ 65 years undergoing surgery or aged ≥ 50 years admitted to ICU.

Measurement: Routine admission health data were used to derive an FI, comprising 36 health deficits. We examined the FI correlation with existing frailty tools (Clinical Frailty Scale and Edmonton Frail Scale) and assessed its predictive ability for negative outcomes including 30-day mortality.

Results: Median (inter-quartile range, IQR) FI was 0.17 (0.10 – 0.24) for ICU patients, and 0.17 (0.11 – 0.25) for surgical patients; maximum FI was 0.58, and 25% (95% CI [10.4 – 29.6]) of patients overall were diagnosed with frailty (FI score of ≥0.25). Correlation was strong between the FI and the Edmonton Frail scale (Spearman coefficient [95% CI] = 0.76, [0.70 – 0.83] for ICU patients; 0.71 [0.64 – 0.78] for surgical patients), and the Clinical Frailty Scale (0.77 [0.70 – 0.84] for ICU patients; 0.72 [0.65 – 0.79] for surgical patients). The FI had good discriminative ability for prediction of 30-day mortality in ICU patients (multivariate OR [95% CI] for each increase in FI of 0.1 = 2.04 [1.19 – 3.48]; comparable with the performance of the Acute Physiology and Chronic Health Evaluation (APACHE) III score (ICU patients), and the Portsmouth-Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (P-POSSUM) score (surgical patients).

Conclusion: It is feasible to construct a FI from hospital admission data in a cohort of critically ill and surgical patients.

Keywords: frailty, perioperative care, risk assessment, critical care

Introduction

Frailty is a state of vulnerability resulting from deficit accumulation in many domains of health.[1] In acutely hospitalized populations, frailty predisposes to poor outcomes, in particular for surgical and intensive care unit (ICU) patients. Frailty affects up to 40-50% of surgical patients,[2] and is associated with increased mortality and post-operative complications.[3] Similar associations are seen in ICU cohorts, in which 30% of critically ill patients are classified frail.[4] Measurement of frailty in these groups is thus a major priority, however considerable challenges exist in its determination in ICU and surgical patients. This includes barriers to interview (eg. coma, sedation), difficulties in functional testing, and acute illness confounding the patient's baseline state.[5] Prospective data collection also requires considerable resources, training and time, ranging from <5 minutes (for the Clinical

Frailty Scale),[6] up to two hours for a comprehensive geriatric assessment upon which the 70-item original frailty index (FI) is based.[7]

Recently, data automatically collected during acute hospitalization have been used to derive a "frailty index" (FI). Such indices are among the most comprehensive ways of measuring frailty, and are calculated using health deficits, dividing the number of deficits present by the total number.[8] Surgery and intensive care, in particular, are especially "data-rich" areas of healthcare, with significant information collected relevant to frailty index construction .[9] A plethora of scales derived from hospital coding data purporting to measure frailty have hence emerged, unfortunately with questionable degrees of utility. The modified frailty index (mFI), for example, only measures 11 variables (of which nine are comorbidities)[10], and the Johns Hopkins Adjusted Clinical Groups Indicator, perhaps the most widely available population health analysis tool, provides only a dichotomous frailty measure, lacking granularity.[11] Expert guidelines exist in constructing an FI- at least 30 deficits should be included, increasing in prevalence with age (without saturating too early), associated with health status, and covering a range of health systems.[8] Small variations in specific health deficit variables in a particular FI are allowed, with FIs demonstrating reproducibility and comparability across different populations. There is, however, limited work to date in comparing properly constructed FIs against other frailty assessment tools.

Our aim, therefore, was to develop an FI of accumulated health deficits, based on hospital data that is routinely collected in our institution for surgical and ICU patients. We aimed to examine how this index compares to existing frailty and risk measurement scales

and to assess the predictive ability of the FI for patient-centred outcomes, including in-hospital mortality and institutional discharge.

Methods

We conducted a prospective, observational cohort study in the Departments of Intensive Care, Anaesthesia and Pain Management of the Royal Melbourne Hospital; the protocol and methodology of data collection have been published previously.[12 13] The Human Research and Ethics Committee of Melbourne Health approved this program of research (20/01/2017, HREC/16/MH/321). Between February and June, 2017, patients aged ≥50 years (when admitted to ICU), or aged ≥65 years (admitted for surgery), were enrolled following patient or surrogate written informed consent. Based on study investigator availability, a convenience sample of non-consecutively admitted patients were enrolled. Patients were able to be enrolled both pre- and post-operatively, or at any stage during their ICU stay, thus the time of ICU admission or operation did not influence eligibility for inclusion in the study. Routine data recorded on admission to our health service were used in the derivation of an FI, comprising 36 health deficits (Supplementary Table S1). An FI for each patient was then calculated by summing positive deficits divided by the total number of non-missing possible deficits, thus deriving a score ranging from 0 (no deficits) to 1 (all deficits).[14] Patients with an FI score of ≥0.25 were considered frail, consistent with accepted definitions.[15] The Clinical Frailty Scale (CFS) and Edmonton Frail Scale were also measured

by one of the study investigators, based on the period of time two weeks prior to the onset of acute illness or hospitalisation.[15] A Reported Edmonton Frail Scale was measured for those patients who were not able to undergo a timed-up-and-go test.[16] Patients' next-of-kin were used for history taking in the event of incapacity. Frailty scores were not shared with the clinical team.

Our primary aim was to develop an FI from routinely collected data within an Australian health service by comparing against existing frailty tools for both screening (the CFS) and measurement (the Edmonton Frail Scale). Secondary aims were to investigate the predictive ability of the FI for adverse outcomes, including 30-day mortality which was compared to reference mortality risk-prediction tools: the Acute Physiology and Chronic Health Evaluation (APACHE) III score (ICU patients), and the Portsmouth-Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (P-POSSUM) score (surgical patients).[17] Secondary outcomes were discharge to a non-home location, peri-operative complications (cardiac arrest, acute myocardial infarction, tracheal reintubation, acute pulmonary oedema, pulmonary embolus, deep venous thrombosis, stroke, acute kidney injury, wound infection, unplanned admission to the ICU, unplanned need for re-operation) and ICU complications (acute kidney injury, cardiac arrest, sepsis, new treatment limitation); (definitions in Supplementary Table S2).

Statistical analysis

Data were summarized using mean (standard deviation [SD]), median [25th – 75th percentile (IQR)] for continuous data, and frequencies (percentages) for categorical data. Patients were considered frail if FI ≥0.25, CFS ≥5, or Edmonton Frail Scale ≥8.[15,18] Comparisons between frail and non-frail groups were conducted with two-sample t-tests, Fisher's exact or Chi-square tests, and Wilcoxon rank-sum tests as indicated. FI values were further categorized by age deciles, from ≥50 years (ICU) and ≥65 years (surgery). Univariable and multivariable regression models were fitted to listed outcomes, the latter adjusting for age, sex, Charlson comorbidity index and admission source for ICU patients, and additionally adjusted for emergency or elective surgery for surgical patients. Binary outcomes with ≥ patient were analysed using Firth logistic regression to obtain the estimated odds ratio (OR) and 95% confidence interval (CI).[19] Correlation was measured using Spearman correlation coefficient between the continuous FI, Edmonton and CFS scales. Firth logistic regression models were used to compare the FI as a mortality predictor with the APACHE 3 score (ICU) and P-POSSUM score (surgery), obtaining the area under the receiver operating characteristic curve (AUCROC, 95% CI), which was categorized using standard guidelines (Hosmer, Lemeshow, and Sturdivant).[20] Hospital length of stay (days) between patients with and without frailty was analysed via estimated median difference (95% CI) using bootstrapped quantile regression with 5000 replications, excluding patients who died in hospital. Discharge location was analysed via estimated relative risk ratios (95% CI) using multinomial logistic regression. All enrolled patients were included in analyses, without

adjustment for multiple testing. STATA 15.0 (College Station, TX, USA) was used for statistical analyses.

Sample size

We planned a convenience sample of 200 surgical and 150 ICU patients, based on a predicted combined frailty prevalence of 24% and mortality rate of 10%. This was based on a meta-analysis of >8000 surgical patients, with 20% frailty prevalence and 5% pooled mortality [21]; and a multicentre study of frailty in critical care demonstrating 30% frailty prevalence and 21% mortality.[22] We calculated that 350 patients would give a 95% CI of ±4.4% around a frailty prevalence of 24%. Additionally, based on the above we predicted a surgical mortality of 5% and 21% in ICU patients; combined approximately 10%. Based on combined ORs in two prior systematic reviews[21,23], we assumed the odds of in-hospital mortality for patients with frailty would be 3.5 times greater, and overall in-hospital mortality would be 6.8% in patients without frailty. With a sample size of 350 patients, the power to detect this effect was 87% (two-sided 5% alpha). A sample size of 200 surgical patients and 150 ICU patients was also calculated to provide a power of at least 80% (two-sided alpha of 5%) for the Spearman coefficient between the FI with existing frailty tools (CFS and EFS) to be at least 0.70, assuming a correlation of 0.80 (strong).

Results

Three-hundred and thirty six patients were enrolled during the study period, 218 surgical patients, 160 ICU patients, with 42 patients undergoing both surgery and an ICU admission (Supplementary Figure S1). Median (IQR) FI was 0.17 (0.10-0.24) for ICU patients, and 0.17 (0.11-0.25) for surgical patients, with maximum FI=0.58 in both cohorts (Figure 1). Baseline demographics are presented in Table 1 (total cohort demographics in Supplementary Tables S3, S4). Eighty-four patients (25%, 95% CI [20.4-29.6]) in total were diagnosed with frailty via the FI, 40/160 (25.0%, [18.3-31.7]) ICU-admitted patients and 55/218 (25.2%, [19.5-31.0]) surgical patients, with frailty increasing with advancing age (4% of patients aged 50-59 years, compared with 34% of those aged >80 years) (Supplementary Table S5). Individual FI health deficits were broadly comparable across ICU and surgical populations (Table 2). The most common health deficits were falls (44% and 48% of ICU and surgical patients respectively), polypharmacy (73% and 64%), visual impairment (43% and 51%) and hearing impairment (36% and 38%). Compared to patients without frailty, those with frailty were older, less likely to be admitted from home, less independent with activities of daily living, and had higher Charlson comorbidity, APACHE 3 and P-POSSUM scores (Table 1). Compared to a contemporary cohort of 1145 ICU patients admitted between 1/11/2019 and 31/5/2020 (during which period CFS scores were routinely measured), the magnitude of differences in age, CFS score, home discharge and mortality were small, although hospital LOS was longer (Supplementary Table S6).

Correlation was strong between the FI and the Edmonton Frail scale for ICU patients (Spearman coefficient [95% CI] = 0.76 [0.70-0.83]) and between the FI and the CFS (0.77

[0.70-0.84]). Similar results were seen in the surgical cohort (Spearman coefficient between the FI and Edmonton scale = 0.71 [0.64-0.78]; between the FI and CFS = 0.72 [0.65-0.79]).

30-day mortality was greater for ICU patients with frailty (11/40 [28%] vs. 12/120 [10%] without frailty, adjusted p=0.009), compared to surgical patients (3/55 [5%] with frailty vs. 5/163 [3%] without frailty, adjusted p=0.056). Patients with frailty were more likely to be discharged to an assisted living facility/rehabilitation vs. home discharge, although on multivariable analysis this association was less evident for ICU patients (Tables 3, 4). On multivariable analysis, the FI had good discriminative ability for prediction of hospital mortality in ICU patients (AUC-ROC [95% CI] = 0.75 [0.64-0.85], OR [95% CI] for each increase in FI of 0.1 = 2.04 [1.19-3.48]), comparable with the performance of the APACHE-III illness severity score (AUC-ROC = 0.80 [0.72-0.88]). For surgical patients, the discriminative ability of the FI for prediction of hospital mortality was comparable with the P-POSSUM score (AUC-ROC = 0.76 [0.61-0.91] vs. 0.81 [0.71-0.92], OR [95% CI] for each increase in FI of 0.1 = 1.90 [0.98-3.66]).

Among ICU complications, only new treatment limitations was significantly associated with the FI (20/40 [50%] patients with frailty vs. 29/120 [24.2%] patients without frailty, adjusted OR [95% CI] = 1.82 [1.14-2.88], p=0.011). For surgical patients, both unplanned return to the operating theatre (7/55 [12.7%] patients with frailty vs. 11/163 [6.7%] patients without frailty, adjusted OR = 1.76 [1.08-2.86], p=0.024) and unplanned admission to the ICU (8/55 [14.5%] vs. 17/163 [10.4%], adjusted OR = 1.56 [1.00-2.43], p=0.051) were more common in patients with frailty (Tables 3, 4).

Discussion

Main findings

We found that a frailty index was able to be derived from routine hospital admission data in ICU and surgical patients, which correlated strongly with existing frailty tools. Although not designed for this purpose, the FI also had good discriminative ability for mortality prediction, comparable with existing risk stratification tools. Patients with frailty had worse outcomes both post-operatively and with critical illness, including increased mortality and discharge to institutional care.

Relationship to prior literature

Automated FIs have been developed in other settings, such as the UK National Health Service "Electronic Frailty Index" (or "eFI") which aims to identify older patients living in the community with frailty.[24] Encompassing 36 deficits, this comprehensive multi-dimensional index has demonstrated predictive validity for mortality, hospitalization and nursing home admission, and correlates well with the research-standard FI (Spearman correlation coefficient [ρ] = 0.68, 95% CI 0.62-0.74), the Edmonton Frail Scale (ρ = 0.63, 95% CI 0.57-0.69), and the CFS (ρ = 0.59, 95% CI 0.49-0.65). [25] A recent study also managed to derive an eFI from routinely collected Australian primary care data.[26] Our study extends the findings of these primary-care setting measures to acutely hospitalized patients, with even stronger

correlation observed (correlation coefficients comparing the FI, CFS and Edmonton Frail Scale all exceeding >0.70).

More recently, McIsaac et al have derived a Canadian surgical-specific FI in over 400,000 patients from administrative health data, validated in a further 95,000.[27] This "perioperative frailty index", or pFI, encompasses 30-items, and is associated with post-operative mortality and institutional discharge. This study demonstrates the potential of automated data collection in the calculation of frailty indices in a surgical cohort. Other investigators have also developed institution-specific FIs, including Shahrokni et al (15 variables, hospital coding data) and Orouji Jokar et al (15 variables, collected by trained researchers).[28,29] These also demonstrate the feasibility of surgical FI application, although with fewer variables potentially risking over-simplification of the frailty construct, and being over-weighted (eg. towards comorbid disease). An alternative approach to FI contruction is the "claims-based" FI of Kim et al.[30] Using administrative Medicare data, this considers both variable prevalence and correlation with age and is predictive of mortality, disability and health care utilization. Our study is novel in that the scope and granularity of data collected is part of routine admission, thus not reliant on researcher time, nor subject to problems with administrative data, such as variable removal from datasets over time as with the mFI. A recent study of 18000 surgical patients demonstrated data for 5 of 11 variables were missing in 55% of patients in 2011, increasing to 100% missing in 2013 coinciding with removal of mandatory NSQIP variable reporting in 2012.[31] Our study applying an FI to the measurement of frailty in ICU patients is, we believe, novel.

Limited prior work has compared frailty scales. A 2018 Canadian study comparing the Fried phenotype and Clinical Frailty Scale demonstrated only moderate agreement (kappa = 0.51).[6] A 2017 epidemiological study cautioned that agreement between 35 different frailty scales varied widely, however multi-dimensional deficit model scales had the best agreement.[32] Although various constructs of frailty exist, and it is important that the choice of frailty instrument measures the underlying construct it represents,[33] our findings thus lend weight to the concept that FIs, the CFS and the EFS belong to the similar deficit-model construct of frailty. Taken together, these results suggest that multi-dimensional frailty scales are promising and comparable measures when used both in research and patient care.

A major finding of our study was of comparable mortality prediction with the FI when compared to the reference scales, APACHE-III and P-POSSUM. This was surprising, particularly when considering that unlike these latter tools, which consider acute illness, age, surgical magnitude and physiological derangement, the FI concerns solely chronic health deficits. The FI is also not conceptualized nor designed as a mortality risk-scoring system. This is hypothesis generating, and suggests that detrimental outcomes in these cohorts may be more a function of chronic underlying health status than of acute illness severity. A similar epidemiological phenomenon has been observed in long-staying "persisting critically ill" patients, with the ultimate determination of death more a function of pre-ICU characteristics than illness severity after ten days.[34] We have previously demonstrated that in-ICU complications in this cohort develop more commonly, including

delirium, new sepsis and ICU acquired weakness.[35] Similarly, it is likely that frailty imparts a vulnerability to critical illness and surgical stress than may outweigh the impact of acute illness in outcome determination. Future research should seek to further understand the complex interplay between acute illness severity, chronic health status, and ultimate outcome in patients with frailty, and integrate frailty in these risk prediction models.

Strengths and Limitations

Strengths of our study include the wide range of patients enrolled, with both critically ill and emergency and elective surgical patients included from a major metropolitan hospital. Our results are likely generalisable to other similar healthcare settings. The construction of our FI, furthermore, conformed to accepted guidelines for inclusion of candidate health deficits.[8] Limitations included the single centre design, as well as overlap of 42 patients between cohorts, although overall findings were similar between groups. We did not quantify the time taken to collect data (although this will be reduced in hospitals utilizing electronic medical records). Missing variables were also completed by the study investigators directly, further work will be required to quantify feasibility in the presence of missing data. Admission patient data also vary between health services; it is thus likely that an exact replica FI is not able to be reproduced in alternative hospital settings. Properly constructed frailty indices, however, are generalisable between populations without exact deficits needing to be reproduced.[8] Similar variables are also likely to be collected routinely as part of surgical and ICU admission processes, thus comparable FIs should be able to be

easily constructed. Further work is required to assess this external validity, ideally validating this approach in a multi-centre study including much larger datasets. We also enrolled a convenience sample; although patients were eligible to be enrolled at any point during their ICU stay or either before or after surgery, it is however possible that our study cohort was less representative of the overall population. Compared to a contemporary population of all ICU patients admitted over a seven month period, however, we found few clinically significant differences with our patient cohort on key patient characteristics.

Conclusion

It is feasible to construct a FI in a cohort of critically ill and surgical patients based on admission data in a metropolitan Australian hospital. The FI correlates well with accepted frailty screening and measurement tools, and is predictive for negative outcomes including mortality and institutional discharge. This study provides the necessary background work prior to widespread development and implementation of frailty indices in routine peri-operative and ICU care.

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Author Contributions:

JND: Study design, patient enrolment, data analysis, writing of manuscript

KG, JL, TB: Study design, patient enrolment, review of manuscript

SB, ADS: Data analysis, review of manuscript

WKL, DAS: Study design, review of manuscript

Legends:

Figure 1: Frailty index distribution

Supplementary Table S1. List of individual health deficits comprising the Frailty Index.

Supplementary Table S2. Definitions for complications

Supplementary Table S3: Baseline demographics of all study participants

Supplementary Table S4. Baseline demographics according to Frailty Index frailty status.

Supplementary Table S5. Frailty Index by age deciles

Supplementary Table S6: Comparison between ICU cohort and all ICU patients aged ≥50 years admitted 1/11/2019 – 31/5/2020.

Supplementary Figure S1: Flowchart of study participants

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Table 1. Baseline demographics according to Frailty Index frailty status.

Variable	ICU patients (N = 160)			Surgical patients (N = 218)		
	Frail N = 40	Not Frail N = 120	*P* value	Frail N = 55	Not Frail N = 163	*P* value
Frailty index	0.31 (0.26-0.39)	0.14 (0.08-0.19)	< 0.001	0.28 (0.25-0.36)	0.14 (0.08-0.19)	< 0.001
Age (years)	75 (69-80)	69 (61-77)	0.004	77 (69-83)	73 (68-79)	0.036
BMI (kg/m^2)	28 (24-32)	30 (26-33)	0.10	26 (24-31)	28 (24-32)	0.15
Female	22 (55.0%)	48 (40.0%)	0.10	24 (43.6%)	75 (46.0%)	0.76
Admission Source						
Home	31 (77.5%)	114 (95.0%)	0.003	43 (78.2%)	152 (93.3%)	< 0.001
Acute hospital	6 (15.0%)	5 (4.2%)		2 (3.6%)	10 (6.1%)	
Residential care	3 (7.5%)	1 (0.8%)		10 (18.2%)	1 (0.6%)	
Admission type						
Medical	29 (72.5%)	71 (59.2%)	0.13			
Surgical	11 (27.5%)	49 (40.8%)				
Surgical type						
Elective				28 (50.9%)	90 (55.2%)	0.58
Emergency				27 (49.1%)	73 (44.8%)	
Charlson Comorbidity Score	4 (2-5)	2 (0-3)	< 0.001	4 (2-6)	2 (1-3)	<0.001
ADL Function (Katz)						
Dependent	8 (20.0%)	0 (0.0%)	< 0.001	7 (12.7%)	1 (0.6%)	<0.001
Partially Dependent	7 (17.5%)	2 (1.7%)		13 (23.6%)	10 (6.1%)	
Independent	25 (62.5%)	118 (98.3%)		35 (63.6%)	152 (93.3%)	
APACHE 3 score	80 (70-90)	62 (49-82)	<0.001			
P-POSSUM mortality risk (%)				7% (3%-17%)	4% (3%-9%)	0.015

Values are expressed as the mean (SD), median (interquartile range), or n (%).
ADL = activities of daily living (Katz number: Dependent = 0-2, Partially Dependent = 3-4, Independent = 5-6). BMI = body mass index. APACHE = Acute Physiology and Chronic Health Evaluation. P-POSSUM = Portsmouth-Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity.

Table 2. Frailty index individual variable prevalence.

	ICU patients (N=160)	Surgical patients (N=218)	All patients (N=336)
Falls in last 12 months, n (%)	71 (44.4%)	105 (48.2%)	154 (45.8%)
Dementia diagnosis, n (%)	7 (4.4%)	6 (2.8%)	12 (3.6%)
Altered cognition, n (%)	25 (15.6%)	25 (11.5%)	45 (13.4%)
On ≥ 4 medications, ≥ 1 affecting CNS/CVS, n (%)	116 (72.5%)	140 (64.2%)	224 (66.7%)
Vision impairment, n (%)	68 (42.5%)	111 (50.9%)	161 (47.9%)
Hear impairment, n (%)	57 (35.6%)	82 (37.6%)	125 (37.2%)
Assistance with transferring, n (%)	11 (6.9%)	19 (8.7%)	28 (8.3%)
Assistance with mobilising, n (%)	53 (33.1%)	69 (31.7%)	105 (31.3%)
Assistance with toileting, n (%)	8 (5.0%)	20 (9.2%)	27 (8.0%)
Assistance with bathing, n (%)	15 (9.4%)	32 (14.7%)	45 (13.4%)
Assistance with dressing, n (%)	18 (11.3%)	23 (10.6%)	36 (10.7%)
Postural hypotension/dizziness, n (%)	46 (28.7%)	89 (40.8%)	118 (35.1%)
Bowel incontinence, n (%)	17 (10.6%)	21 (9.6%)	35 (10.4%)
Urinary incontinence, n (%)	39 (24.4%)	58 (26.6%)	85 (25.3%)
Eating poorly, n (%)	55 (34.4%)	52 (23.9%)	94 (28.0%)
Lost weight without trying*, n(%)	54 (33.8%)	57 (26.1%)	99 (29.5%)
Pressure injury - current or past, n (%)	5 (3.1%)	9 (4.1%)	13 (3.9%)
Neuropathic foot disease, n (%)	31 (19.4%)	20 (9.2%)	43 (12.8%)
Problems managing at home prior to admission, n (%)	34 (21.3%)	47 (21.6%)	69 (20.5%)
Often feels sad or depressed, n (%)	57 (35.6%)	40 (18.3%)	82 (24.4%)
Needs assistance with eating, n (%)	7 (4.4%)	8 (3.7%)	14 (4.2%)
Myocardial infarction, n (%)	34 (21.3%)	39 (17.9%)	62 (18.5%)
Congestive heart failure, n (%)	26 (16.3%)	25 (11.5%)	43 (12.8%)
Peripheral vascular disease, n (%)	19 (11.9%)	31 (14.2%)	45 (13.4%)
Cerebrovascular disease, n (%)	27 (16.9%)	38 (17.4%)	58 (17.3%)
Hemiplegia, n (%)	1 (0.6%)	3 (1.4%)	3 (0.9%)
Chronic lung disease, n (%)	29 (18.1%)	40 (18.3%)	63 (18.8%)
Connective tissue disease, n (%)	12 (7.5%)	15 (6.9%)	23 (6.8%)
Peptic ulcer disease, n (%)	9 (5.6%)	29 (13.3%)	35 (10.4%)
Chronic liver disease, n (%)	2 (1.3%)	3 (1.4%)	5 (1.5%)
Diabetes, n (%)	43 (26.9%)	52 (23.9%)	84 (25.0%)
Leukaemia/lymphoma, n (%)	12 (7.5%)	5 (2.3%)	17 (5.1%)
Malignant tumour, n (%)	19 (11.9%)	63 (28.9%)	73 (21.7%)
Metastatic cancer, n (%)	9 (5.6%)	17 (7.8%)	25 (7.4%)
Moderate/severe kidney disease, n (%)	16 (10.0%)	24 (11.0%)	35 (10.4%)
Moderate/ severe liver disease, n (%)	2 (1.3%)	2 (0.9%)	4 (1.2%)
Total score, median (IQR)	0.2 (0.1-0.2)	0.2 (0.1-0.3)	0.2 (0.1-0.2)

Frail, n (%)	**40 (25.0%)**	**55 (25.2%)**	**84 (25.0%)**

Table 3. Main outcomes according to frailty status

Variable	ICU patients (N = 160)		Surgical patients (N = 218)		All patients (N = 336)	
	Frail N = 40	Not Frail N = 120	Frail N = 55	Not Frail N = 163	Frail N = 84	Not Frail N = 252
Mortality within 30 days	11 (27.5%)	12 (10.0%)	3 (5.5%)	5 (3.1%)	14 (56.0%)	17 (35.4%)
Mortality (six-month follow up)	13 (34.2%)	26 (22.0%)	12 (22.2%)	22 (13.8%)	25 (30.9%)	47 (19.0%)
Hospital length of stay (days)	14.2 (9.6-18.9)	11.5 (7.8-23.8)	8.0 (2.0-13.5)	4.0 (1.0-9.6)	8.1 (3.0-14.2)	7.0 (2.0-12.6)
Discharge location						
Home	13 (32.5%)	64 (53.3%)	25 (45.5%)	122 (74.8%)	34 (40.5%)	169 (67.1%)
Assisted living facility/rehabilitation	14 (35%)	27 (22.5%)	22 (40%)	24 (14.7%)	30 (35.7%)	42 (16.7%)
Other acute hospital	2 (5.0%)	17 (14.2%)	5 (9.1%)	13 (8.0%)	6 (7.1%)	25 (9.9%)
Died in hospital	11 (27.5%)	12 (10.0%)	3 (5.5%)	4 (2.5%)	14 (16.7%)	16 (6.3%)
Acute myocardial infarction			1 (1.8%)	3 (1.8%)		
Re-intubation			3 (5.5%)	3 (1.8%)		
Acute pulmonary oedema			5 (9.1%)	12 (7.4%)		
Wound infection			7 (12.7%)	11 (6.7%)		
Acute kidney injury	3 (7.5%)	9 (7.5%)	8 (14.5%)	20 (12.3%)	11 (61.1%)	25 (56.8%)
Unplanned return to operating theatre			7 (12.7%)	11 (6.7%)		
Unplanned admission to ICU			8 (14.5%)	17 (10.4%)		
New sepsis	10 (25.0%)	47 (39.2%)				
Critical illness weakness	1 (2.5%)	5 (4.2%)				
New limitation of medical treatment	20 (50.0%)	29 (24.2%)				

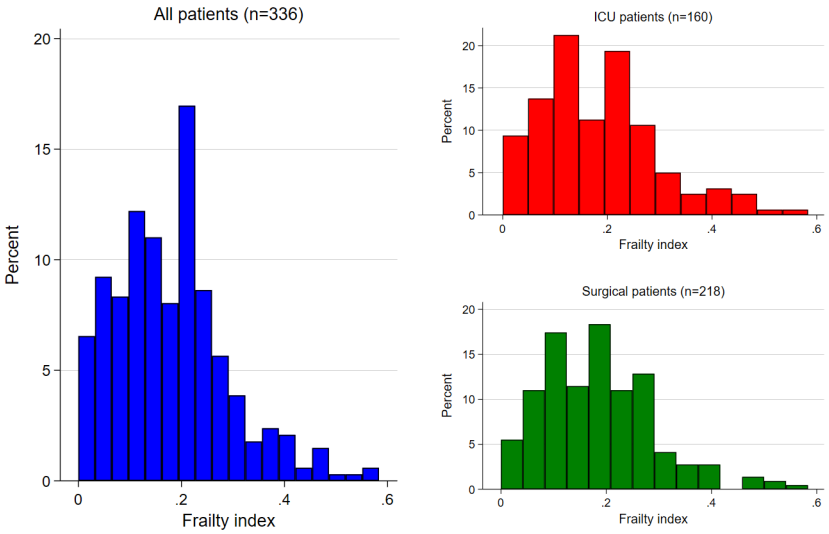
23 ICU patients and 7 Surgical patients who died in hospital were excluded from the analysis of hospital length of stay.

Table 4. Logistic regression models for outcomes and complications with frailty.

Variable	Univariate regression model		Multivariate regression model	
ICU patients (N = 160)	**Estimate (95% CI)**	**P value**	**Estimate (95% CI)**	**P value**
Mortality within 30 days	1.64 (1.15-2.35)	0.006	2.04 (1.19-3.48)	0.009
Mortality at six-month follow up	1.44 (1.06-1.96)	0.021	1.57 (0.99-2.48)	0.054
New sepsis	0.82 (0.61-1.11)	0.198	1.00 (0.66-1.51)	0.987
Acute kidney injury	1.20 (0.74-1.92)	0.459	1.14 (0.57-2.28)	0.702
Critical illness weakness	1.23 (0.65-2.33)	0.529	1.27 (0.50-3.24)	0.614
New limitation of medical treatment	1.88 (1.36-2.60)	<0.001	1.82 (1.14-2.88)	0.011
Hospital length of stay (days)	2.48 (-2.36-7.32)	0.313	2.60 (-3.71-8.91)	0.417
Discharge location				
Home	Ref.	0.007	Ref.	0.151
Assisted living facility/rehabilitation	2.55 (1.06-6.15)		1.43 (0.49-4.24)	
Other acute hospital	0.58 (0.12-2.82)		0.67 (0.12-3.93)	
Died in hospital	4.51 (1.64-12.42)		3.58 (1.06-12.08)	
Surgical patients (N = 218)	**Estimate (95% CI)**	**P value**	**Estimate (95% CI)**	**P value**
Mortality within 30 days	1.57 (0.91-2.71)	0.102	1.90 (0.98-3.66)	0.056
Mortality at six-month follow up	1.58 (1.14-2.19)	0.006	1.32 (0.88-1.99)	0.176
Acute myocardial infarction	1.15 (0.48-2.75)	0.749	0.73 (0.18-2.95)	0.663
Re-intubation	2.00 (1.12-3.57)	0.018	2.10 (0.96-4.61)	0.064
Acute pulmonary oedema	0.92 (0.57-1.49)	0.727	0.88 (0.48-1.60)	0.665
Wound infection	1.42 (0.95-2.12)	0.089	1.43 (0.89-2.32)	0.143
Acute kidney injury	1.11 (0.77-1.59)	0.583	1.19 (0.77-1.84)	0.433
Unplanned return to operating theatre	1.57 (1.06-2.33)	0.025	1.76 (1.08-2.86)	0.024
Unplanned admission to ICU	1.31 (0.91-1.88)	0.142	1.56 (1.00-2.43)	0.051
Hospital length of stay (days)	4.00 (1.49-6.51)	0.002	2.44 (0.04-4.83)	0.046
Discharge location				
Home	Ref.	0.0005	Ref.	0.005
Assisted living facility/rehabilitation	4.47 (2.18-9.20)		4.97 (1.99-12.43)	
Other acute hospital	1.88 (0.61-5.74)		2.44 (0.69-8.68)	
Died in hospital	3.66 (0.77-17.37)		5.22 (0.93-29.30)	

Multivariable regression models are adjusted for age, sex, admission source and Charlson comorbidity score for ICU patients and additionally adjusted for emergency/elective surgery for surgical patients.

Estimates are odds ratios (95% confidence intervals), with the exception of the estimates for hospital length of stay (median difference (95% confidence interval) and the estimates for discharge location (relative risk ratios (95% confidence intervals)).
23 ICU patients and 7 Surgical patients who died in hospital were excluded from the analysis of hospital length of stay.
Estimates and 95% confidence intervals correspond to a 0.1 unit change in Frailty Index.
The outcomes cardiac arrest, deep venous thrombosis, pulmonary embolus, stroke and cardiac arrest were not analysed due to numbers of patients < 5.



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