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CLINICAL INVESTIGATION

Postoperative outcomes in older patients living with frailty and multimorbidity in the UK: SNAP-3, a snapshot observational study

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Abstract

Background: Older surgical patients experience longer hospital stays and a higher risk of morbidity and mortality than their younger counterparts. Frailty (19.6% of cohort) and multimorbidity (63.1% of cohort) increase these risks. The 3rd Sprint National Anaesthesia Project (SNAP-3) describes the impact of frailty and multimorbidity on postoperative outcomes.
Methods: We conducted a prospective observational cohort study over 5 days in 2022 aiming to recruit all UK patients aged ≥60 yr undergoing surgery (excluding minor procedures). Data included patient characteristics, clinical variables, Clinical Frailty Scale (CFS), multimorbidity (*two or more comorbidities*), length of stay (LOS), postoperative delirium, morbidity, and mortality. Quantile regression and mixed effects logistic regression were used to analyse relationships.
Results: We recruited 7129 patients from 214 hospitals. Increasing frailty was associated with longer LOS, higher odds of delirium, morbidity, and mortality ≥1 yr, with a clear increase noted from CFS of 4 (19.0% of cohort). Amongst those without multimorbidity, individuals with CFS score of 4 had longer admissions than non-frail individuals (median LOS 0.75 days longer, 95% confidence interval [CI] 0.34–1.16), increasing to 2.69 days longer for CFS 5 (95% CI 0.76–4.62). Multimorbidity increased the odds of postoperative morbidity by 46% (adjusted odds ratio 1.46, 95% CI 1.24–1.73), but there was no evidence for multimorbidity impacting LOS, delirium, or mortality.
Conclusions: SNAP-3 highlights the impact of frailty on postoperative outcomes. Multimorbidity had less impact, with an effect on postoperative morbidity the only one to have strong statistical evidence. The impact of these conditions must be discussed with older patients considering surgical intervention.

Keywords: ageing; epidemiology; frailty syndrome; geriatric medicine; health service; multimorbidity; perioperative care; surgery

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Editor's key points

- The third Sprint National Anaesthesia Project (SNAP-3) is a large prospective study of the impact of frailty and multimorbidity on postoperative outcomes in elective and emergency surgical patients aged ≥60 yr in the UK conducted over 1 week in 2022.
- In 7129 patients recruited from 214 hospitals, increasing frailty was associated with longer hospital length of stay and higher odds of delirium, morbidity, and mortality ≥1 yr. Multimorbidity increased the odds of postoperative morbidity, but did not impact length of stay, delirium, or mortality.
- Even patients living with very mild frailty are at greater postoperative risk than non-frail individuals. These risks should be discussed with older patients considering surgical interventions.

The surgical population is ageing, with those aged ≥60 yr accounting for half of all patients undergoing surgery in the UK.[1] Older people are more likely to live with frailty and multimorbidity, and experience longer postoperative stays, complications, and death, than their younger counterparts.[1–4] Organisations in the UK and beyond have produced guidance on perioperative care of older patients.[2,5–7]

Frailty is a distinctive health state related to ageing in which multiple body systems gradually lose their in-built reserves.[2] Research demonstrates a strong association between frailty and postoperative mortality; one meta-analysis reported an odds ratio (OR) of 4.89 for 30-day mortality and a systematic review reported ORs for 1-yr mortality ranging from 1.1 to 4.97.[4,8,9] Frailty is also associated with a greater likelihood of postoperative complications.[8–11]

Multimorbidity is less easily defined; the literature uses varying definitions or in some cases does not define the term explicitly. The most widely accepted definition is the coexistence of two or more long-term physical or mental health conditions.[12,13] Studies report multimorbidity in 43.9–74% of surgical patients, with prevalence increasing with age.[14,15] The observed association between multimorbidity and poor postoperative outcomes varies, with some studies reporting impact of multimorbidity on postoperative outcomes and others not.[14] A multicentre study of major abdominal surgery reported that multimorbidity was associated with 30-day postoperative mortality and morbidity, with adjusted odds ratios (aORs) of 2.22 and 1.68, respectively.[15]

The impact of frailty and multimorbidity on postoperative outcomes within a large, prospective and representative cohort has not been fully described. The 3rd Sprint National Anaesthesia Project (SNAP-3) is a prospective, national study of elective and emergency surgical patients aged ≥60 yr in the UK. It examines the associations between frailty, multimorbidity, delirium, and postoperative outcomes. It adds new information to smaller single specialty and administrative database studies by using face-to-face clinical assessment in a large population. This report analyses the impact of frailty and multimorbidity on postoperative length of stay (LOS), morbidity, delirium, and mortality at 30 days, 120 days, and 1 yr.

Methods

Data are reported in accordance with STROBE guidelines (Supplementary Table 3).

Data collection and sample

The methods and regulatory approvals have been fully described.[16] In summary, all UK hospitals that deliver adult surgical services were invited to participate in a prospective observational cohort study. The study aimed to recruit all patients aged ≥60 yr undergoing a surgical procedure during 5 consecutive days (Monday–Friday) in March 2022. The study was conducted between waves of the COVID-19 pandemic.

SNAP-3 recruited patients undergoing surgery under general, regional, neuraxial, and local anaesthesia. SNAP-3 also included participants unable to consent to study participation. Patients undergoing very minor procedures, such as cataract surgery, were excluded (Supplementary Table 1). Ethical approval was granted by the Wales Research Ethics Service (21/WA/0203) for England, Northern Ireland, and Wales in July 2021. The Scotland A Research Ethics Committee (302033) provided ethical approval in September 2021. Regulatory approvals were obtained from relevant UK health authorities. Informed consent or assent was recorded electronically or in writing from participants, consultees, or personal legal representatives.

Local investigators, including anaesthetists and research nurses, collected patient characteristic, medical, surgical, laboratory, risk score, socioeconomic, and frailty data. A central team ensured data quality and completeness, addressing queries with sites. Access to web-based training on Clinical Frailty Scale (CFS) assessment was promoted.[17]

Exposures

In this paper we study two exposures, frailty and multimorbidity, within one conceptual and statistical model.

Frailty status was evaluated using the CFS, with frailty defined as CFS ≥5 for descriptive analyses.[18,19] In statistical models, frailty was treated as a 5-point scale (CFS 1–3, 4, 5, 6, 7–8) for all outcomes except for 30-day mortality, where a 3-point scale (CFS 1–3, 4–6, 7–8) was used owing to small numbers of events in each category. Five participants recorded as CFS 9 or 'terminally ill' were excluded from all analyses to minimise risk of disclosure.

Multimorbidity was defined as the presence of two or more specified comorbidities. We based our definition on the Charlson Comorbidity Index and conclusions from a recent Delphi study.[3,12,13,20] Our list of comorbidities included additional conditions relevant to the perioperative period, such as obstructive sleep apnoea and atrial fibrillation (Supplementary Table 2). Data on discharges, mortality, and comorbidities were from population-based healthcare administration records from NHS Digital (England), Digital Health and Care Wales, the Office for National Statistics (ONS), and NHS National Services Scotland.

Outcomes

The primary outcome was postoperative LOS, which is presented as both 50th (median) and 80th percentiles. Although no single measure fully captures the success of a surgical management pathway, postoperative LOS encapsulates

clinical, organisational, and social factors, all of which are influenced by frailty and multimorbidity. Secondary outcomes were postoperative morbidity, delirium, and mortality.

Postoperative morbidity was assessed using Postoperative Morbidity Survey (POMS), with specific versions for cardiac surgery and those with hip fracture.[21–23] Patients discharged on the day of surgery were assumed to have no significant postoperative morbidity. Inpatients were followed up on postoperative days 3 and 7.

Postoperative delirium was assessed using the 4 'A's Test (4AT) or Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) for inpatients on postoperative days 3 and 7.[24,25] Patients discharged on the day of surgery were assumed not to have delirium. The signs of delirium fluctuate, making it challenging to diagnose, so a retrospective notes review was conducted for those staying at least 1 night, extending up to discharge or 7 days post-procedure, to identify Diagnostic and Statistical Manual of Mental Illnesses-5-aligned indicators of delirium.[26]

Postoperative mortality data were obtained from death registrations through the ONS (England and Wales), National Records of Scotland (NRS), and local research teams (Northern Ireland). Mortality was assessed at 30 days, 120 days, and 1 yr.

Covariates

Age was centred (age in years minus 72 [median age in whole years]) and scaled (divided by 40 [approximate age range]) to aid model convergence for binary outcomes. A single eight-category nationality/deprivation variable was constructed as follows: the Index of Multiple Deprivation (IMD) deciles for those participants living within the UK were combined into quintiles. Those living in Northern Ireland, Scotland, and Wales were each treated as their own category, but not further divided into deprivation groups (owing to small numbers of patients in those countries). Biological sex assigned at birth, multimorbidity, dementia, malignancy, visual impairment, and hearing impairment were recorded as binary variables.

Directed acyclic graphs

To improve the reliability of causal inference, we developed directed acyclic graphs (DAGs) to define hypothesised relationships between exposures, outcomes, and related variables (detailed in a separate report).[27] This ensured transparency in our assumptions and guided the selection of covariates for adjusted models based on an evidence-driven rationale.

Statistical analysis

All analyses were conducted in R (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria).[28] In descriptive analyses, confidence intervals (CIs) for continuous variables were obtained using bootstrapping, and CIs for proportions were calculated using Rubin's rules.

For the primary outcome, we used quantile regression to model the median and 80th percentile of the LOS distribution. Bootstrapping with 1000 samples was used to estimate standard errors in the presence of clustering by hospitals in the data. All other outcomes were binary and were modelled using mixed effects logistic regression, with a random intercept for hospitals.

We studied frailty and multimorbidity within the same model in all our analyses.[29] The inclusion of two exposures captures the interplay between frailty and multimorbidity, reported in the literature.[30,31] In the analysis, this interplay is represented as an interaction term between frailty and multimorbidity. This allows the effect of frailty on outcomes to vary depending on multimorbidity status. The converse is also true: the effect of multimorbidity on outcomes is allowed to vary with the severity of frailty.

Multiple imputation

Missing exposure and covariate data were handled using multiple imputation under the assumption that data are Missing At Random (MAR) conditional on all variables included in the imputation model (Supplementary information 1). Twenty imputed datasets were analysed for each outcome; results were pooled using Rubin's rules. Where we have presented conditional predicted probabilities, we have used a 72-yr-old (median age) female residing in the UK in the third IMD quintile, with multimorbidity, but without malignancy, hearing impairment, visual impairment, and dementia.

Results

SNAP-3 recruited 7821 patients from 214 UK hospitals. After withdrawal of patients for reasons including postponement of surgery, not meeting inclusion criteria, and patient wishes, 7129 were included for analysis (Supplementary Fig. 1). The most frequently missing data points were complete assessments of all listed comorbidities (11.6% missing) and educational attainment (11.0% missing). In all remaining variables, <4% of data were missing (Supplementary Table 4). Mean (standard deviation) age of the cohort was 72.8 (8.2) yr, 50.9% were male, 35.6% were ASA physical status 3, 3.7% were ASA physical status 4 (Table 1), and 69.7% of SNAP-3 participants underwent elective surgical procedures.[31]

The prevalence of those living with frailty was 19.6% (95% CI 18.6–20.5%) and those living with multimorbidity was 63.1% (95% CI 62–64.3%). Amongst patients living with frailty, 78.8% (1079/1369) were also experiencing multimorbidity. In comparison, 27.1% (1079/3978) of individuals with multimorbidity also were living with frailty.[31]

Postoperative length of stay

Data on postoperative LOS are shown in Figure 1a with additional data in Tables 2 and 3, Supplementary Tables 5–7, and Supplementary Figures 2 and 3. Overall, median LOS for all older surgical patients was 1 (interquartile range [IQR] 0–5) day, with 34% of participants undergoing day surgery (34%). For those admitted overnight, the median LOS was 3 days (1–7 days). Patients undergoing elective surgery had a median LOS of 1 (IQR 0–3) day, whereas those undergoing nonelective surgery had a median LOS of 5 (IQR 1–13) days.

There was a strong effect of frailty on both the median and the 80th percentile of LOS. Those living with very mild frailty (CFS 4) and not with multimorbidity are estimated to have 0.75 days longer median LOS than those without frailty or multimorbidity (95% CI 0.34–1.16). There was no association between multimorbidity and LOS (in the absence of frailty) when compared with those without frailty and multimorbidity. Greater severity of frailty is associated with longer median and 80th percentile LOS, whereas at each severity of frailty, differences between patients without and with multimorbidity were comparatively small. There was no consistent evidence

Table 1 Demographic and clinical characteristics according to presence/absence of delirium. ASA, American Society of Anesthesiologists physical status score; CFS, Clinical Frailty Scale; ENT, ear nose and throat. Percentages have been rounded so might not total 100% exactly. Missing data are omitted from this table, but reported in Supplementary Table 4. Surgical urgency is defined using NCEPOD categorisations.[32]

	Overall cohort	Delirium	No delirium
	N=7134	N=482	N=6652
Sex, *n* (%)			
Female	3465 (49.1)	254 (52.7)	3211 (48.8)
Male	3595 (50.9)	228 (47.3)	3367 (51.2)
Age (yr), mean	72.8	79.8	71.9
60–69	2585 (36.6)	85 (17.7)	2500 (38.0)
70–79	2839 (40.2)	145 (30.1)	2694 (41.0)
80–89	1401 (19.9)	172 (35.8)	1229 (18.7)
≥90	231 (3.3)	79 (16.4)	152 (2.3)
ASA physical status, *n* (%)			
1	513 (7.3)	4 (0.8)	509 (7.8%)
2	3725 (53.2)	105 (21.8)	3620 (55.5)
3	2490 (35.6)	290 (60.3)	2200 (33.8)
4	261 (3.7)	80 (16.6)	181 (2.8)
5	10 (0.1)	2 (0.4)	8 (0.1)
Frailty by CFS ≥5, *n* (%)			
Not frail	5628 (80.4)	198 (41.3)	5430 (83.3)
Frail	1369 (19.6)	281 (58.7)	1088 (16.7)
CFS, *n* (%)			
1	808 (11.5)	15 (3.1)	793 (12.2)
2	1351 (19.3)	35 (7.3)	1316 (20.2)
3	2141 (30.6)	69 (14.4)	2072 (31.8)
4	1328 (19.0)	79 (16.5)	1249 (19.2)
5	696 (9.9)	100 (20.9)	596 (9.1)
6	421 (6.0)	84 (17.5)	337 (5.2)
7	222 (3.2)	81 (16.9)	141 (2.2)
8	25 (0.4)	13 (2.7)	12 (0.2)
9	5 (0.1)	3 (0.6)	2 (0.0)
Multimorbidity, *n* (%)			
No	2325 (36.9)	92 (19.9)	2233 (38.2)
Yes	3978 (63.1)	391 (80.1)	3607 (61.8)
Number of comorbidities, median	2	3	2
Dementia, *n* (%)			
No dementia	6875 (97.4)	397 (78.6)	6496 (98.7)
Dementia	186 (2.6)	103 (21.4)	83 (1.3)
Surgical urgency, *n* (%)			
Emergency	161 (2.3)	31 (6.4)	130 (2.0)
Expedited	1062 (15.0)	216 (44.8)	846 (12.9)
Urgent	915 (13.0)	101 (21.0)	814 (12.4)
Elective	4922 (69.7)	134 (27.8)	4788 (72.8)
Postoperative morbidity (excluding delirium), *n* (%)			
No morbidity	2953 (60.9)	63 (13.1)	2890 (66.2)
Morbidity	1895 (39.1)	419 (86.9)	1476 (33.8)

of an interaction effect between frailty with multimorbidity and LOS.

Postoperative delirium

Data on postoperative delirium are shown in Figure 1b with additional data in Tables 2 and 3, Supplementary Tables 8 and 9, and Supplementary Figure 5. The incidence of delirium among all older surgical participants in the SNAP-3 study was 6.8% (95% CI 6.2–7.3%). The incidence was higher for individuals living with frailty at 20.5% (95% CI 18.4–22.6%) than for those without frailty at 3.5% (95% CI 3.0–4.0%). Amongst those living with multimorbidity, the incidence of delirium was 9.3% (95% CI 8.4–10.3%), whereas in those without multimorbidity it was 4.8% (95% CI 4.1–5.7%).

There was a positive relationship between severity of frailty and delirium. For example, those living with very mild frailty (CFS 4) and not with multimorbidity are estimated to have more than twice the odds of delirium than those without frailty or multimorbidity (aOR 2.33 [95% CI 1.33–4.06]). There was no evidence of an association between living with multimorbidity and developing delirium amongst those without frailty. We found no evidence for an interaction between frailty and multimorbidity for the odds of postoperative delirium. For CFS ≥4, the additional presence of multimorbidity did not modify the adjusted odds of developing postoperative delirium.

Postoperative morbidity

Data on postoperative morbidity are shown in Figure 1c with additional data in Tables 2 and 3, Supplementary Tables 10 and 11, and Supplementary Figure 6. Postoperative morbidity (excluding delirium) within 7 days of surgery occurred in 26.6%

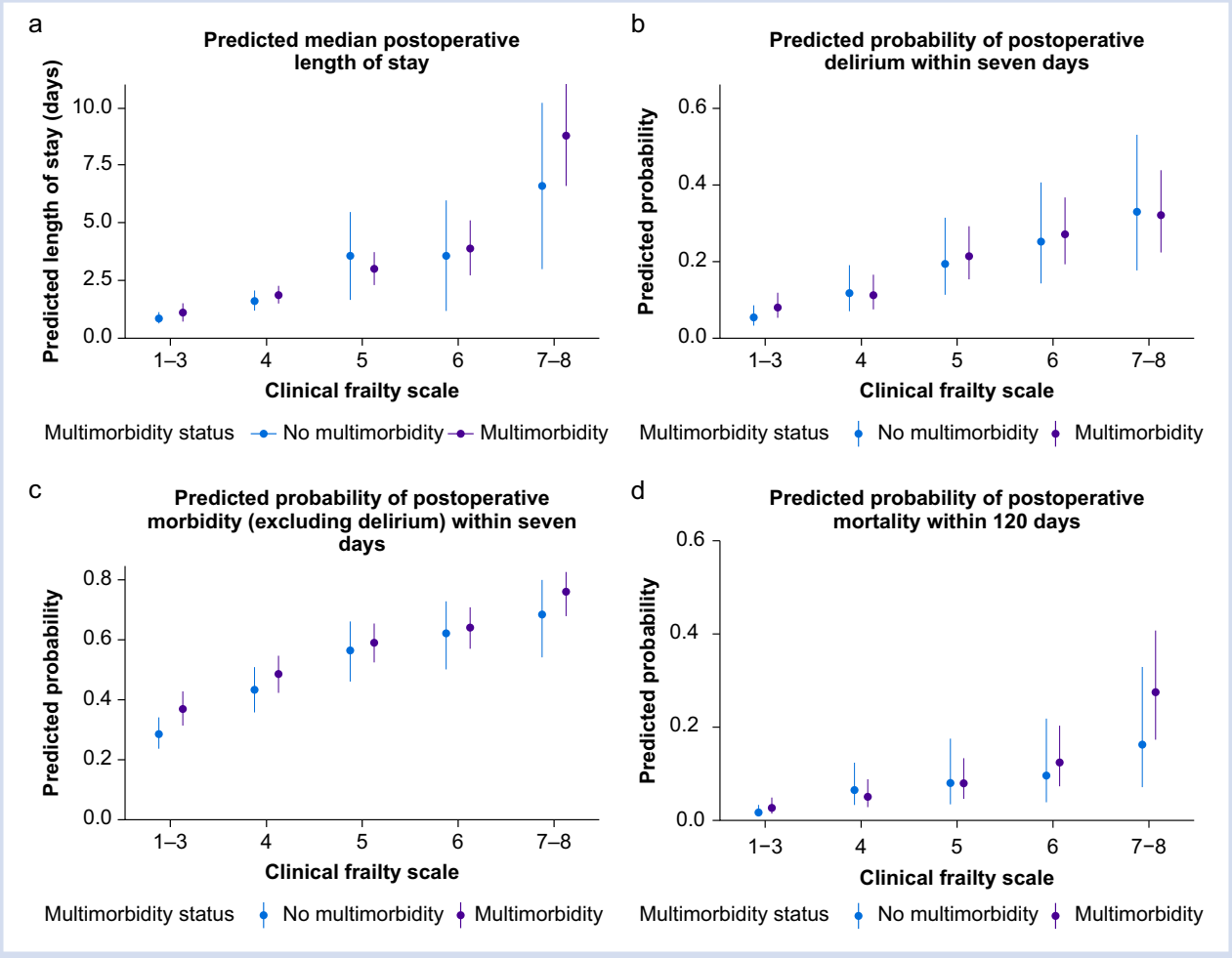

Fig 1. The predicted median length of stay (LOS) and the conditional probabilities of postoperative outcomes in older patients, described by frailty status (Clinical Frailty Scale ≥5) and multimorbidity status (two or more comorbidities). (a) The predicted median postoperative LOS in days for older patients, derived from a quantile regression model adjusted for age, dementia, malignancy, hearing impairment, visual impairment, sex, and area social deprivation/nation. (b–d) The predicted probabilities of delirium within 7 days (b); morbidity within 7 days of surgery (excluding delirium) (c); and mortality within 120 days (d), for those who are female, age 72.8 yr (median for the cohort), without dementia, hearing impairment or visual impairment, and living in an area which is defined as Index of Multiple Deprivation (IMD) level 5–6 (of 10) in UK. The predicted probabilities and confidence intervals are derived from multilevel logistic regression models, adjusted for age, dementia, malignancy, hearing impairment, visual impairment, sex, and area social deprivation/nation. This figure is produced using data from Supplementary tables.

(95% CI 25.6–27.6%) of participants. The incidence was double in those living with frailty (49.1% [95% CI 46.7–51.9%]) and was higher in those living with multimorbidity (34.0% [95% CI 32.3–35.5%]) than in those without these conditions.

Increasingly severe frailty was associated with increasing odds of postoperative morbidity. The aOR for morbidity in those living with very mild frailty (CFS 4) *vs* without frailty was 1.91 (95% CI 1.47–2.48) amongst those without multimorbidity. For those living with multimorbidity, the aOR for developing postoperative morbidity was 1.46 (95% CI 1.24–1.73) compared with those without multimorbidity or frailty. We found no evidence for an interaction between multimorbidity and frailty for postoperative morbidity, as living with multimorbidity was associated with increased odds of postoperative morbidity at all levels of frailty.

30-day postoperative mortality

Data on 30-day postoperative mortality are shown in Tables 2 and 3, Supplementary Tables 12 and 13, and Supplementary Figures 7 and 8. Thirty-day mortality was 1.2% (95% CI 0.9–1.4%); this was higher for those living with frailty and multimorbidity than for those without these conditions. There is a positive association between severity of frailty and predicted probabilities of death within 30 days of surgery. The aOR for 30-day mortality, for a person living with very mild to moderate frailty (CFS 4–6 and not multimorbidity) was 4.66 (95% CI 1.31–16.64) when compared with an individual living without frailty and multimorbidity.

Amongst patients without frailty, living with additional multimorbidity showed no evidence of an effect on 30-day mortality (aOR 1.91 [95% CI 0.55–6.56]). Once an individual is

Table 2 Incidence of postoperative outcomes according to frailty and multimorbidity. These descriptive data describe the incidence of SNAP-3 postoperative outcomes including length of stay (LOS); delirium within 7 days after surgery; morbidity (excluding delirium) within 7 days after surgery; 30-day, 120-day, and 1-yr mortality. Frailty is defined as Clinical Frailty Scale ≥5 and multimorbidity as two or more comorbidities. Normal-based 95% confidence intervals were calculated using bootstrapped standard errors (1000 replications).

Outcome	Overall cohort	*Frail and multimorbid*	*Frail but not multimorbid*	*Multimorbid but not frail*	*Not frail or multimorbid*
	N=7134	N=1079	N=177	N=2863	N=2129
	95% CI	95% CI	95% CI	95% CI	95% CI
Median LOS	1.0 (0.0–5.0)	5.0 (1.0–13.0)	5.0 (1.0–13.0)	1.0 (0.0–5.0)	1.0 (0.0–3.0)
80th percentile LOS	6.0 (6.0–6.0)	16.0 (14.0–18.0)	17.0 (11.0–21.0)	6.0 (5.0–6.0)	4.0 (3.0–4.0)
Delirium	6.8 (6.2–7.3)	22.1 (19.6–24.5)	18.1 (13.0–23.7)	4.6 (3.8–5.3)	2.8 (2.1–3.4)
Morbidity excluding delirium	26.6 (25.6–27.6)	60.3 (57.0–63.5)	56.0 (48.0–64.6)	37.1 (35.0–39.2)	29.6 (27.2–32.0)
30-day mortality	1.2 (0.9–1.4)	4.0 (2.9–5.2)	2.3 (0.6–4.5)	0.6 (0.4–0.9)	0.3 (0.1–0.6)
120-day mortality	3.0 (2.6–3.4)	10.0 (8.1–11.8)	5.6 (2.3–9.6)	2.1 (1.6–2.6)	1.1 (0.7–1.6)
1-yr mortality	6.8 (6.3–7.4)	18.2 (15.8–20.7)	10.2 (6.2–14.7)	6.4 (5.5–7.3)	2.8 (2.1–3.5)

Table 3 Adjusted effect estimates from regression of postoperative outcomes on frailty and multimorbidity (as a joint exposure). CFS, Clinical Frailty Scale; CI, confidence interval; LOS, length of stay. Estimates are given as quantile regression coefficients (for LOS) and odds ratios from mixed effects logistic regressions (for all other outcomes). Estimates represent the effect of having a certain combination of CFS scale point and multimorbidity relative to the common reference 'CFS 1–3, not multimorbid'. All estimates are adjusted for age, dementia, malignancy, hearing impairment, visual impairment, sex, and area social deprivation/nation (see Fig. 1). Mixed effects logistic regressions include a random intercept for hospital. Normal-based 95% CIs were calculated using bootstrapped standard errors (1000 replications) for length of stay. Rubin's rules were applied in secondary outcomes.

Outcome	Exposure variable		Quantile regression coefficient	(95% CI)	*P*-value
	(ref: CFS 1–3, no multimorbidity)				
Median LOS	No multimorbidity	CFS 4	0.75	(0.34–1.16)	<0.001
		CFS 5	2.69	(0.76–4.62)	0.007
		CFS 6	2.71	(0.32–5.10)	0.025
		CFS 7–8	5.66	(2.22–9.09)	0.002
	Multimorbidity	CFS 1-3	0.25	(−0.20 to 0.70)	0.267
		CFS 4	1.02	(0.65–1.39)	<0.001
		CFS 5	2.15	(1.45–2.85)	<0.001
		CFS 6	3.05	(1.83–4.26)	<0.001
		CFS 7–8	7.96	(5.72–10.19)	<0.001
80th percentile LOS	No multimorbidity	CFS 4	2.66	(0.70–4.61)	0.008
		CFS 5	5.74	(2.42–9.06)	0.001
		CFS 6	8.92	(2.20–15.64)	0.009
		CFS 7–8	21.16	(6.78–35.54)	0.004
	Multimorbidity	CFS 1-3	0.76	(−0.01 to 1.53)	0.051
		CFS 4	2.47	(1.52–3.42)	<0.001
		CFS 5	7.53	(5.69–9.38)	<0.001
		CFS 6	10.39	(7.85–12.93)	<0.001
		CFS 7–8	15.33	(9.74–20.93)	<0.001
Outcome	**Exposure variable**		**Odds ratio**	**(95% CI)**	***P*-value**
	(ref: CFS 1–3, no multimorbidity)				
Delirium	No multimorbidity	CFS 4	2.33	(1.33–4.06)	0.003
		CFS 5	4.19	(2.25–7.78)	<0.001
		CFS 6	5.84	(2.81–12.16)	<0.001
		CFS 7–8	8.57	(3.62–20.26)	<0.001
	Multimorbidity	CFS 1–3	1.50	(0.99–2.26)	0.055
		CFS 4	2.20	(1.45–3.34)	<0.001
		CFS 5	4.73	(3.10–7.23)	<0.001
		CFS 6	6.45	(4.13–10.09)	<0.001
		CFS 7–8	8.21	(4.81–14.00)	<0.001

Continued

Table 3 Continued

Outcome	Exposure variable (ref: CFS 1–3, no multimorbidity)		Quantile regression coefficient	(95% CI)	P-value
Morbidity	No multimorbidity	CFS 4	1.91	(1.47–2.48)	<0.001
		CFS 5	3.24	(2.19–4.79)	<0.001
		CFS 6	4.12	(2.57–6.61)	<0.001
		CFS 7–8	5.45	(3.00–9.88)	<0.001
	Multimorbidity	CFS 1–3	1.46	(1.24–1.73)	<0.001
		CFS 4	2.36	(1.96–2.84)	<0.001
		CFS 5	3.62	(2.91–4.49)	<0.001
		CFS 6	4.48	(3.45–5.81)	<0.001
		CFS 7–8	7.93	(5.48–11.48)	<0.001
30-day mortality	No multimorbidity	CFS 4–6	4.66	(1.31–16.64)	0.018
		CFS 7–8	27.69	(6.4–119.86)	<0.001
	Multimorbidity	CFS 1–3	1.91	(0.55–6.56)	0.305
		CFS 4–6	6.00	(2.05–17.57)	0.001
		CFS 7–8	48.7	(15.46–153.47)	<0.001
120-day mortality	No multimorbidity	CFS 4	4.03	(1.99–8.17)	<0.001
		CFS 5	5.05	(2.03–12.56)	<0.001
		CFS 6	6.17	(2.3–16.53)	<0.001
		CFS 7–8	11.25	(4.24–29.85)	<0.001
	Multimorbidity	CFS 1-3	1.6	(0.87–2.93)	0.131
		CFS 4	3.09	(1.70–5.62)	<0.001
		CFS 5	5.01	(2.73–9.20)	<0.001
		CFS 6	8.22	(4.39–15.39)	<0.001
		CFS 7–8	21.99	(11.49–42.08)	<0.001
1- yr mortality	No multimorbidity	CFS 4	3.21	(2.08–4.97)	<0.001
		CFS 5	2.58	(1.30–5.11)	0.007
		CFS 6	2.65	(1.21–5.80)	0.015
		CFS 7–8	10.12	(5.14–19.95)	<0.001
	Multimorbidity	CFS 1–3	1.43	(1.01–2.02)	0.042
		CFS 4	2.64	(1.85–3.77)	<0.001
		CFS 5	3.37	(2.30–4.95)	<0.001
		CFS 6	6.0	(4.01–9.00)	<0.001
		CFS 7–8	14.37	(9.17–22.53)	<0.001

living with any degree of frailty, from very mild (CFS 4) to very severe (CFS 8), there was no evidence that additional multimorbidity increases the risk of 30-day mortality. We did not find evidence of an interaction between multimorbidity and frailty related to the odds of 30-day mortality.

120-day and 1-yr postoperative mortality

Data on 120-day and 1-yr postoperative mortality are shown in Figure 1d with additional data in Tables 2 and 3, Supplementary Tables 14–17, and Supplementary Figures 9–11. Overall mortality was 3.0% (95% CI 2.6–3.4%) at 120 days and 6.8% (95% CI 6.3–7.4%) at 1 yr. The 120-day and 1-yr mortality were higher for those living with frailty (120-day mortality: 9.0% [95% CI 7.5–10.5%]; 1-yr mortality: 16.4% [95% CI 14.6–18.6%]), and those living with multimorbidity (120-day mortality: 4.2% [95% CI 3.5–4.9%]; 1-yr mortality: 9.2% [95% CI 8.2–10.1%]) than for those without frailty (120-day mortality: 1.6% [95% CI 1.3–1.9%]; 1-yr mortality: 4.8% [95% CI 4.1–5.7%]) and without multimorbidity (120-day mortality: 2.0% [95% CI 1.5–2.5%]; 1-yr mortality: 4.8% [95% CI 4.1–5.7%]).

The odds of 120-day and 1-yr mortality increased with increasing severity of frailty. The aORs for 120-day and 1-yr mortality for individuals living with very mild frailty (CFS 4) and not with multimorbidity were 4.03 (95% CI 1.99–8.17) and 3.21 (95% CI 2.08–4.97), respectively, when compared with an individual without frailty and multimorbidity. The impact of frailty was more pronounced on 120-day mortality than on 1-yr mortality. There was no strong evidence that living with multimorbidity has an effect on mortality at 120 days or 1 yr, after adjustment. We did not find evidence of an interaction between multimorbidity and frailty related to the odds of 120-day or 1-yr mortality.

Discussion

SNAP-3 reports a strong association between frailty and adverse postoperative outcomes, including increased LOS, delirium, morbidity, and mortality (up to 1 yr), in a large, representative UK population. These findings are consistent with prior research most often conducted on smaller or more selective cohorts from the UK, Canada, Europe, and the USA.[15,19,33–39]

The impact of frailty on these adverse outcomes is observed for CFS 4, not just for CFS 5 which has traditionally been used as a cut-off for frailty. This aligns with other studies including a recent Canadian study reporting elevated postoperative mortality and morbidity rates from CFS 4.[19,40] Furthermore, risk of adverse outcomes increases with each increase in CFS score (from 1–3 through 7–8), calling into

question the value of dichotomising frailty at CFS 5 to inform clinical decision-making. Expanding the definition of frailty to include individuals with CFS ≥4 would double the prevalence to 38.6% within the older surgical population, highlighting the importance of dedicated frailty services.[31]

Like any observational study, our results are valid estimates of causal effects conditional on the assumption that there is no unobserved confounding. SNAP-3 benefitted from the use of DAGs to clarify the causal assumptions that underpinned our analyses *a priori*, enabling researchers to contrast our results with results that might be obtained under different assumptions. Technically, our models assume that frailty and multimorbidity are separate exposures that do not influence one another. There might actually be mutual causation such that multimorbidity increases the risk of frailty and *vice versa*. To the extent that such mutual causation exists, we cannot claim to have estimated the total effect of multimorbidity on our outcomes, as in order to do so we should not have adjusted for frailty. This is because under the assumption of mutual causation, frailty is on the causal pathway from multimorbidity to the outcome. What we have estimated instead is the direct effect of multimorbidity on our outcomes through pathways other than frailty. The same goes, *vice versa*, for frailty: insofar as there is a causal path from frailty to outcomes via multimorbidity, our models have blocked this path, so we have estimated the effect of frailty on outcomes through pathways other than via multimorbidity.

Surgery is often a single episode punctuating the longer-term care of an older individual. One in five older surgical patients live with frailty, a modifiable risk factor for adverse outcomes. Optimisation before surgery, informed decision-making, and tailored postoperative care can help mitigate its effects. Early frailty screening for older patients, ideally starting in primary care and confirmed before surgery is imperative.[2] A US study found that frailty screening and referral for enhanced presurgical evaluation in elective patients reduced 1-yr mortality.[35] However, it is not universal with preoperative screening only occurring in around 29% of nurse-led preoperative assessment clinics.[11,41]

Identification of frailty should prompt holistic assessment for related syndromes using tools such as 4AT and Montreal Cognitive Assessment (MoCA) and referral for comprehensive geriatric assessment (CGA) and optimisation.[2] These interventions, alongside proactive complication detection, can reduce LOS, delirium, and mortality.[42] However, managing frailty requires specialist expertise, typically from geriatricians, whose shortage limits perioperative CGA access. Alternative CGA models including a toolkit approach delivered by an alternative workforce including anaesthetists did not demonstrate improved clinical outcomes.[43] Such workforce challenges might be compounded by the growing evidence that lower levels of frailty (CFS 4) also confer increased risk of adverse postoperative outcomes.

Addressing frailty management in the context of a limited geriatric medicine workforce requires a multifaceted approach: cross-specialty training, early patient segmentation for appropriate referral, and expanding geriatric medicine training numbers to meet healthcare demands.[44] Although preoptimisation is mainly managed in primary care, with specialist input, a skilled generalist workforce is essential, emphasising the need for retention and expansion in this area.[45]

The effect of multimorbidity on postoperative outcomes was only observed for morbidity, and even there the estimated effect of multimorbidity was smaller than that of frailty. We did not find evidence for an interaction between frailty and multimorbidity. Our findings align with a multicentre cohort of emergency surgical admissions where no association was found between multimorbidity and LOS, 30-, and 90-day mortality.[14] However, another multicentre study of major abdominal surgery found evidence of an association between multimorbidity and 30-day mortality in a more selective cohort.[15] Given these inconsistent findings, future research might benefit from adopting a more selective definition of multimorbidity. Although the term 'complex multimorbidity' is not widely used or clearly defined in the literature, it might offer a useful approach to investigating varying levels of risk associated with the cumulative effects of chronic disease.[12] In its simplest form, this concept could be defined by raising the threshold to define multimorbidity to three or more chronic conditions. Alternatively, a more nuanced approach might consider comorbidity severity or specific comorbidity combinations that influence outcomes.[46] Refining the definition of multimorbidity to include only those whose comorbidities impact postoperative outcomes to an important extent would enhance discrimination and clinical relevance. The SNAP-3 dataset provides researchers with the opportunity to explore this further.

Shared decision-making improves patient satisfaction, adherence, and reduces decisional regret.[47,48] Gaps in clinician knowledge of the impact of frailty and multimorbidity on postoperative outcomes are an important barrier to its widespread implementation.[49,50] Although risk scores such as National Surgical Quality Improvement Program (NSQIP) and National Emergency Laparotomy Audit (NELA) assist decision-making, they often focus narrowly on mortality, neglecting morbidity, LOS, and geriatric syndromes.[33,51] SNAP-3 enhances these conversations by illustrating how frailty influences outcomes, though gaps remain in understanding outcomes and decisional regret in patients choosing operative *vs* nonoperative care.

Shared decision-making requires estimation of likely outcomes based on individual patient risk profiles both with and without surgery and has been shown to improve patient satisfaction, adherence, and reduce decisional regret.[47–50] SNAP-3 enhances shared decision-making by enhancing our understanding of how frailty impacts on postoperative outcomes.

We believe our findings are robust. First, SNAP-3 recruited an unselected population from almost all UK hospitals with prospective study-specific data, so the risk of selection bias is low. Second, we prospectively defined analyses based on clinically relevant hypothesised causal relationships from existing literature, reviewed by clinical experts outside our group.[27] This ensured that the adjustment variables were based on evidence, theory, and clinical experience, making the selection process transparent. Third, our data are concordant with the largely administrative datasets that have reported.[34,52] SNAP-3 had a low proportion of missing information and our use of multiple imputation using chained equations aimed to mitigate the risk of bias through nonresponse (Supplementary Table 4, Supplementary information 1). Detecting delirium in a large observational study with limited resource is challenging, but we mitigated this risk by

combining clinical assessments with retrospective notes review. Similarly, detecting postoperative morbidity is complex; our protocol assumed that participants discharged on the day of surgery did not experience significant morbidity. Although this approach is pragmatic, it might underestimate the incidence of complications that are managed on an outpatient basis. Additionally, the low incidence of 30-day mortality limited the opportunity for detailed analysis.

Conclusions

SNAP-3 describes the impact of frailty on adverse postoperative outcomes, including longer hospital stays, higher risks of delirium and morbidity, and increased mortality up to 1 yr, compared with those without frailty. Even patients living with very mild frailty (CFS 4) are at greater postoperative risk than non-frail individuals, despite the traditional use of CFS 5 as the frailty 'threshold'. We found that multimorbidity in the absence of frailty has an effect on postoperative morbidity, but no strong evidence that multimorbidity increases LOS, delirium, or mortality risk up to 1 yr after surgery.

Authors' contributions

Project initiation, guarantor, and grant holder: IKM
Patient-facing document design and patient and public insights: BE, CJS, JSLP, IKM
Ethical and regulatory approvals: CJS, KW
Data collection tools and protocol design: CJS, JSLP, IKM, TP, AS
Study implementation in the UK: CJS, KW, IKM, JSLP
Site and UK-wide activity coordination: KW, CJS
Analysis plan development: IKM, PM, HAB, CJS
Monitoring data collection: CJS
Finalising data collection: SN
Statistical expertise in study design and analysis methods: PM, HAB
Data cleaning: CJS, IKM
Data analysis: CJS, HAB, IKM, PM
Review of final draft and contributions to revisions: all authors

Declarations of interest

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Appendix A. Supplementary data

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