Perioperative Medicine

CASE STUDY

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The impact of frailty on functional recovery after cardiac surgery—a case control study

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Abstract

Background Good functional recovery after cardiac surgery can be reported as 'days alive and out of hospital' in the first 30 days after a procedure ($DAOH_{30}$) and 'days at home' in the first year (DAH_{365}), which integrate several clinically important outcomes, including death, hospital length of stay, quality of recovery and hospital readmission. They depend on the preservation or early recovery of physiological and functional capacity, both of which may be lost in patients living with frailty.

Case presentation We measured frailty with a multidimensional approach, incorporating 30 variables spanning comorbidity, sensory, cognitive, psychosocial, disability and pharmaceutical domains, which together make up the Patient Frailty Index (pFI). We further explored the impact of socioeconomic factors on functional recovery using the Welsh Index of Multiple Deprivation (WIMD). The outcome measures included duration of level 3 and level 2 care, duration of hospital stay, readmission and both short- and longer-term mortality. A total of 669 patients were included in the final analysis. A total of 224 (33.5%) of the patients were 'frail'. They were more likely to have chronic obstructive pulmonary disease, heart failure and diabetes and to be in the lowest decile for deprivation. Frailty was not associated with either sex or advanced age. Patients deemed to be 'frail' had a longer stay in intensive care, required level 3 cardiovascular and respiratory support for longer and stayed longer in the hospital. They spent fewer days at home in the first 30 days, largely due to days requiring advanced cardiovascular support, and fewer days at home in the first year, with most days lost to patients who died in the first year following their surgery. A moderation analysis examined whether the WIMD modified the effect of frailty on recovery after cardiac surgery. The interaction term, after confirming there were no collinearity concerns, was not significant, either for $DAOH_{30}$ or DAH_{365}, indicating no evidence of moderation.

Conclusions Short- and medium-term measures of good functional recovery were lower in 'frail' patients, and longer-term survival was also significantly reduced. An accumulation of deficits assessment of frailty, incorporating multiple domains, builds a more accurate picture of increasing vulnerability and can be acquired from patients' electronic health records. In a surgical population that is increasingly comorbid, these findings should inform decisions on preoperative priority setting, prehabilitation, postoperative resources and discharge planning.

Keywords Frailty, Functional recovery, Socioeconomic deprivation

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Background

Outcomes after cardiac surgery can be measured and reported in various ways. The concept of a good functional recovery after a procedure or surgery is increasingly used, including 'days alive and out of hospital' in the first 30 days after a procedure ($DAOH_{30}$) and 'days at home' in the first year (DAH_{365}) (Jerath et al. 2019), (Myles 2020). These integrate several clinically important outcomes, including death, hospital length of stay, quality of recovery and hospital readmission. In contrast, in the UK, the main method of assessing surgical risk after cardiac surgery, the EuroSCORE II, is designed to predict short-term mortality following cardiac surgery. It may be incompletely calibrated to identify patients who will recover well and those who will not.

Good functional recovery depends on the preservation of physiological and functional capacity. Loss of these is strongly correlated with higher levels of frailty (Afilalo et al. 2017). The demographics of patients referred for cardiac surgery over the past 20 years has demonstrated an increase in mean patient age and logistic EuroSCORE, and therefore by inference only, in frailty (Grant et al. 2021). Frailty results from the cumulative decline in multiple physiological systems. Therefore, the use of single-domain instruments (grip strength or gait speed), the frailty phenotype model (unintentional weight loss, fatigue, weakness, slow walking speed and low physical activity) or proxies, such as nutritional status, together with age, which has often been the case in cardiac surgery, may misrepresent the incidence of frailty is this population (Rodriguez-Manas et al. 2013). Instead, a multidimensional approach to assess frailty can be used.

The accumulation of deficits model (Mitnitski et al. 2001), to generate a frailty index, counts deficits in health, which can be symptoms, signs, diseases, disabilities or abnormalities in health-related investigations. At least 30 variables should be considered, across a range of systems. The chosen deficits should not saturate too early, so that in the case of an index used in a cardiac surgical setting, a variable should not be universally present in this population. The index is expressed as a ratio of deficits present, to the total number of deficits considered (Searle et al. 2008). Such an index has been described in a cardiac population (McIsaac et al. 2021). It consists of 30 variables (McIsaac et al. 2019) that together make up the Patient Frailty Index (pFI). One of the 30 variable included in the original index was socioeconomic status, subdivided by quintiles.

In addition to the calculation of the pFI, we recorded the Welsh Index of Multiple Deprivation (WIMD) for each patient, based on the patients' postcode, as a measure of socioeconomic deprivation. We used this to measure the modifying effect of material, behavioural and psychosocial influences on outcomes after surgery.

Methods

We retrospectively analysed the locally held cardiac surgical database, together with Intensive Care National Audit & Research Centre (ICNARC) data, to determine the morbid outcomes of a cohort of patients who underwent cardiac surgery in a tertiary referral centre in South Wales, UK. Days in level 3 (ITU) and 2 (HDU) care, together with the quantification of days requiring advanced cardiovascular, respiratory, renal and neurological care, were collated from the ICNARC data. Length of stay in the hospital included time spent in another hospital, other than the main cardiac centre, if the patient was immediately transferred for rehabilitation. The 30-day and 1-year mortality data were acquired from electronic patient records, which include primary and secondary care records, and were automatically updated if the patient died. We excluded data of patients who underwent emergency surgery. Readmission to the main cardiac centre hospital and to other hospitals in Wales was used to calculate $DAOH_{30}$ and DAH_{365}.

Frailty assessment

We used the electronic patient record (Welsh Clinical Portal) to score the pFI. Data were acquired and collated by investigators unaware of the clinical outcomes of the patients. We used the same domains as those reported by McIsaac et al. (McIsaac et al. 2021) and adapted for UK data fields held in the Welsh Clinical Portal, as shown in Table1.

Household income and deprivation

We used the Office of National Statistics data and the patients' postcodes to estimate the relative wealth (England and Wales) before housing costs (Income 2018) and WIMD (Welsh 2019) to rank the overall deprivation by lower-layer super output areas (LSOAs). This inventory is compiled from 8 domains: income, employment, health, education, access to services, community safety, the physical environment and housing. One of the 30 variables in the pFI is household income, which is also a component of the WIMD. This overlap introduces potential collinearity, which we accounted for in our analysis.

Statistical analysis

Statistical analysis was performed via Jamovi software. Continuous data are presented as the means ± standard deviations (SDs) or medians with ranges and were compared via Student's *t*-test or the Mann–Whitney *U* test for nonparametric data. Categorical data are presented as numbers and percentages and were compared via the

Table 1 Scoring system to calculate the Patient Frailty Index (pFI)—adapted from McIsaac et al. (McIsaac et al. 2021)]

Variable	Source	Points		
		0	0.5	1
Anticholinergic risk scale	ACB[a]	0	1–2	> 2
Arrhythmia	WCP[b]	None		Present
Cancer	WCP[c]	None		Present
Cerebrovascular disease	WCP[d]	None		Present
COPD	WCP[e]	None		Present
Dementia	WCP	None		Present
Dental	WCP	None		Present
Dermatologic	WCP[f]	None		Present
Diabetes mellitus	WCP	None		Present
Dialysis	WCP	None		Present
Drug or alcohol abuse	WCP	None		Present
Heart failure	WCP[g]	None		Present
Hemiparesis	WCP[h]	None		Present
History of falls	WCP[i]	None		Present
Home oxygen	WCP	None		Present
HOMR score	HOMR[j]	0–21	22–55	> 55
Hypertension	WCP[k]	None		Present
Injury	WCP	None	Minor	Major
Liver disease	WCP	None		Present
Multimorbidity	CCI[l]	0	1–2	> 2
Myocardial infarction	WCP	None		Present
Peripheral vascular disease	WCP	None		Present
Psychosocial	WCP[m]	None		Present
Resource use	WCP[n]	0–1	2–3	4–5
Rheumatic disease	WCP	None		Present
Socioeconomic status	ONS[o]	4 th/5 th	3rd	1 st/2nd
Ear, nose, throat	WCP	None	Stable	Unstable
Eye	WCP	None	Stable	Unstable
Weight loss	WCP[p]	None		Present

The pFI is calculated by adding the score for each deficit and dividing this number by the total number of deficits measured

WCP Welsh Clinical Portal, *COPD* chronic obstructive pulmonary disease, *NYHA* New York Heart Association

[a] Anticholinergic Burden Calculator http://acbcalc.com (King and Rabino)

[b] Any recorded history of atrial fibrillation or flutter, 2nd– or 3rd-degree heart block, sick sinus syndrome, ventricular arrhythmia or pacemaker. Not 1 st-degree heart block

[c] Lymphoma, metastatic cancer, solid tumour without metastasis—not low-grade skin cancers

[d] Carotid occlusion or > 50% stenosis

[e] FEV1 < 75% of the predicted value or on chronic inhaled or oral bronchodilator therapy

[f] Dermatologic condition requiring systemic therapy

[g] NYHA II or greater

[h] Hemiparesis. Not TIA with full recovery

[i] Any inpatient or emergency department record following injury

[j] Hospital-patient one-year mortality risk (HOMR) score (van Walraven et al. 2015)

[k] Hypertension diagnosed and treated with medication, diet and/or exercise

[l] Charlson comorbidity index (Armitage and van der Meulen 2010)

[m] Behavioural problems or depression. Cannabis abuse, panic disorder, bulimia, schizophrenia, alcohol withdrawal delirium tremens

[n] Resource use—non or healthy user (0). Low or moderate (0.5). High or very high (1)

[o] Office for National Statistics. Income quintiles (Income 2018)

[p] Body mass index < 20. Unplanned weight loss in the past 6 months > 5%

chi-square test (Pearson's chi^2 test or Fisher's exact test, as appropriate).

Differences between groups are reported as [mean (SD), 95% CI: (lower limit, upper limit)].

Linear regression was used to demonstrate the associations between frailty and both the $DAOH_{30}$ and the DAH_{365}, reported as the relationship between the number of days and the pFI. To avoid overadjustment bias, we did not adjust for comorbidities, as many of these are also included in the calculation of pFI.

Moderation and mediation analysis

To estimate the degree to which socioeconomic deprivation moderated the impact of pFI as a cause of reduced $DAOH_{30}$ and $DAH_{365,}$ we completed a moderation analysis.

We used a mediation analysis to investigate the degree to which delayed discharge (level 0 care), mortality and readmission contributed to any decrease in $DAOH_{30}$ and DAH_{365}.

Case presentation

A total of 669 patients were included in the final retrospective analysis. All surgeries between 31/10/19 and 31/12/21 that required a full or mini sternotomy were included. We included patients who underwent elective or urgent surgery but excluded those who underwent emergency surgery. The surgery types were limited to coronary artery bypass (CABG), valve surgery or combined CABG and valve surgery. The mean duration of follow-up was 884 days (range 519–1326). The baseline characteristics of the patients are shown in Table 2.

The distribution of the calculated pFI score is shown in Fig. 1. The mean pFI score was 0.19 (0.06). A total of 224 (33%) patients were deemed 'frail' with a pFI ≥ 0.21, according to the definition applied in a previous large cardiac surgery cohort (McIsaac et al. 2021).

'Frailty' was associated with a wide range of preoperative comorbidities, as shown in Table 2. The incidence of non-sinus rhythm, chronic obstructive pulmonary disease, heart failure diabetes, a previous myocardial infarction and peripheral vascular disease were all higher in patients living with frailty.

Frailty was strongly associated with being in the lowest decile for deprivation and, to a lesser degree, with deep poverty and deep-rooted deprivation. Notably, frailty was not associated with either sex or advanced age (whether analysed as a binary outcome (age > 70 years) or as a continuous variable (Mann–Whitney *U*)).

An ANOVA revealed a significant effect ($p = 0.005$) of frailty on the duration of intensive care stay and level 3 support, with post hoc tests indicating patients living with frailty spent an extra day longer in intensive care

Table 2 Baseline characteristics by binary frailty status ($n = 669$)

Characteristic	'Frail' pFI ≥ 0.21 (n = 224)	'Not frail' pFI < 0.21 (n = 445)	*p*	*Cc*	Test
Age, year, mean (SD)	68.9 (9.25)	67.5 (10.1)	NS		a
Female	61 (27.2%)	100 (22.5%)	NS		c
Comorbidities					
Chronic obstructive pulmonary disease	77 (34.4%)	37 (8.3%)	< 0.001	0.31	c
Peripheral vascular disease	30 (13.4%)	19 (4.3%)	< 0.001	0.16	c
Arrhythmia	51 (22.8%)	45 (10.1%)	< 0.001	0.17	c
AF/flutter	46 (20.5%)	45 (10.1%)			
Pacing	2 (0.8%)	0			
Other abnormal rhythm	3 (1.3%)	0			
Cancer	54 (24.1%)	31 (7.0%)	< 0.001	0.24	c
Heart failure	136 (60.7)	140 (31.5%)	< 0.001	0.27	c
Diabetes mellitus	111 (49.6%)	104 (23.4%)	< 0.001	0.26	c
Dialysis	0 (0%)	1 (0.2%)	NS	0.04	d
Drug or alcohol abuse	21 (9.3%)	11 (2.4%)	< 0.001	0.16	d
Hemiparesis	18 (8.0%)	6 (1.3%)	< 0.001	0.17	c
Hypertension	213 (95.1%)	376 (84.5%)	< 0.001	0.15	c
Myocardial infarction	106 (47.3%)	129 (29%)	< 0.001	0.18	c
Multimorbidity (CVS + > 2)	136 (60.7%)	51 (11.5%)	< 0.001	0.5	c
Rheumatic disease	15 (6.7%)	12 (2.7%)	NS	0.09	c
Cerebrovascular disease	3 (1.3%)	1 (0.2%)	NS	0.07	d
BMI (kg/m^2)	30 (5.59)	28.3 (4.87)	< 0.001		a
Smokers (current/ex)	166 (76.1%)	265 (59.6%)	< 0.001	0.14	c
EuroSCORE (median, range)	3.9 (5.23)	2.25 (2.81)	< 0.001		a
Admission conditions					
Elective	119 (53.1%)	268 (60.2%)	NS	0.07	c
Urgent	105 (46.9%)	177 (39.8%)			
Type of surgery					
CABG	112 (50.0%)	213 (47.9%)	NS	0.10	c
Valve	60 (26.8%)	159 (35.7%)			
CABG&Valve	52 (23.2%)	73 (16.4%)			
% income (E + W)	21 (17.6)	26.2 (18.7)	< 0.001		a
WIMD					
0–10% most deprived	26 (11.7%)	21 (4.8%)	< 0.001	0.22	c
10–20% most deprived	35 (15.7%)	36 (8.1%)			
50% least deprived	83 (37.2%)	256 (57.9%)			
Deep-rooted deprivation, yes	8 (3.6%)	0 (0%)	< 0.001	0.15	d
Deep poverty, yes	64 (28.6%)	76 (17.1%)	< 0.001	0.13	c

Cc contingency coefficient, *a* Mann–Whitney, *U* test, *b* Student's *t*-test, *c* Pearson's chi^2 test, *d* Fisher's exact test

('frail' patients [4.92 (7.82), 95% CI: (3.89, 5.95)] versus 'non frail' patients [3.45 (4.63), 95% CI: (3.02, 3.88)]). Patients living with frailty also required level 3 cardiovascular and respiratory support for longer periods (Table 3).

Significant differences were found in hospital length of stay ($p < 0.001$), with patients living with frailty remaining in the hospital longer [13.3 (14.3), (11.4, 15.2)] than 'non frail' patients [8.8 (6.51), (8.21, 9.42)].

At 30 days after surgery, the mean days alive and out of hospital ($DAOH_{30}$) was 19.2 (7.68), and the median was 23 days (interquartile range [IQR], 18–24) (Table 3). ANOVA revealed a significant effect ($p < 0.001$), with post hoc tests indicating that 'frail' patients spent 3 days less at home in the first 30 days [17.2 (8.69), (16.2, 18.2)] than 'non frail' patients [20.3 (6.90), (19.6, 21.0)] (Fig. 2). Without adjustment, each 10% increase in the pFI was associated with a 23% (95% CI, 15–30%; $p < 0.001$) relative

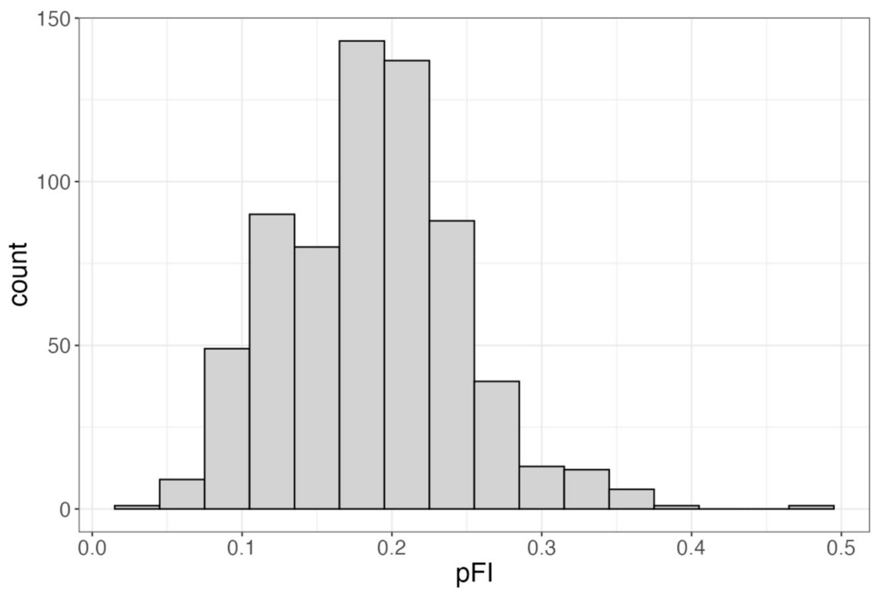

Fig. 1 Histogram of pFI in the cohort of 669 patients undergoing cardiac surgery

Table 3 Association of frailty with short- and long-term outcomes

Outcome measure	Frailty index ≥ 0.21	Frailty index < 0.21	*p*	Test
ITU LOS (days)	4.92 (7.82)	3.45 (4.63)	0.005	a
Level 3 (days)	3.56 (6.51)	2.43 (3.69)	0.029	a
Level 2 care (days)	2.31 (2.6)	2.0 (2.56)	NS	
LOS hospital (days)	13.3 (14.3)	8.82 (6.51)	< 0.001	a
Level 3 care (days)				
Cardiovascular	3.02 (4.04)	2.22 (2.97)	0.023	a
Respiratory	2.49 (5.78)	1.66 (3.43)	0.018	a
Renal	0.61 (4.54)	0.26 (1.93)	NS	a
Neurological	0.01 (0.20)	0.13 (0.58)	NS	a
30-day mortality	4/224 (1.8%)	10/445 (2.2%)	NS	c
1-year mortality	12/224 (5.4%)	20/445 (4.5%)	NS	c
$DAOH_{30}$ (days)	17.2 (8.69)	20.3 (6.90)	$p < 0.001$	a
DAH_{365} (days)	335 (62.2)	340 (65.5)	$p < 0.001$	a

Data is shown as duration of outcome measures—mean (SD), or proportions of individuals with the outcome (%). *LOS* length of stay

decrease in $DAOH_{30}$. The number of days at home in the first year after surgery (DAH_{365}) was also strongly correlated with the frailty index. Each 10% increase in the pFI was associated with a 10% (95% CI, 2.7–18%; $p = 0.008$) relative decrease in the DAH_{365}.

In the first 30 days after surgery, the major mediator of people living with frailty having fewer days at home was time requiring cardiovascular support (68.5%). In addition, there were additional days requiring noncardiac care (4.2%), readmission (3.0%), delayed discharge (3.8%) and 30-day mortality (7.1%). At 365 days, mortality (70.4%) was the major mediator of the reduced number of days at home in 'frail' patients. In the full cohort, mortality accounted for 47.5%, and readmission accounted for 22.4%, of reduced days at home in the first year (Table 4).

Neither 30-day mortality (frail 1.8%, not frail 2.2%) nor 1-year mortality ('frail' 5.4%, 'non frail' 4.5%) was significantly associated with frailty.

Survival curves with a median follow-up of 884 days (range 519–1326) for the continuous explanatory variable pFI, with a calculated cut-off of 0.17, revealed a significant association between a high frailty index and the hazard ratio for death, where every 0.1 unit increase in pFI increased the hazard 28 times (0.6–1323, $p = 0.004$) (Fig. 3).

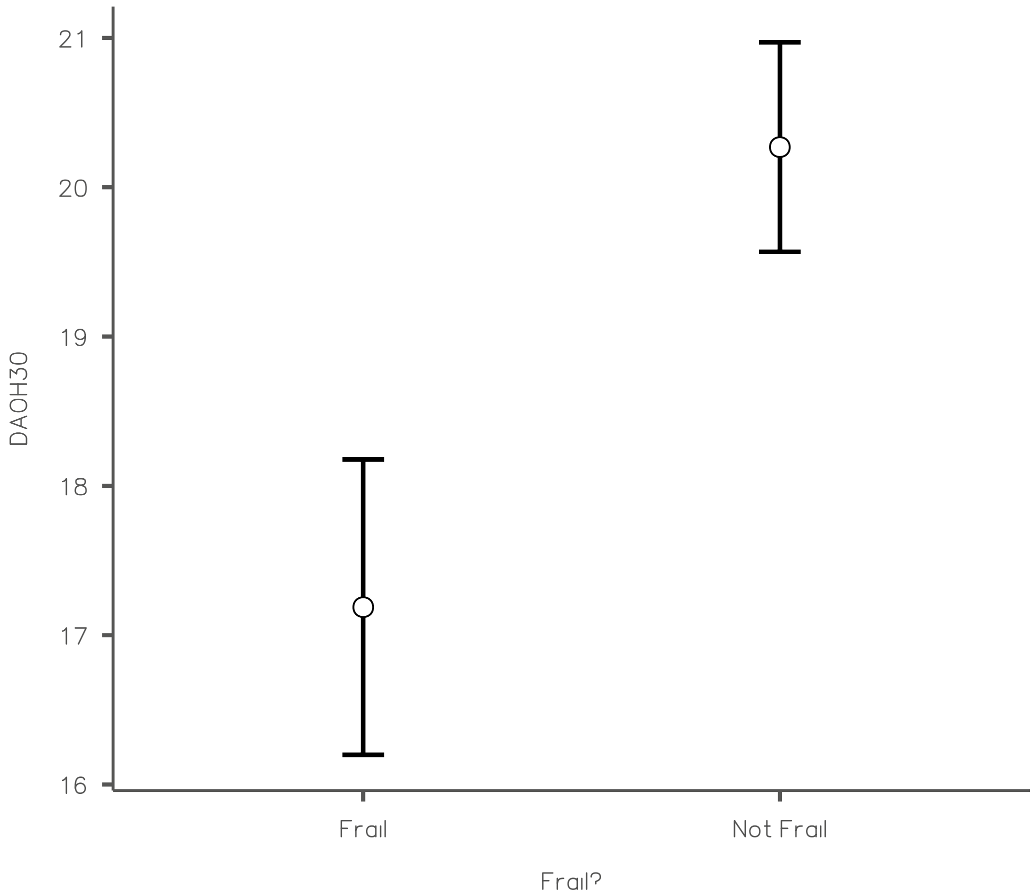

Fig. 2 Marginal means plot with 95% CI of days alive and out of hospital in the first 30 days ($DAOH_{30}$) after cardiac surgery, depending on frailty status

Table 4 Mediators of reduced $DAOH_{30}$ (a) and DAH_{365} (b), in the full cohort and in patients living with frailty

a. Days alive and out of hospital in the first 30 days		
Mediator	**Full cohort (*n* = 669)**	**'Frail' (*n* = 224)**
Cardiac inpatient days	75.4%	68.5%
Additional 'noncardiac' days	2.20%	4.24%
Level '0'—delayed discharge	3.55%	3.84%
30-day mortality	4.60%	7.08%
Readmission	1.01%	2.95%
b. Days at home in the first 365 days		
Mediator	**Full cohort (*n* = 669)**	**'Frail' (*n* = 224)**
Inpatient days	50.4%	29.8%
Additional 'noncardiac' days	22.4%	5.65%
Level '0'—delayed discharge	4.63%	2.71%
Mortality	47.5%	70.4%
Readmission	22.4%	5.65%

A multiple regression analysis was conducted to assess whether the WIMD modified the effect of frailty on recovery after cardiac surgery. The interaction term (pFI × WIMD) for $DAOH_{30}$ was not statistically significant (estimate = 9.77×10^{-4}, 95% CI [− 0.0176, 0.0196], $p = 0.92$). Nor was it significant for DAH_{365} (estimate

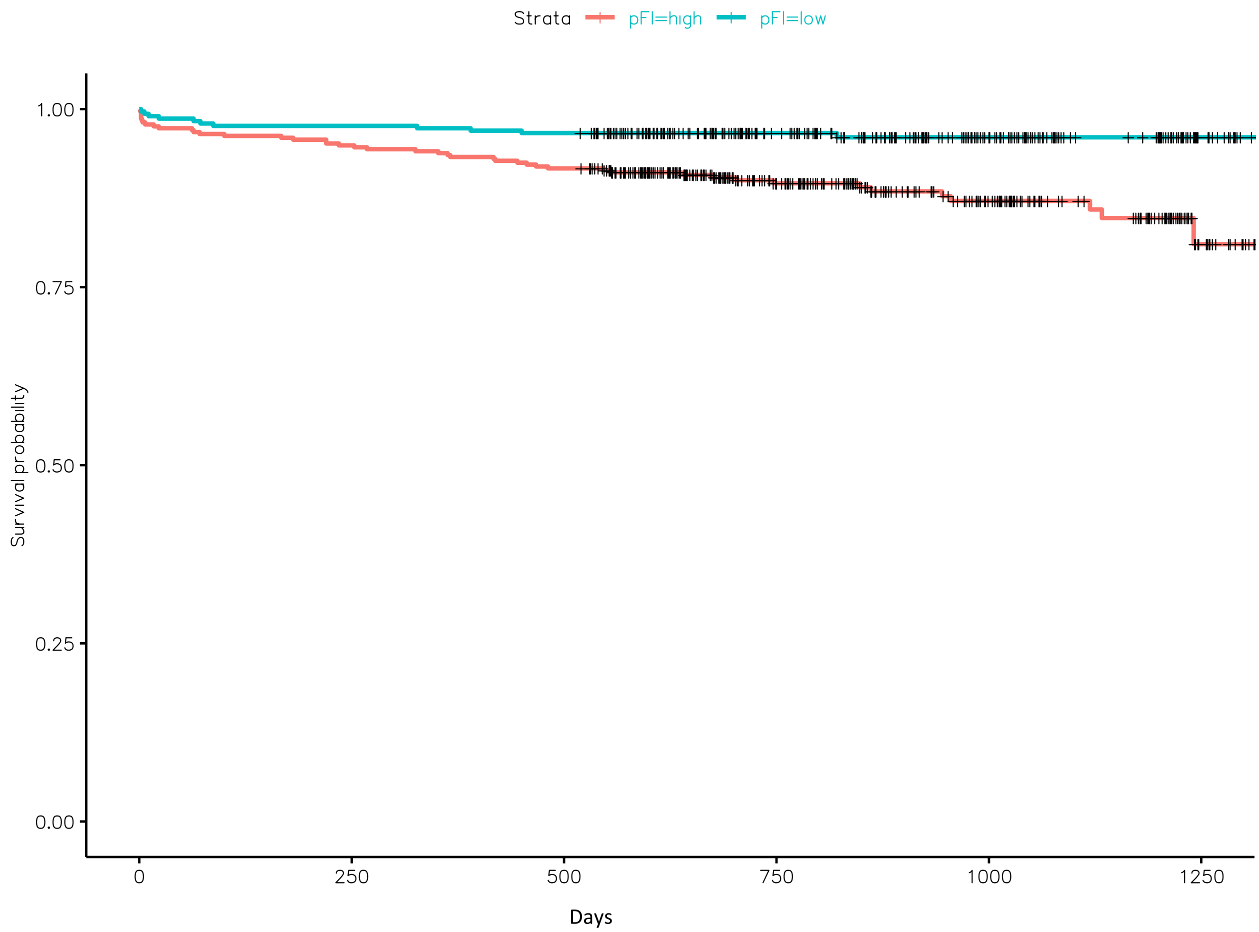

Fig. 3 Survival curve with a median follow-up of 884 days (range 519–1326) for the continuous explanatory variable pFI, with a calculated cut-off of 0.17

= 0.0244, 95% CI [− 0.136, 0.184], $p = 0.765$), indicating no evidence of moderation. Variance inflation factors (VIF) suggested no collinearity concerns (all ≈ 1, except the socioeconomic frailty component = 3). These findings suggest that socioeconomic deprivation does not significantly alter the relationship between frailty and functional recovery after cardiac surgery.

Discussion and conclusions

The UK cardiac surgery report (2002–2016) showed an ageing surgical population (Grant et al. 2021). While procedural trends have evolved with transcatheter aortic valve implantation (TAVI) and transcutaneous coronary stenting, as suggested by the latest National Adult Cardiac Surgery Audit (NASCA) 2023 report (National 2023), the increasing number of combined CABG + AVR and redo-surgeries suggests an older and more comorbid patient group (Grant et al. 2021). This study found that approximately one-third of patients referred for routine cardiac surgery in a UK centre were living with frailty. Notably, frailty was not directly associated with age but rather with cumulative physiological decline. The pFI is a continuous variable but our results have been analysed with the same dichotomized value pFI > 0.21 to define 'frailty' as described in the original derivation of the index (McIsaac et al. 2019) and subsequently used by the same authors in a cardiac surgical population (McIsaac et al. 2021). The advantage of this approach is to define a population of patients, in our case and in the earlier paper by McIsaac et al. (McIsaac et al. 2021), of a third of the full cohort, in which an intervention might be targeted.

This study reinforces previous findings that frailty impacts recovery patterns (McIsaac et al. 2020), with patients living with frailty experiencing deviations from typical postoperative recovery. Importantly, recovery outcomes in patients living with frailty often fall outside standard follow-up protocols, leading to under-recognition of their needs.

Beyond the immediate postoperative period, quality-of-life outcomes up to 1 year after surgery warrant further investigation (Delaney et al. 2020), (Miguelena-Hycka et al. 2019). A comprehensive frailty assessment using electronic health records could enable better preoperative planning, prioritization and tailored interventions. These findings support the need for structured prehabilitation, targeted resource allocation and optimized discharge planning.

Optimizing modifiable deficits, including lung function, cardiac status, diabetes control, nutrition, mobility, polypharmacy and psychological preparedness, presents an opportunity for intervention. However, the challenge lies in developing efficient, automated frailty assessments that integrate seamlessly into clinical workflows.

We were unable to demonstrate any effect of socioeconomic deprivation to significantly influence functional recovery after cardiac surgery.

This study of consecutive elective and urgent cardiac surgery patients in a tertiary UK centre demonstrates that preoperative frailty is strongly associated with prolonged intensive care stays, increased need for advanced cardiorespiratory support and longer hospital stays. Short- and medium-term functional recovery measures were lower in frail patients, and long-term survival was significantly reduced.

Good functional recovery, measured by $DAOH_{30}$ and DAH_{365}, is an essential patient-centred outcome reflecting reduced hospital costs, effective medical care and improved patient satisfaction. These findings align with previous studies showing prolonged hospitalization in frail patients and fewer days at home postoperatively.

Accurate frailty assessment is critical, as frailty is not synonymous with old age. The frailty phenotype often overlooks psychosocial and cognitive dimensions. The accumulation of deficits model provides a more precise measure, but its manual calculation is time intensive. Electronic health record integration offers a feasible alternative for systematic frailty assessment and pre-emptive planning (Clegg et al. 2016).

The association between frailty and the lowest decile for socioeconomic deprivation, despite the absence of a modifying effect across all levels of deprivation, underscores the need for equitable access to prehabilitation and rehabilitation services, as has been highlighted by other investigators (Lai et al. 2024). Future research should explore interventions that mitigate frailty-related risks and improve long-term functional recovery after cardiac surgery.

Acknowledgements
Not applicable.

Authors' contributions
M.A., M.E., D.A. and O.D. compiled the anonymised database from the Welsh Clinical Portal. R.H.B. and O.G.M. compiled the socioeconomic and environmental pollution data from the Office of National Statistics data and the Welsh Index of Multiple Deprivation (WIMD). S.P. compiled the data to determine deep poverty and deep-rooted deprivation. C.A. analysed the data to further determine postoperative pulmonary complications. M.M. developed a method to assess sarcopenic frailty. M.J.B. is the principal investigator, designed the database, performed the data analysis, and wrote the manuscript. All authors read and approved the final manuscript.

Funding
This study was unfunded and was undertaken in the author's own time.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approval by the hospital audit department and ratified by the Joint Study Review Committee (JSRC) of Swansea University. It was service evaluation/development/non-research, and a R&D and NHS REC application was not required.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 29 January 2025 Accepted: 8 April 2025
Published online: 23 April 2025

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