Original Article

Functional decline after major elective non-cardiac surgery: a multicentre prospective cohort study

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Summary

Self-reported postoperative functional recovery is an important patient-centred outcome that is rarely measured or considered in research and decision-making. We conducted a secondary analysis of the measurement of exercise tolerance before surgery (METS) study for associations of peri-operative variables with functional decline after major non-cardiac surgery. Patients who were at least 40 years old, had, or were at risk of, coronary artery disease and who were scheduled for non-cardiac surgery were recruited. Primary outcome was a reduction in mobility, self-care or ability to conduct usual activities (EuroQol 5 dimension) from before surgery to 30 days and one year after surgery. A decline in at least one function was reported by 523/1309 (40%) participants at 30 days and 320/1309 (24%) participants at one year. Participants who reported higher pre-operative Duke Activity Status indices more often reported functional decline 30 days after surgery and less often reported functional decline one year after surgery. The odds ratios (95%CI) of functional decline 30 days and one year after surgery with moderate or severe postoperative complications was 1.46 (1.02-2.09), p = 0.037 and 1.44 (0.98-2.13), p = 0.066. Discrimination of participants who reported functional decline 30 days and one year after surgery were poor (c-statistic 0.61 and 0.63, respectively). In summary, one-quarter of participants reported functional decline up to one postoperative year.

Introduction

Postoperative assessment has focused primarily on death and complications, typically occurring within 30 postoperative days [1]. These important outcomes do not encompass the totality of a patient's experience in the peri-operative period. Other outcomes, such as function, are crucially important to patients but are rarely considered in decision-making or measured postoperatively [2].

A recent review recommends reporting patient-centred postoperative outcomes [3]. While the term postoperative 'recovery' can have varying meanings, it can be broadly defined as the point at which an individual's function is restored and adverse postoperative symptoms have resolved [4]. Recovery is an important goal, not only for patients but also for clinicians, institutions and systems that seek to increase the value of care delivered [5, 6].

Previous research suggests that many patients experience postoperative functional decline [7, 8]. However, these studies have focused on subgroups of surgical patients, defined by age or procedure type. We performed a secondary analysis of a multicentre prospective cohort of adults who underwent major non-cardiac surgery to determine the incidence of self-reported functional decline and peri-operative variables associated with it [9, 10].

Methods

The research ethics board for each participating hospital approved the measurement of exercise tolerance before surgery (METS) prospective cohort study [9, 10]. We recruited patients who were at least 40 years old, scheduled for elective inpatient non-cardiac surgery and who had at least one risk factor for cardiac complications or coronary artery disease (online Supporting Information Table S1). All participants provided written informed consent. We specified this analysis after we recruited participants but before we analysed their data.

We used the three EuroQol 5 Dimension (EQ-5D) function-related questions: mobility; self-care; and ability to conduct usual activities – categorised by participants as 'no problems', 'some problems' or 'unable to perform' [3, 11, 12]. Participants completed the EQ-5D when recruited and 30 days and one year after surgery. We prespecified comparisons of participants with or without a reduction in any functional domain from before surgery to 30 days and one year after surgery. We added a post-hoc analysis based on the Pareto principle to define change in patients' status as: better (improvement in one domain, with no decline in any other domain); same (no change in any domain); mixed (improvement in at least one domain and a decline in at least one domain); or worse (decline in one domain with no improvement in any other domain) [13].

We planned analyses of associations of change in function with participant characteristics, including the Duke Activity Status Index (DASI), and moderate or severe postoperative complications, using a modified Clavien-Dindo classification of severity (online Supporting Information Table S2) [14, 15].

We entered all variables into multivariable logistic models to determine their adjusted associations with change in function at 30 days and at one year after surgery [16]. We used restricted four-knot cubic splines to model the non-linear associations of age and Duke Activity Status Index score with outcome. We assessed multicollinearity with the variation inflation factor and model discrimination with the c-statistic. We tested interactions of age with heart failure, sex with type of surgery, and complications with each comorbidity in the primary model at 30 days, including any significant interaction in the model. We performed secondary post-hoc analyses of change in each functional domain. We used t-tests and chi-square tests, as indicated. Sample size was determined by recruitment for the METS study. No post-hoc power calculation was conducted and instead 95%CIs were used to help interpret the results of the analysis [17].

Our primary analysis excluded participants who died before one postoperative year, or had missing covariate data, or whose follow-up was incomplete at 30 days or one year after surgery. We performed sensitivity analyses, one in which we included participants who completed only one postoperative questionnaire, and one in which we included participants who died, for whom we inferred a reduction in function. All analyses were conducted in Stata Version 14.2 (StataCorp, College Station, TX, USA).

Results

We analysed function assessed by 1309 participants (Table 1 and online Supporting Information Figure S1). Categorisations of quality of life by these participants, before and after surgery, are in Table 2 and online Supporting Information Table S3.

Decline in at least one functional domain 30 days and one year after surgery was reported by 523 (40%) participants and 320 (24%) participants, respectively. The number of participants reporting decline in the domains of usual activity, self-care and mobility were: at 30 postoperative days, 442 (34%), 116 (9%) and 153 (12%), respectively: and at one postoperative year, 221 (17%), 85 (6%) and 153 (12%), respectively. In unadjusted comparisons, postoperative moderate or severe complications were associated with postoperative functional decline (Table 3), as were pre-operative Duke Activity Status Index, heart failure, stroke and pre-operative pain (Table 4). After adjustment for other variables, higher

self-reported pre-operative activity was associated with higher rates of functional decline 30 days after surgery and lower rates of functional decline one year after surgery (Table 5). The discrimination of both models was poor, with a c-statistic of 0.61 at 30 days and 0.63 at one year. Secondary analyses suggested that pre-operative activity was associated with less decline in all three functions at one postoperative year, whilst complications were only associated with decline in self-care at one year (online Supporting Information Table S4). Analyses that included participants with only one follow-up measure and participants who died were consistent with the primary analysis, including the association of postoperative complications with functional decline (online Supporting Information Tables S5 and S6).

Discussion

A quarter of participants reported a decline in at least one EQ-5D functional domain one year after surgery. Lower self-reported pre-operative physical fitness was associated with self-reported functional decline up to one postoperative year. Postoperative moderate or severe complications were associated with functional decline at 30 postoperative days.

Age was not associated with functional decline, the rate of which in participants aged < 60 y was similar to rates in older patients, in our study and others [7, 8, 18-20]. The association of peri-operative variables and postoperative function changed with duration of follow up, which might explain heterogeneous results between studies [8, 18]. We think that function is dominated by recent surgery, particularly when accompanied by moderate or severe postoperative complications, but by other factors as more time passes. The association of worse fitness with more postoperative decline is consistent with other studies [7, 8, 19]. The general improvement in function caused by exercise has been replicated in the short-term after surgery, but has yet to be confirmed for longer postoperative periods [21]. More frequent assessments of postoperative function might distinguish the effects of competing factors on function. Notably, higher activity levels as measured by Duke Activity Status Index were associated with greater odds of decline at 30 days. This finding may be because we used change in a three-category measure to determine our outcome and decline is both subjective and relative. This meant that participants with high levels of pre-operative function could only get worse and those with the lowest levels could only improve.

Functional decline in patients who had no (or minor) postoperative complications highlights the need to modify how success is defined in the peri-operative period. Pre-operative information should include changes in function, as well as rates of postoperative complications, to inform consent. This

finding carries significant implications given the millions of patients undergoing surgery in the UK every year [22, 23].

At one postoperative year, the distribution of participants reporting each functional category was similar to the pre-operative distribution: functional decline in some participants was matched by improvement in other participants. In fact, with respect to mobility, a higher proportion of patients reported an improvement in mobility vs. decline at one year. A similar result was also seen in the domains of anxiety or depression and pain or discomfort. Peri-operative variables had little ability to discriminate participants who did report functional decline from those who did not, preventing us from recommending interventions to any particular subgroup of patients.

There are some features of our study that might limit its interpretation. Individual components of the EQ-5D have not undergone psychometric evaluation. However, mobility and the ability to perform usual activities appear to be the domains most affected by postoperative disability [24]. We used the version of the questionnaire with three ordinal categories (rather than five), which limited our ability to discriminate between participants with relevant differences in function. We did not study patients without coronary artery disease or risk factors for adverse cardiac events and we do not know whether our results would be replicated in such patients. We have already commented that two postoperative assessments limited our ability to delineate trajectories of recovery, which should be considered in the design of future studies. As with all observational studies, we are unable to attribute functional decline to any particular cause.

In conclusion, more participants reported decline than improvement in at least one EQ-5D functional domain 30 days after surgery but not one year after surgery. Functional decline was associated with worse pre-operative fitness and moderate or severe postoperative complications.

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Table 1. Characteristics of 1309 participants who completed functional questionnaires before surgery and 30 days later and one year later. Values are mean (SD) or number (proportion).

Characteristic	Cohort n = 1309
Age; y	64 (10)
Sex; female	518 (40%)
ASA physical status	
1	95 (7%)
2	757 (58%)
3	439 (34%)
4	18 (1%)
Coronary artery disease	163 (12%)
Heart failure	20 (2%)
Stroke	52 (4%)
Peripheral artery disease	41 (3%)
Pulmonary disease	161 (12%)
Arthritis	484 (37%)
Pain	731 (56%)
Anxiety/depression	414 (32%)
DASI	40.9 (15.1)
Surgery	
Abdominal	410 (31%)
Urologic or gynaecologic	385 (29%)
Orthopaedic	339 (26%)
Head and neck	90 (7%)
Thoracic	25 (2%)
Vascular	24 (2%)
Other	36 (3%)
Moderate or severe complication	160 (12%)

DASI, Duke Activity Status Index

Table 2. Quality of life reported by 1309 participants before and after major non-cardiac surgery. Values are number (proportion) or median (IQR [range]).

EQ-5D domain (n = 1309)	Quality of life before and after surgery				
	Before	After			
		30 days	p value*	1 year	p value*
Usual activities					
No problems	932 (71%)	637 (49%)		912 (70%)	
Some problems	355 (27%)	562 (43%)	< 0.001	344 (26%)	0.001
Unable to perform	22 (2%)	110 (8%)		53 (4%)	
Less problem	—	106 (8%)		188 (14%)	
No change	—	761 (58%)		900 (69%)	
More problem	—	442 (34%)		221 (17%)	
Self-Care					
No problems	1186 (91%)	1129 (86%)		1177 (90%)	
Some problems	119 (9%)	174 (13%)	0.002	127 (10%)	0.82
Unable to wash or dress	4	6		5	
Less problem	—	60 (5%)		74 (6%)	
No change	—	1133 (87%)		1150 (88%)	
More problem	—	116 (9%)		85 (6%)	
Mobility					
No problems walking	910 (70%)	932 (71%)		963 (74%)	
Some problems walking	398 (30%)	375 (29%)	0.53	343 (26%)	0.037
Confined to bed	1	2		3	
Less problem	—	174 (13%)		204 (16%)	
No change	—	982 (75%)		952 (73%)	
More problem	—	153 (12%)		153 (12%)	
Pain or Discomfort					
None	578 (44%)	588 (45%)		710 (54%)	
Moderate	636 (49%)	668 (51%)	0.002	541 (41%)	< 0.001
Severe	95 (7%)	53 (4%)		57 (4%)	
Missing				1	
Less problem	—	288 (22%)		352 (27%)	
No change	—	772 (59%)		758 (58%)	
More problem	—	249 (19%)		198 (15%)	
Anxiety or Depression					
None	895 (69%)	970 (74%)		964 (74%)	
Moderate	383 (29%)	310 (24%)	0.005	308 (24%)	0.0036
Severe	29 (2%)	29 (2%)		35 (3%)	
Missing	2			2	
Less problem	—	233 (18%)		224 (17%)	
No change	—	921 (70%)		922 (71%)	
More problem	—	153 (12%)		159 (12%)	
Health score	77 (65-87 [3-100])	80 (65-90 [0-100])	0.007	80 (70-90 [0-100])	< 0.001
Missing (n)	20	6		10	

*Compared with pre-operative values.

Table 3. Rates of 1309 participants who reported a decline in at least one functional domain of the EQ-5D questionnaire 30 days (n = 523) and one year (n = 320) after surgery, categorised by whether they were diagnosed with a moderate or major postoperative complication. Values are number (proportion).

EQ-5D domain	30 days Complication			1 year Complication		
	No n = 1149	Yes n = 160	p value	No n = 1149	Yes n = 160	p value
Any	444 (39%)	79 (49%)	0.009	268 (23%)	52 (33%)	0.011
Usual activities	374 (33%)	68 (43%)	0.013	187 (16%)	34 (21%)	0.12
Self-care	90 (8%)	26 (16%)	< 0.001	65 (6%)	20 (13%)	< 0.001
Mobility	121 (11%)	32 (20%)	< 0.001	127 (11%)	26 (16%)	0.055

Table 4. Rates of postoperative decline in at least one functional EQ-5D domain 30 days and one year after surgery, by peri-operative variable. Values are mean (SD) or number (proportion).

Variable	30-day decline			1-year decline		
	No n = 786	Yes n = 523	p value	No n = 989	Yes n = 320	p value
Age; y	64.7 (10.2)	63.4 (10.6)	0.026	64.0 (10.2)	64.8 (11.0)	0.22
Sex; female	306 (39%)	212 (41%)	0.56	392 (40%)	126 (39%)	0.93
ASA physical status						
1	53 (7%)	42 (8%)	0.13	75 (87.6%)	20 (6%)	0.82
2	439 (56%)	318 (61%)		573 (58%)	184 (58%)	
3	282 (36%)	157 (30%)		327 (33%)	112 (35%)	
4	12 (2%)	6 (1%)		14 (1%)	4 (1%)	
Coronary artery disease	96 (12%)	67 (13%)	0.75	117 (12%)	46 (14%)	0.23
Heart failure	14 (2%)	6 (1%)	0.36	11 (1%)	9 (3%)	0.031
Stroke	30 (4%)	22 (4%)	0.72	29 (3%)	23 (7%)	< 0.001
Peripheral artery disease	25 (3%)	16 (3%)	0.90	29 (3%)	12 (4%)	0.47
Pulmonary disease	95 (12%)	66 (13%)	0.77	117 (12%)	44 (14%)	0.36
Arthritis	305 (39%)	179 (34%)	0.093	363 (37%)	121 (38%)	0.72
Pain	436 (56%)	295 (56%)	0.74	537 (54%)	194 (61%)	0.048
Anxiety/depression	224 (29%)	190 (36%)	0.003	308 (31%)	106 (33%)	0.51
Pre-operative DASI	40.6 (15.3)	41.3 (14.7)	0.38	42.0 (14.9)	37.6 (15.2)	< 0.001
Surgery						
Abdominal	231 (29%)	179 (34%)		303 (31%)	107 (33%)	
Urologic or gynaecologic	224 (29%)	161 (31%)		289 (29%)	96 (30%)	
Orthopaedic	215 (27%)	124 (24%)		264 (27%)	75 (23%)	
Head and neck	65 (8%)	25 (5%)	0.12	70 (7%)	20 (6%)	0.91
Intra-thoracic	15 (2%)	10 (2%)		19 (2%)	6 (2%)	
Vascular	15 (2%)	9 (2%)		18 (2%)	6 (2%)	
Other	21 (3%)	15 (3%)		26 (3%)	10 (3%)	
Moderate or severe complication	81 (10%)	79 (15%)	0.009	108 (11%)	52 (16%)	0.011

DASI, Duke Activity Status Index

Table 5. Adjusted odds ratio (95%CI) for decline in at least one functional EQ-5D domain 30 days and one year after surgery, by peri-operative variable.

Variable	30-day decline		1-year decline	
	Odds ratio (95%CI)	p value	Odds ratio (95%CI)	p value
Age; y*				
40	1 (ref)		1 (ref)	
60	0.86 (0.47-1.58)	0.23	0.91 (0.45-1.84)	0.049
80	0.75 (0.41-1.38)		1.26 (0.64-2.50)	
Sex; female	1.12 (0.87-1.44)	0.40	0.85 (0.63-1.13)	0.26
ASA physical status				
1	1 (ref)		1 (ref)	
2	1.01 (0.64-1.60)	0.96	1.16 (0.67-2.02)	0.59
3	0.75 (0.46-1.23)	0.26	1.03 (0.57-1.86)	0.91
4	0.59 (0.19-1.77)	0.35	0.72 (0.20-2.62)	0.62
Coronary artery disease	1.27 (0.88-1.85)	0.20	1.05 (0.69-1.59)	0.83
Heart failure	0.69 (0.25-1.91)	0.48	2.32 (0.90-6.00)	0.082
Stroke	1.23 (0.68-2.22)	0.49	2.36 (1.30-4.27)	0.005
Peripheral artery disease	1.07 (0.52-2.19)	0.86	1.20 (0.55-2.61)	0.65
Pulmonary disease	1.04 (0.73-1.48)	0.82	0.98 (0.66-1.46)	0.92
Arthritis	0.93 (0.69-1.25)	0.62	1.13 (0.81-1.58)	0.48
Pain	1.16 (0.88-1.54)	0.29	1.28 (0.93-1.77)	0.13
Anxiety/depression	1.38 (1.07-1.79)	0.013	0.90 (0.67-1.20)	0.47
DASI*				
10	1 (ref)		1 (ref)	
35	1.30 (0.77-2.18)	0.024	0.64 (0.37-1.11)	< 0.001
58.2	1.13 (0.66-1.93)		0.30 (0.16-0.54)	
Surgery				
Abdominal	1.78 (1.06-2.99)	0.029	1.20 (0.68-2.13)	0.53
Urologic or gynaecologic	1.94 (1.15-3.26)	0.013	1.40 (0.79-2.49)	0.25
Orthopaedic	1.70 (0.97-2.98)	0.065	0.67 (0.36-1.24)	0.21
Head and neck	1 (ref)		1 (ref)	
Intra-thoracic	1.83 (0.70-4.79)	0.22	1.36 (0.46-4.04)	0.58
Vascular	1.39 (0.49-3.91)	0.54	0.71 (0.22-2.25)	0.56
Other	1.75 (0.76-4.00)	0.19	1.38 (0.55-3.44)	0.49
Moderate or severe complication	1.46 (1.02-2.09)	0.037	1.44 (0.98-2.13)	0.066

*Cut-off values were pre-specified and do not represent the location of the cubic spline knots.

DASI, Duke Activity Status Index

Online supporting information