Changes in cardiac and cognitive function and self-reported outcomes at one year after coronary artery bypass grafting

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Objective: Although health status after coronary artery bypass grafting improves at the group level, individual outcomes demonstrate variation. We aimed to evaluate relative importances of changes in cardiac and cognitive function and symptom status regarding physical and mental health at 1 year after coronary artery bypass grafting.

Methods: Outcomes in multivariable regression analysis ($n = 86$) were self-reported physical and mental health (Medical Outcomes Study 36-Item Short Form) at 12 months' follow-up, adjusting for baseline. Independent variables were change in exercise capacity (staged ergometer protocol), cognitive function (neurocognitive test battery), and self-reported improvement of angina. Graft patency was evaluated by angiography (82/86 patients).

Results: After surgery, health status was comparable to the age- and sex-matched population norm. Improvement of angina was associated with gain in physical health in the range of 0.5 SD ($\beta = 0.23$, $P = .012$). Change in observed physical exercise capacity (mean $\pm$ SD 199 ± 426 W $\cdot$ min) accounted for 9% of variance in physical health ($\beta = 0.42$, $P = .001$). Positive change in cognitive function was significantly related to mental ($\beta = 0.52$, $P = .007$) but not physical health. Graft occlusion (22/82 patients) was not significantly related to health status.

Conclusions: Individual variation in objective functional performance and symptom relief is significant for self-reported health status, beyond the predictive ability of preoperative health status, sex, and graft patency. Awareness of the extent and impact of outcome variation is important when counseling patients before and after coronary artery bypass grafting. (*J Thorac Cardiovasc Surg* 2010;140:122-8)

Coronary artery bypass grafting (CABG) aims to reduce the burden of ischemic heart disease by prolonging survival, relieving angina pectoris, and improving on the health-related quality of life.¹ A possible causal path suggests that successful revascularization to improve coronary flow reserve is followed by improvement in cardiac work capacity, symptoms, and self-reported health status, where personal and environmental characteristics may influence each level of outcome.² Previous research supports the contention that health status improves at the group level after CABG, although much variation among individuals has been documented with respect

to objective measures of clinical outcome as well as self-reported symptoms and health status.³⁻⁵ Thus although the patients as a group share a clinically significant benefit of surgery, the degree of benefit is not uniform. In fact, some patients experience a decline.^{5,6}

The effect of change in physiologic function on change in self-reported outcome is not well understood. Cross-sectional studies that combine objective and self-reported variables do not account for individual changes after CABG.^{7,8} Longitudinal studies are rare and focus on either cardiac function⁹ or cognitive function^{10,11} in relation to self-reported variables but not on the combination of these aspects. It is of particular interest to evaluate the importance of change in cognitive function in combination with cardiac function and symptom relief, because CABG has been associated with intraoperative and postoperative neurologic injury, ranging from stroke through transient confusion to subclinical cognitive decline.¹² Thus the aim of this study was to investigate the relative importance of changes in objectively measured cardiac and cognitive function together with symptom status with respect to self-reported health status at 1 year after CABG.

MATERIALS AND METHODS

Patient Sample and Procedure

The patient sample for this planned, longitudinal analysis came from a clinical study of CABG performed on or off pump. Preoperative and postoperative assessments took place at a single facility, with standardized procedures for

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
SF-36 = Medical Outcomes Study 36-Item Short Form

collection and interpretation of data. The parent study included 120 patients aged 40 to 80 years with stable angina and moderate to good left ventricular function. The study protocol was approved by the regional ethics committee, and patients provided written, informed consent. Details of the surgical procedure have been reported elsewhere.^{13,14} We have previously reported on the association of preoperative cerebral ischemic lesions with health status at 3 months after CABG¹⁵ and on bidirectional relationships between overall life satisfaction and general health perceptions.¹⁶

Patients were recruited for the study at the time of preoperative angiography. Cardiac and cognitive tests were performed after admission for surgery, 1 to 4 days preoperatively. All inpatient assessments of self-reported data were scheduled before any further clinical or research diagnostic studies. Initial flowmetric control for graft quality was performed during surgery, followed by coronary angiography after closure of the sternum and chest to ensure that all patients were left with an optimal technical result.¹³

Individual characteristics at baseline included age, sex, education, and comorbidity (diabetes, asthma, rheumatoid arthritis, hypertension, or other). Environmental characteristics were measured as cohabitation versus living alone, perceived quality of social support, and centrality of residence (as a surrogate for access to health care services).

In addition to preoperative data collection, follow-up assessments were completed for cardiac function (exercise stress testing at 12 postoperative months), exercise stress testing (12 postoperative months), cognitive function (3 and 12 postoperative months), and self-reported outcomes (3, 6, and 12 postoperative months). Thus complete sets of observed and self-reported data were available from 2 time points, baseline and 12-month follow-up. Complete sets of objective and subjective data for this analysis were available for 86 of 120 patients enrolled in the main study (71.7%). At 12 postoperative months, 82 of 86 patients in this sample underwent follow-up angiography to determine graft patency.

During the study period, early mortality (2 patients) and withdrawal (3 patients) left 115 of 120 patients eligible for follow-up. Both preoperative and postoperative stress tests were performed in 99 patients. Six patients refused follow-up testing of cognitive function, and 2 were not tested for other reasons. Three patients were lacking in 1 or more subscales of the Medical Outcomes Study Short Form 36 (SF-36), precluding calculation of SF-36 Physical and Mental health component scales. Six patients, 5 at baseline and 1 at follow-up, were unable to grade their angina on the Canadian Cardiovascular Society scale.

Observed Functional Status

Change in cardiac function was measured as change in observed maximum physical exercise work capacity (in Watt-minutes). On an ergometer bicycle and according to standardized protocol, entry-level resistance of 50 W was followed by incremental increases of 50 W for every 6 minutes of exercise completed.¹⁷ Testing was limited by exhaustion, angina, or persistent ST-segment changes of at least 1 mm below baseline recording.

A detailed assessment of cognitive function was performed with a standard neuropsychologic test battery, including assessment of 6 neuropsychologic components, comprising a total of 10 measures: motor coordination, psychomotor speed, attention, verbal learning and delayed recall, verbal abstraction and fluency, and visual constructive abilities.¹⁸ The neurocognitive examinations, administered by psychologists trained in neuropsychologic testing, took approximately 90 minutes. Preoperative scores for each test were standardized to yield *z* scores (sum score minus group mean score,

divided by SD) and combined to a single sum score for each individual. At 12-month follow-up, the individual test scores were *z* transformed relative to the preoperative mean and SD. The use of continuous *z* scores reflected individual changes in the direction of a decline (lower score than baseline test results) or improvement (higher score).

Self-Reported Variables

Self-reported data were angina and health status. Angina was assessed on the ordinal-level Canadian Cardiovascular Society scale.¹⁹ The 36-item SF-36 reflects health status during the previous 4 weeks. Two summary scores, Physical and Mental health, are calculated from 8 subscales, ranging from 0 to 100, with higher scores indicating better health.²⁰ We report norm-based SF-36 Physical and Mental health component scores comparable to those of an age- and sex-matched national reference population with a mean of 50 ± 10 . SF-36 subscales loading most heavily on the mental component include vitality, emotional role functioning, social functioning, and mental health. The physical component represents physical functioning, physical role functioning, bodily pain, and general health.

Statistical Analyses

Characteristics of patients included and excluded in the analysis were assessed with nonparametric (χ^2 test, Fisher's Exact Test, Mann-Whitney test) and parametric (Student *t* test) tests for independent samples. Use of cardiopulmonary bypass was recorded as actual use, regardless of the random assignment in the parent study. Patients who had undergone coronary reintervention since surgery were included in the analysis because their cases were managed according to the current standard of practice. Change in the norm-referenced SF-36 summary scores in the range of 0.5 SD, usually corresponding to 5 points, is currently regarded as a conservative estimate of clinical significance, whereas smaller differences may represent a change that would be perceived as beneficial by the patient or might lead to a change in treatment.²¹ Data management and analysis were handled with the SPSS version 15.0 statistical software package (SPSS Inc, Chicago Ill).

Initial analysis examined associations among the predictor variables and the 8 SF-36 subscales.²⁰ Bivariate correlations of changes in cognitive and cardiac function with the SF-36 subscales were analyzed with change scores, calculated by subtracting the baseline score from the follow-up score, with a positive number indicating improvement and a negative number indicating decline. The ordinal-level angina scale was dichotomized to represent improvement versus no change or worsening of angina relative to preoperative status.

In 2 hierarchic regression models, we evaluated the combined influences of change in cardiac function, change in cognitive function, and symptom relief on self-reported physical and mental health statuses at follow-up, adjusting for sex, preoperative health status, and cardiac and cognitive functions in all models. To be able to compare the standardized regression (β) coefficients, changes were evaluated by entering the 1-year total scores, rather than change scores, with adjustment for preoperative scores. The analysis was guided by the causal pathway model of Wilson and Cleary.² Objective functional tests represented biophysiologic variables believed to influence symptom status and self-reported health status (functioning and general health perceptions). Two-way interactions were tested for angina status, change in observed exercise capacity, and sex. The number of covariates was limited to 1 per 10 respondents. Stability of the final models was tested with potential covariates, specifically including on-pump versus off-pump procedure, graft patency at 12 months, coronary reintervention, comorbidity (previous myocardial infarction, preoperative obstructive lung disease, diabetes), age, education, cohabitation versus living alone, perceived quality of social support, and centrality of residence.

RESULTS

Preoperative Assessment

The patient sample is characterized in Table 1. The SF-36 Physical and Mental health scores were comparable between

TABLE 1. Preoperative and procedural characteristics

	Included (n = 86)	Excluded (n = 34)	P value*
Male/female ratio	74:12	20:14	.002†
Age (y, mean ± SD)	64.0 ± 8.0	65.7 ± 8.0	.282
Education (y, mean ± SD)	10.5 ± 3.0	9.9 ± 2.8	.313
Living alone (no.)	15 (17.4%)	3 (8.8%)	.273‡
Exercise capacity (W · min, mean ± SD, n = 104)	794 ± 449	762 ± 420	.783
Cognitive function (z score, mean ± SD, n = 118)	0.09 ± 0.56	0.20 ± 0.64	.019
Vessels with significant stenosis (no.)			.951§
3 (or left main)	45 (52.3%)	17 (50.0%)	
1–2	41 (47.7%)	17 (50.0%)	
Ejection fraction (% , mean ± SD, n = 117)	70 ± 11	73 ± 11	.186
Previous myocardial infarction (no.)	43 (50.0%)	12 (35.3%)	.160†
Chronic obstructive pulmonary disease (no.)	12 (14.0%)	3 (8.8%)	.552‡
Stroke or transient ischemic attack (no.)	6 (7.0%)	3 (8.8%)	.712‡
Diabetes (no.)	11 (12.8%)	9 (26.5%)	.101†
Hypertension (no.)	32 (37.2%)	19 (55.9%)	.069†
Self-reported data			
No angina (no.)	9 (10.5%)	1 (2.9%)	.279‡
Canadian Cardiovascular Society class III or IV (no., n = 115)	20 (24.4%)	13 (39.4%)	.117†
>1 comorbidity (no.)	16 (18.6%)	13 (38.2%)	.033†
SF-36 Physical health (mean ± SD, n = 118)	42.4 ± 8.4	40.2 ± 8.2	.196
SF-36 Mental health (mean ± SD, n = 118)	42.7 ± 11.5	43.2 ± 11.5	.819
Procedural characteristics			
No. of distal anastomoses (mean ± SD)	2.7 ± 0.9	2.5 ± 1.0	.283§
Total duration of surgery (min, mean ± SD)	175 ± 51	181 ± 59	.637
Off-pump procedure (no.)	44 (51.2%)	9 (26.5%)	.015†

*By Student *t* test unless otherwise specified. †By *P*² test. ‡By Fisher's Exact Test. §By Mann–Whitney *U* test.

patients included in the analysis and those excluded because of the lack of complete sets of data. Differences were noted for cognitive function scores, the proportion of off-pump procedures, female sex, and patients reporting more than 1 comorbidity, with subsequent adjustments in later multivariable analyses. Before surgery, SF-36 Physical and Mental health scores were significantly lower than in the observed normative population mean of 50 points: -7.6 and -7.3 points, respectively (1-sample *t* test, $P < .001$). Preoperative cognitive function (Table 2) was comparable to age group norms, with the exception of marginally lower memory scores. Preoperative observed physical exercise capacity correlated with SF-36 Physical health ($r = 0.34$, $P = .001$)

and with self-reported angina class ($r = -0.26$, $P = .017$, $n = 82$), whereas cognitive function correlated with SF-36 Mental health ($r = 0.35$, $P = .001$).

Objective Evaluations at 12 Months After CABG

The mean improvement in observed physical exercise capacity was 199 ± 426 W · min (paired *t* test, $P < .001$). Cognitive function scores improved overall by z of 0.25 ± 0.32 (paired *t* test $P < .001$), with a strong test–retest correlation ($r = 0.86$, $P < .001$).

Six patients had undergone coronary reintervention since CABG, 5 of them to previously grafted coronary arteries. One patient had recovered completely at 3 months after surgery from a mild postoperative stroke. Follow-up angiography revealed that 21 of 82 patients had a single graft without detectable flow, whereas 1 patient had 3 occluded grafts.

Subjective Evaluations at 12 Months After CABG

Sixty-four patients (74.4%) reported improvement of angina. Sixty-three patients (73.3%) reported no angina at follow-up. Table 3 displays the corresponding SF-36 subscale change scores with correlation coefficients to changes in cardiac function, cognitive function, and symptom relief. Change in physical exercise capacity was associated with self-reported physical functioning, bodily pain, and physical role limitations. Change in cognitive function demonstrated minor correlation coefficients with social functioning, vitality, and physical functioning. Symptom relief was primarily associated with bodily pain and physical role limitations.

For the group, the mean change in SF-36 Physical and Mental health scores was clinically significant, showing SF-36 Physical and Mental health scores that improved from below the population mean before surgery to within at follow-up (95% confidence interval Physical health 48.3–52.0 points, Mental health 46.7–50.4 points). The correlation coefficients between SF-36 Physical and Mental health were r of 0.17 ($P = .108$) at baseline and r of 0.15 ($P = .163$) at 12 postoperative months. The correlation coefficient between change scores was -0.13 ($P = .219$).

Regression Analyses of Subjective Physical and Mental Health

The initial regression models included sex and preoperative self-reported health status; these variables together explained 17.0% of the variance (adjusted R^2) in SF-36 Physical health scores and 18.2% of the variance in SF-36 Mental health scores at 1 year postoperative year. After adding all planned independent variables (Table 4), the analysis demonstrated that improvement of angina and change in observed physical exercise capacity were significantly associated with change in SF-36 Physical health. Improved angina class was associated with an improvement in Physical health score of 4.7 points, independently accounting for 5.1% of the total variance. The mean improvement in

TABLE 2. Neurocognitive function, scores by component and test before and 1 year after coronary artery bypass grafting (n = 86)

Neurocognitive component and test	Scoring	Score (mean ± SD)	
		Preoperative	12 mo
Motor coordination			
Grooved Pegboard Test	Mean time (s) for both hands to complete	81.5 ± 17.6	77.9 ± 18.2
Psychomotor speed			
Digit Symbol (WAIS-R)	No. of symbols completed in 90 s	37.3 ± 8.9	39.3 ± 10.1
Trail Making Test	Time (s) to complete part B minus part A	61.8 ± 31.6	56.4 ± 35.4
Attention			
Digit Span (WAIS-R)	Correctly repeated digits (forward and backward)	10.0 ± 1.6	10.2 ± 1.7
Stroop Color-Word Interference Test*	Time (s) to name color of 48 color words	72.1 ± 28.5	68.5 ± 27.8
Verbal memory			
Rey Auditory Verbal Learning Test, L	Total words learned, test 1–5	34.7 ± 8.6	39.0 ± 10.1
Rey Auditory Verbal Learning Test, R	Correctly recalled words after 20-min delay	6.2 ± 2.8	7.5 ± 2.7
Verbal comprehension and fluency			
Similarities (WAIS-R)	Raw score	18.8 ± 4.1	20.6 ± 3.8
Controlled Oral Word Association Test	Number of F, A, and S words for 1 min each	35.5 ± 11.4	37.9 ± 13.1
Visuoconstructive abilities			
Block Design (WAIS-R)	Raw score	26.8 ± 8.7	28.2 ± 9.3

WAIS-R, Wechsler Adult Intelligence Scale—Revised. *At baseline, n = 84; at 12 months, n = 85.

exercise capacity was associated with 1.2 points increase in SF-36 Physical health, accounting for 9% of the variance. These findings seemed predominately to represent independent effects. Change in exercise capacity, improvement of angina, and sex did not show significant interaction effects on SF-36 Physical or Mental health scores. Change in SF-36 Mental health scores was associated with change in cognitive function; decline of 0.5 SD in cognitive function corresponded to a 3.7-point decline in mental health.

The regression models were stable when individually adding possible confounders, identified through bivariate analysis or clinical judgment. Preoperative obstructive lung disease (ΔR^2 of 4.7%, $P = .014$), and more than 1 self-reported comorbidity (ΔR^2 of 2.9%, $P = .054$) added ex-

plained variance to the physical health model without major alterations in the other predictors. No control variables showed significant effects in the Mental health score regression model. The final regression models explained 33% of the variance in SF-36 Physical health scores and 27% of the variance in SF-36 Mental health scores at 1 postoperative year.

Two follow-up analyses were run to evaluate the influence of graft patency or multivariable outliers. The presence of an occluded graft was not significant for SF-36 Physical health ($df = 81$, $\beta = 0.02$, $P = .807$) or SF-36 Mental health ($df = 81$, $\beta = 0.13$, $P = .204$). Two multivariable outliers were identified in the Mental health score model. Exclusion of these outliers increased the explanatory value of the

TABLE 3. Health status, change scores at 1 year after coronary artery bypass grafting with bivariate correlations with predictor variables (n = 86)

	Change (mean ± SD)	Correlation coefficient		
		Physical exercise capacity change	Neurocognitive function change	Angina, improved
SF-36 subscales				
Physical functioning	19.2 ± 23.2	0.25*	0.12	0.11
Bodily pain	21.4 ± 31.4	0.32†	0.06	0.31†
Role, physical	35.2 ± 46.2	0.23*	−0.06	0.29*
General health	9.1 ± 19.5	0.01	0.07	0.03
Vitality	14.0 ± 21.2	0.07	0.10	0.14
Social functioning	14.2 ± 22.4	0.05	0.19	0.03
Role, emotional	29.1 ± 49.0	0.02	0.15	−0.02
Mental health	8.7 ± 14.8	−0.04	0.07	−0.03
SF-36 summary scores				
Physical health	7.8 ± 9.1‡	0.37†	0.02	0.33†
Mental health	5.8 ± 10.9‡	−0.1	0.16	−0.08

All correlation coefficients are Pearson r . Change scores are relative to preoperative scores; a positive change indicates improvement. The scale is 0 to 100. * $P < .05$. † $P < .01$. ‡Paired t test comparing preoperative to 1 year after surgery, $P < .001$.

TABLE 4. Multivariable models of physical and mental health at 1 year after coronary artery bypass surgery

Independent variable	SF-36 Physical health*		SF-36 Mental health†	
	β	P value	β	P value
Observed physical exercise capacity at 1 postoperative y	0.42	.001	−0.07	.591
Preoperative observed physical exercise capacity	−0.37	.005	−0.13	.315
Cognitive function at 1 postoperative y	0.28	.120	0.52	.007
Preoperative cognitive function	−0.33	.065	−0.15	.426
Improvement of angina	0.23	.012	−0.03	.785
Sex (female coded 1)	−0.06	.530	−0.07	.502
Preoperative SF-36 Physical/Mental health score	0.44	<.001	0.36	<.001

The β values represent standardized regression coefficients indicating relative strength of association between independent variables. * $R^2 = 0.39$; adjusted $R^2 = 0.33$. † $R^2 = 0.33$; adjusted $R^2 = 0.27$.

model (ΔR^2 of 3%) without altering the main effect associated with change in cognitive function.

DISCUSSION

There are 2 key findings in our study of change in physical and mental health at 1 year after CABG. The first is that the combined influences of symptom relief, change in observed physical exercise capacity, and change in cognitive function revealed significant and unique associations with changes in physical and mental health. The physiologic and symptomatic variation in outcome was statistically beyond what could be predicted from preoperative health status or sex, the difference was clinically relevant, and the presence of graft occlusion per se was not apparently of importance for this variation in self-reported outcomes. The extent and impact of outcome variation are relevant when counseling patients regarding expectations of surgery. Because symptom relief and increased exercise capacity each represent different aspects of change in health status (Table 3) and do not cancel each other out in the multivariate analysis (Table 4), the clinical interpretation is to evaluate, counsel on, and optimize each of these outcomes in parallel, possibly aided by standardized health status questionnaires. The second key finding is that change in cognitive function, although predictive of mental health, was not significant for physical health. This study suggests that changes in physical health may be interpreted independently of cognitive functioning.

The primary aim of CABG is to prolong life, with secondary aims of reducing angina and improving health status.¹ A concept of successful surgery may cover multiple related elements, such as patent coronary grafts, relief of angina, objectively measured functional improvement, the absence of complications such as adverse neurologic outcomes,

and improved health status as experienced by the patient. At the group level, this patient sample demonstrated an expected benefit of surgery, increasing SF-36 Physical and Mental health scores to within the age- and sex-matched population norm. Our results are consistent with previous studies in that the experience of symptom relief varied; 1 in 5 patients with preoperative symptoms still reports exertional angina at 1 postoperative year.²²

We observed a mean improvement in exercise capacity of 25% relative to preoperative status. Cross-sectional studies regarding the correlation of exercise capacity with self-reported physical health are in line with our findings.^{7,23} Previous longitudinal studies combining objective and self-reported outcomes after CABG, however, are rare, report weaker correlations with change in exercise capacity, and lack control for cognitive function.^{7,9} The last variable is important in light of reports that suggest a causal association of cognitive function with self-reported physical health,^{10,24} results that were not replicated in this study. We noted a modest bivariate association between change in cognitive function and the SF-36 subscale Physical functioning (Table 3). Cognitive functioning may play a role in patients' ability to gain maximum health benefits during rehabilitation.^{8,24} We suggest, however, that cognitive function may also be interpreted as representing an underlying causal variable. Single-organ indicators of a multiorgan disease may share an association with the underlying disease process—atherosclerosis—and show up as significant predictors on a broad spectrum of outcomes, including self-reported health status after CABG. In line with this interpretation, Ho and coworkers²⁵ established noncoronary manifestations of atherosclerosis as predictive of cognitive decline after CABG. It is notable that our patient sample was representative of those with moderate to good left ventricular function. Patients with less well-preserved left ventricular function may demonstrate known but still not fully understood correlations between physical and cognitive indicators.²⁶ We observed a trend toward improvement in cognitive function score from baseline for 74% of the patients, probably reflective of a learning effect related to testing.²⁷ Because this analysis was not by intention to treat but controlled for the actual use of cardiopulmonary bypass, the results are not informative regarding the off-pump versus on-pump CABG controversy. Cognitive function at 1 year after the procedure, however, was not indicative of a general decline. Although patients with coronary artery disease may demonstrate more cognitive impairment than control subjects with healthy hearts, studies within the last decade with a control group suggest that little postoperative change in cognitive function is attributable to CABG.^{27,28}

The presence of occluded grafts was not significant for self-reported health status, a finding that was unrelated to the number of distal anastomoses created at surgery.

Furthermore, graft occlusion did not correlate significantly with change in observed physical exercise capacity (data not shown). Providing that sufficient global improvement in coronary flow reserve has been achieved, a coronary graft may occlude without objective evidence of ischemia, usually because of adequate collateral or competing circulation. In other cases, an occluded graft may lead to silent ischemia without angina. Two issues complicate comparison across studies. First, previous studies demonstrate a wide range of completeness of follow-up angiography of patients included or randomly assigned. The less complete is the follow-up, the greater is the potential for a relative oversampling of patients with symptomatic graft occlusion leading to angiographic evaluation. Second, a pathologic graft may be defined as the absence of flow, as in this study, or as a stenosis greater than 50% or perhaps 75% of the vessel diameter. The wider definition will cover a greater proportion of a patient sample, thus increasing the probability of identifying a statistical association, although no additional argument for clinical relevance is implied.

Several features and limitations of this study should be acknowledged. Preoperative and postoperative standardization and protocol adherence were enhanced by a single-center design. Although our patient sample was of moderate size, limited by the clinical resources available in the parent clinical trial, the surgical results and graft patency rates were comparable to those in larger studies after on- or off-pump procedures.²⁹ All our regression models adjusted for baseline health status, providing statistical adjustment for scaling effects and the tendency for extreme scores to be followed by less deviation from the mean (regression to the mean). This study illustrates that theory-guided, multivariable, longitudinal analysis of clinical and self-reported indicators is feasible and informative regarding their relative importance for health status outcomes at a higher level of abstraction. Patient-reported outcomes add to our understanding of the impact of illness and treatment. The interpretation of patient-reported outcomes may be complicated, however, by selective reporting or the recalibration of respondents' internal values.³⁰ Our study did not allow quantification of such effects. Baseline and follow-up medications were not entered into the analysis. Missing data, in particular for observed physical exercise capacity, suggest a potential for sampling bias. A comparison between patients included in our analysis versus those excluded, however, did not demonstrate a difference in health status at follow-up. We also performed a sensitivity analysis of the effect of missing physical exercise test data. This confirmed our overall findings by first imputing the 12.5th percentile (low end) for all missing preoperative and postoperative results of physical exercise capacity (n = 104) and then repeating the procedure with the 87.5th percentile (high end). Use of a theoretic causal pathway model to guide the analysis strengthens this study.

We acknowledge the possibility of bidirectional causal effects within a chain of self-reported outcomes,² although we have previously found this to be evident at other time points than at 1 year after CABG regarding the relationship between the SF-36 general health subscale and overall quality of life.¹⁶

Summing up, at 1 year after CABG, changes in objective functional performance and symptom relief are significant for self-reported health status beyond the predictive ability of preoperative health status, sex, or graft patency. Symptom relief and change in observed physical exercise capacity are significant for self-reported physical health, independent of cognitive function. A positive change in cognitive function is significantly related to self-reported mental health. Awareness of the extent of outcome variation and its effects on health status is important when counseling patients before and after CABG. As related but unique outcomes, angina and physical capacity should both be assessed, possibly with the inclusion of a standardized health status questionnaire.

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