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The Postoperative Morbidity Survey was validated and used to describe morbidity after major surgery

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Abstract

Objectives: To describe the reliability and validity of the Postoperative Morbidity Survey (POMS). To describe the level and pattern of short-term postoperative morbidity after major elective surgery using the POMS.

Study Design and Setting: This was a prospective cohort study of 439 adults undergoing major elective surgery in a UK teaching hospital. The POMS, an 18-item survey that address nine domains of postoperative morbidity, was recorded on postoperative days 3, 5, 8, and 15.

Results: Inter-rater reliability was perfect for 11/18 items (Kappa = 1.0), with Kappa = 0.94 for 6/18 items. A priori hypotheses that the POMS would discriminate between patients with known measures of morbidity risk, and predict length of stay were generally supported through observation of data trends, and there was statistically significant evidence of construct validity for all but the wound and neurological domains. POMS-defined morbidity was present in 325 of 433 patients (75.1%) remaining in hospital on postoperative day 3 after surgery, 231 of 407 patients (56.8%) on day 5, 138 of 299 patients (46.2%) on day 8, and 70 of 111 patients (63.1%) on day 15. Gastrointestinal (47.4%), infectious (46.5%), pain-related (40.3%), pulmonary (39.4%), and renal problems (33.3%) were the most common forms of morbidity.

Conclusion: The POMS is a reliable and valid survey of short-term postoperative morbidity in major elective surgery. Many patients remain in hospital without any morbidity as recorded by the POMS.

Keywords: Outcome Assessment (Health Care); Health Services Research; Morbidity; Epidemiology; Surgery; Surgical Procedures; Operative

1. Introduction

Calls for increased clinical safety and accountability after high profile health care scandals, the drive to give patients a choice between different health care providers, and the linkage of funding to measured results have driven the outcomes reporting agenda forward. Cardiac surgery has led the way in the reporting of outcomes after surgery [1–3] and other surgical specialties are now following [4]. These initiatives are limited by the lack of validated instruments for describing the variety of outcomes occurring to individual patients. The measures currently used to assess outcome after surgery have significant limitations.

Mortality is the most commonly cited variable, but the low event rate after elective surgery limits its applicability as a general outcome measure. Length of hospital stay is known to be affected by medical and nonmedical factors and therefore functions as a hybrid measure of process and outcome [5–9]. Recording of perioperative morbidity has hitherto been limited: a recent systematic review of the measurement and monitoring of surgical adverse events found inconsistency in the quality of reporting of postoperative adverse events limiting accurate comparison of rates over time and between institutions [10]. A reliable and valid index of short-term postoperative morbidity would be of enormous value in quality of care, prognostic, and effectiveness research.

The Postoperative Morbidity Survey (POMS) is the only published prospective method for describing short-term

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morbidity after major surgery [11]. The POMS was designed with two guiding principles. First, it should only identify morbidity of a type and severity that could delay discharge from hospital. Second, the data collection process should be as simple as possible so that large numbers of patients can be routinely screened. Following on from these principles, a measure was produced that focused on easily collectable indicators of clinically important dysfunction in key organ systems. The indicators are obtainable from routinely available sources and do not require special investigations. These sources include observation charts, medication charts, patient notes, routine blood test results, and direct questioning and observation of the patient. Crucially, the indicators define morbidity in terms of clinically important consequences rather than traditional diagnostic categories.

Item generation was achieved through a three-stage process [11]. First, investigators collected information directly from patients, nurses, and doctors using open questions to identify reasons why the patients remained in hospital after surgery. Second, the responses obtained were categorized into domains of morbidity type. Thresholds were set for individual domains to achieve the primary goal of identifying morbidity of a type and severity that could delay discharge from hospital. Finally, the derived survey was reviewed and amended by an international consensus panel of anesthesiologists and surgeons. The POMS (Table 1) contains 18 items that address nine domains of postoperative morbidity. For each domain, either presence or absence of morbidity is recorded on the basis of objective criteria. The POMS is starting to be used in outcomes research [12] and in effectiveness research [13].

The aims of this study were to describe the level and pattern of short-term postoperative morbidity in a UK teaching hospital and to establish the reliability and validity of the POMS in patients undergoing elective major surgery.

2. Methods

All adult patients (aged 18 years or above) undergoing major elective surgery at the Middlesex NHS Hospital (London, UK) between July 1, 2001 and September 30, 2003 were eligible for inclusion in this prospective cohort study. Recruitment was interrupted during periods of study nurse annual leave.

Major elective surgery was defined as procedures expected to last more than 2 hours or with an anticipated blood loss greater than 500 mL. The following procedures were included: orthopedic surgery (revision hip arthroplasty, total hip replacement, total knee replacement, fusion/instrumentation of multiple lumbar or thoracic vertebrae), general surgery (laparotomy including partial hepatectomy, pancreatic surgery, reoperative colon surgery, abdominoperineal resections, anterior resections, panproctocolectomies, hepatobiliary bypass procedures), and urological surgery (radical prostatectomy, radical cystectomy, radical nephrectomy).

Having obtained institutional ethics committee approval, candidate inpatients were asked to provide informed consent to participate in the study. The POMS was administered by one of two study nurses to consenting patients on postoperative days 3, 5, 8, and 15. Acceptability of the POMS to patients was noted. Thirty-four patients were administered the POMS by both research nurses to assess

Table 1
The POMS

Morbidity type	Criteria	Source of data
Pulmonary	Has the patient developed a new requirement for oxygen or respiratory support.	Patient observation Treatment chart
Infectious	Currently on antibiotics and/or has had a temperature of $>38\,^{\circ}$C in the last 24 hr.	Treatment chart Observation chart
Renal	Presence of oliguria <500 mL/24 hr; increased serum creatinine ($>30\%$ from preoperative level); urinary catheter in situ.	Fluid balance chart Biochemistry result Patient observation
Gastrointestinal	Unable to tolerate an enteral diet for any reason including nausea, vomiting, and abdominal distension (use of antiemetic).	Patient questioning Fluid balance chart Treatment chart
Cardiovascular	Diagnostic tests or therapy within the last 24 hr for any of the following: new myocardial infarction or ischemia, hypotension (requiring fluid therapy >200 mL/hr or pharmacological therapy), atrial or ventricular arrhythmias, cardiogenic pulmonary edema, thrombotic event (requiring anticoagulation).	Treatment chart Note review
Neurological	New focal neurological deficit, confusion, delirium, or coma.	Note review Patient questioning
Hematological	Requirement for any of the following within the last 24 hr: packed erythrocytes, platelets, fresh-frozen plasma, or cryoprecipitate.	Treatment chart Fluid balance chart
Wound	Wound dehiscence requiring surgical exploration or drainage of pus from the operation wound with or without isolation of organisms.	Note review Pathology result
Pain	New postoperative pain significant enough to require parenteral opioids or regional analgesia.	Treatment chart Patient questioning

inter-rater reliability. POMS criteria were evaluated through direct patient questioning and examination, review of clinical notes and charts, retrieval of data from the hospital clinical information system, and/or consulting with the patient's caregivers. Patients were cared for by the normal attending clinicians who were blinded to the survey results.

We also recorded patient's age, sex, surgical procedure, measures of preoperative risk (American Society of Anaesthesiology [ASA] Physical Status Score [14], Physiological Score of the Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity [POSSUM]) [15], length of stay, mortality, and admission to intensive care unit (ICU). The ASA score subjectively categorizes patients into five subgroups by preoperative physical fitness. The POSSUM score is a means of predicting outcome after surgery based on 12 physiological variables obtained before surgery (physiologic score) and six operative variables available during or after surgery (operative severity score). Observed rates of mortality and morbidity are compared with expected values obtained by inputting the physiologic score and operative severity score into the POSSUM predictor equation. Where patients remained in hospital without identifiable morbidity (as defined by the POMS), we recorded reasons for delay in hospital discharge including nonmedical reasons as a free text entry (last 200 recruited patients only). This was done by detailed review of the patients' charts (medication, observation, and fluid balance) and clinical note review. Where no clear answer was identified from these sources direct questioning of patients, nurses, and doctors was undertaken to define the reason for remaining in hospital.

Inter-rater reliability was analyzed using the Kappa coefficient of agreement [16]. The extent to which the nine POMS domains comprise a scale that measures the same underlying construct (internal consistency) was examined using the Kuder-Richardson formula 20 [17]. For the sake of brevity, we confine our validity analyses to data collected on postoperative day 5. The predictive validity of POMS was explored first on a univariate basis using *t*-tests to compare the mean subsequent length of stay of patients with and without POMS-defined morbidity. We also performed a multivariate linear regression analysis to determine the independent predictive strength of each POMS domain. To do this, we adjusted the raw differences in length of stay between patients with and without morbidity on each POMS domain to take account of morbidity in other domains. To test "known-groups" construct validity, we examined the extent to which POMS domain frequencies were higher in patients with a greater risk of postoperative morbidity. To do this, we used chi-square tests to compare patients with preoperative ASA grades I and II to patients with ASA grades III and IV. We also used chi-square tests to compare patients with <50% risk of postoperative morbidity (as defined by the POSSUM assessment) to those with ⩾50% risk. All *P*-values are two-sided, and *P*-values lower than 0.05 were considered a statistically significant result. Stata software (Release 8; StataCorp LP, College Station, TX) was used for all calculations.

3. Results

3.1. Characteristics of study population

Of the 706 patients, 450 (63.7%) who were candidates for inclusion were enrolled into the study. The main reasons for nonenrollment were lack of preoperative consent (139 patients), communication problems (47 patients), and enrollment in other studies (37 patients). One of the enrolled patients withdrew after provision of consent, one was found to be participating in an interventional study, one was withdrawn by the attending consultant, and eight did not have surgery.

Patient and perioperative characteristics of the 439 evaluated patients are summarized in Table 2. The mean age of the 439 patients who completed the study was 62.9 years (range, 19–90 years) and 260 patients were female (59.2%). In the 434 patients where ASA score was recorded 79 (18.2%) were rated grade I, 253 (58.3%) were grade II, 100 (23.0%) were grade III, and 2 (0.5%) were grade IV. The range of postoperative morbidity risk predicted by POSSUM was high (mean risk of morbidity, 31.9%; SD, 21.3%; range, 7.6–98.0%). The median postoperative length of hospital stay for all patients was 10 days (mean, 13.4 days; SD, 12.8; range, 1–136 days) and six patients (1.4%) died during their hospital stay. Patients in ASA grades I or II had a shorter postoperative length of stay (mean, 12.6 days; median, 10 days) than those in grades III or IV (mean, 16.4 days; median, 12 days). Similarly, patients with ⩾50% risk of postoperative morbidity as defined by POSSUM had a longer postoperative length of stay (mean, 21.0 days; median, 18 days) than those with a lower risk (mean, 11.8 days; median, 9 days). Seventy patients (16.0%) were directly admitted to ICU after surgery and a further 35 patients (8.0%) required admission to ICU after a period of ward care.

Two hundred and eighty-nine patients (65.8%) underwent orthopedic surgery, 101 (23.0%) had general surgery, and 49 (11.2%) had urological surgery. Patients undergoing orthopedic surgery (mean, 65.2 years) were slightly older than those undergoing general (60.2 years) and urological surgery (55.2 years), but were judged to be at lower risk of postoperative morbidity using POSSUM criteria (24.4% vs. 48.5% for general surgery and 42.0% for urological surgery patients). The POSSUM physiology scores were slightly higher in patients undergoing orthopedic surgery (mean, 17.2; median, 17) than in patients undergoing general (mean, 16.1; median, 15) or urology (mean, 16.1; median, 15) surgery. The POSSUM operative severity scores were higher for urological surgery (mean, 15.9; median, 17) and general surgery (mean, 17.3; median, 17) than for orthopedic surgery (mean, 10.2; median, 9). Duration of

Table 2
Patient and perioperative characteristics for the 439 evaluated patients

Group	Total	Orthopedic	General	Urology
(% of study population)	439 (100%)	289 (65.8%)	101 (23.0%)	49 (11.2%)
Mean age *(years)	62.9	65.2	60.2	55.2
(±SD)	(±15.7)	(±16.1)	(±13.9)	(±13.1)
[Range]	[19–90]	[19–90]	[24–88]	[27–80]
Sex				
Female	59.2	63.7	53.5	44.9
ASA score				
ASA I	18.0	22.2	7.9	14.3
ASA II	57.6	55.0	66.3	55.1
ASA III	22.8	21.1	24.8	28.6
ASA IV	0.5	0	1.0	2.0
Missing value	1.1	1.7	0	0
Postoperative environment				
ICU/HDU	16.0	10.1	25.7	30.6
>1 d in ICU	2.5	0	8.9	4.1
Ward	84.0	89.9	74.3	69.4
Median ICU/HDU LOS *(days)	0	0	0	0
(Range)	(0–11)	(0–1)	(0–11)	(0–4)
Median postoperative LOS *(days)	10	10	13	8
(Range)	(1–136)	(2–136)	(4–75)	(1–40)
Returned to theater	4.3	3.5	5.0	8.2
Readmitted to ICU/HDU	2.0	1.3	3.0	4.1
Died in hospital	1.4	1.0	2.0	2.0
Discharge destination				
Home	96.8	97.6	95.0	95.9
Rehabilitation	0.9	1.0	1.0	0
Other hospital	0.7	0.3	1.0	2.0

*All data expressed as percentage of total patients for each column unless otherwise stated.
ICU indicates intensive care unit; HDU, high dependency unit; LOS, length of stay.

surgery was longer for urological surgery (mean, 268 minutes; median, 285 minutes) and general surgery (mean, 282 minutes; median, 255 minutes) than for orthopedic surgery (mean, 183 minutes; median, 168 minutes). Estimated blood loss was greater for urological surgery (mean, 2,173 mL; median, 1,700 mL) than for orthopedic surgery (mean, 1,084; median, 650) or general surgery (mean, 942 mL; median, 700 mL).

The POMS was administered to those members of this cohort who remained in hospital on postoperative days 3 (433 patients), 5 (407 patients), 8 (299 patients), and 15 (111 patients).

3.2. Prevalence and pattern of postoperative morbidity

The percentage of patients with and without POMS-defined morbidity, by surgical specialty, for all postoperative time points is reported in Table 3. The POMS-defined morbidity was present in 75.1% of inpatients on day 3, 56.8% on day 5, 46.2% on day 8, and 63.1% on day 15. The most common sources of morbidity were gastrointestinal (recorded in 47.4% of all 439 patients at one or more than one postoperative time point), infectious (46.5%), pain (40.3%), pulmonary (39.4%), and renal (33.3%). Wound (11.2%), hematological (10.5%), cardiovascular (3.6%), and neurological (2.3%) morbidities were relatively rare. Orthopedic patients were much more likely to avoid any form of POMS-defined morbidity over the course of their hospital stay (29.4% vs. 2.0% for general surgery and 6.1% for urological surgery). However, they were also more likely to remain in hospital despite having no form of POMS-defined morbidity (e.g., 55.0% remained in hospital with no morbidity on day 5 compared to 19.4% of general surgery patients and 22.5% of urological surgery patients). The prevalence of each type of morbidity for the different surgical specialties at each postoperative time point is shown in Table 3. The most extreme discrepancies in specialty-specific morbidity rates were observed in the gastrointestinal domain on day 3 (20.1% for orthopedic surgery vs. 91.1% for general surgery and 51.0% for urological surgery).

3.3. Reasons for nondischarge in patients with no POMS morbidity

For the last 200 patients enrolled into the study, if no POMS-defined morbidity was identified, we recorded alternative reasons for remaining in hospital and did not identify any additional unrecorded morbidity. One hundred and

Table 3
Percentage of patients according to discharge status and prevalence of overall morbidity (as defined by the POMS) and POMS domains categorized by surgical specialty at all postoperative time points

	Orthopedic (*N* = 289)				General (*N* = 101)				Urology (*N* = 49)			
	Day				Day				Day			
	3	5	8	15	3	5	8	15	3	5	8	15
Discharged from hospital	1.7	6.9	34.9	83.0	0	3.0	15.8	53.5	2.0	18.4	46.9	69.4
In hospital without morbidity	35.6	51.2	40.5	8.7	2.0	18.8	34.7	12.9	6.1	18.4	18.4	6.1
In hospital with morbidity	62.6	41.9	24.6	8.3	98.0	78.2	49.5	33.7	91.8	63.3	34.7	24.5
Pulmonary	30.1	7.3	2.4	1.7	58.4	19.8	12.9	5.9	36.7	22.4	8.2	6.1
Infectious	26.6	21.5	14.5	7.6	43.6	28.7	18.8	11.9	59.2	36.7	14.3	16.3
Renal	24.9	8.7	2.8	1.0	39.6	21.8	5.9	3.0	53.1	30.6	10.2	4.1
Gastrointestinal	20.1	15.9	7.3	1.0	92.1	65.3	37.6	25.7	51.0	40.8	18.4	10.2
Cardiovascular	0.7	1.4	0.3	0	3.0	4.0	1.0	1.0	2.0	2.0	0	0
Neurological	1.7	0.7	0.3	0	3.0	2.0	0	0	0	0	4.1	0
Wound	1.7	5.5	5.9	2.4	0	1.0	6.9	6.9	0	2.0	4.1	4.1
Hematological	7.3	2.4	1.0	0.3	4.0	2.0	1.0	0	16.3	2.0	0	0
Pain	30.8	4.2	1.4	0.7	58.4	24.8	10.9	5.9	49.0	20.4	2.0	2.0

Morbidity rates for individual domains do not sum to total ‘‘in-hospital with morbidity’’ as many patients had more than one type of morbidity.

sixty-one patients on day 8 and 41 patients on day 15 remained in hospital in the absence of any identifiable morbidity. Common reasons for nondischarge included mobility problems (41 patients on day 8, 8 patients on day 15), awaiting equipment at home (14 patients on day 8, 3 patients on day 15), and social problems (3 patients on 8, 3 patients on day 15). Four patients on day 8 and one patient on day 15 remained in hospital without any identifiable reason.

3.4. Reliability and acceptability

The subjective view of study nurses was that there was little or no dissatisfaction among patients during POMS administration. Inter-rater agreement for 11 items was perfect (Kappa = 1.0), with Kappa = 0.94 for six further items. Agreement was slightly lower on one item (assessment of nausea, vomiting or abdominal distension; Kappa = 0.71), and a more precise definition that included the prescription of antiemetics as a criterion was subsequently adopted.

3.5. Internal consistency

The internal consistency of the nine POMS domains on day 3 was 0.60, which is below the accepted minimum standard of 0.70 [18]. This indicates an insufficient level of homogeneity among the nine POMS domains to regard the survey as a scale addressing a unified underlying construct. Given this lack of unidimensionality, the nine POMS domains were treated separately in subsequent statistical analyses. Similar coefficients for internal consistency of POMS domains were observed on days 5 (0.57), 8 (0.51), and 15 (0.54).

3.6. Construct validity

Across all nine POMS domains, patients with morbidity on day 5 had a longer subsequent mean length of stay than those without morbidity (Table 4). In five domains (pulmonary, infectious, renal, gastrointestinal, and pain), these differences were statistically significant. The largest domain-specific difference was between patients with and without pain-related morbidity (21.1 vs. 7.6 days) and the smallest was for wound-related morbidity (10.3 vs. 9.2 days). When taking account of morbidity in other domains using multivariate linear regression, the only statistically significant independent predictors of length of stay were gastrointestinal and pain-related morbidity.

Patients in higher preoperative risk categories (ASA grades III/IV and those with ⩾50% risk of postoperative morbidity as defined by POSSUM) tended to have greater POMS-defined morbidity on day 5 after surgery (Table 4). The POMS tended to discriminate more clearly between patients in lower and higher POSSUM risk categories, than between those in lower and higher ASA grades. ‘‘Wound’’ was the only POMS domain where patients in high-risk groups tended to have the same levels of POMS-defined morbidity as patients in low-risk groups. Although not presented in this paper, the trends described above were present in POMS data collected on days 3, 8, and 15.

When we used chi-square tests to compare the differences between the POMS-defined morbidity levels of patients with low and high-risk ASA grades, only one comparison reached statistical significance: patients with ASA grades I or II had a lower risk of infectious morbidity than patients with ASA grades III or IV. In contrast, the same comparisons for patients with low vs. high-risk of POSSUM-defined postoperative morbidity showed significantly higher levels of POMS-defined morbidity in the high-risk group for all but the neurological and wound domains.

Table 4
Remaining length of stay (days) in patients with and without POMS-defined morbidity on day 5

	With morbidity		Without morbidity		Independent predictive strength of each POMS domain based on multivariate regression analysis		
Morbidity type	N	Mean	N	Mean	Adjusted difference in length of stay (days) beyond day 5	P	95% CI
Pulmonary	52	16.3	355	8.2*	1.7	0.43	−2.5 to 5.8
Infectious	109	12.4	298	8.0*	2.5	0.07	−0.2 to 5.3
Renal	62	12.1	345	8.7*	−1.8	0.31	−5.4 to 1.7
Gastrointestinal	132	14.1	275	6.9*	4.3	0.002	1.6 to 7.1
Cardiovascular	9	15.4	398	9.1	0.1	0.98	−8.7 to 8.9
Neurological	4	18.0	403	9.1	5.4	0.40	−7.3 to 18.0
Wound	18	10.3	389	9.2	2.6	0.37	−3.1 to 8.4
Hematological	10	14.9	397	9.1	3.4	0.39	−4.4 to 11.2
Pain	47	21.1	360	7.6*	10.6	<0.001	6.4 to 14.9

Abbreviation: CI, confidence interval.
*$P < 0.05$ for univariate *t*-test of differences in length of stay between patients with and without morbidity.

4. Discussion

4.1. Summary of findings

In this first use of the POMS in a UK setting, gastrointestinal, infectious, pain-related, pulmonary, and renal problems were the most common sources of morbidity after major surgery. Many patients remained in hospital despite having no morbidity, but no patient free of morbidity as defined by the POMS was found to have a morbidity-related reason for remaining in hospital: the POMS captured all relevant morbidity in inpatients. A variety of nonmedical reasons were identified as being responsible for prolonged hospital stay. Morbidity levels were lowest in patients undergoing orthopedic surgery but these patients were also more likely to remain in hospital without any form of morbidity. The POMS had good inter-rater reliability and acceptability to patients. A priori hypotheses that the POMS would discriminate between patients with known measures of morbidity risk, and predict length of stay were generally supported through observation of data trends, and we have demonstrated statistically significant evidence of construct validity for all but the wound and neurological domains (Tables 4 and 5). By predicting length of stay the POMS behaves in a similar way to both the ASA and POSSUM measures, providing evidence of convergent validity. The internal consistency of the POMS was relatively low indicating that it does not have the scaling properties necessary to generate a total score, which could be used as an index of overall morbidity.

The epidemiology of postoperative morbidity observed in this study reflects the health of the study population, the nature and severity of the surgery undertaken, and the definitions of morbidity used.

Although patients undergoing orthopedic surgery were marginally older and less fit than patients undergoing urological or general surgery, this was not reflected in the overall prevalence of morbidity for the three surgical groups. The differences in overall morbidity levels between surgical groups seem predominantly to reflect severity of surgery as indicated by differences in the Operative Severity Score of the POSSUM and differences in the duration of surgery. The POSSUM operative severity score, and therefore POSSUM predicted morbidity level, and duration of surgery were all greatest in patients undergoing general surgery, less in patients undergoing urological surgery, and substantially lower in patients undergoing orthopedic surgery. Interestingly, estimated intraoperative blood loss, which has previously been used as an index of severity of surgery, was similar for orthopedic and general surgery but greater for urological surgery.

Although severity of surgery is reflected in the overall prevalence of morbidity, the nature of surgery is reflected in the pattern of morbidity. For example, gastrointestinal morbidity was observed most frequently after general

Table 5
Rates (%) of POMS-defined morbidity on day 5 after surgery in patients with different ASA grades[a] and in different POSSUM-defined morbidity risk categories

	ASA grade		POSSUM risk category	
	I/II	III/IV	<50%	≥50%
Morbidity type	(n = 305)	(n = 98)	(N = 333)	(N = 74)
Pulmonary	11.2	18.4	10.8	21.6*
Infectious	22.6	39.8*	24.6	36.5*
Renal	13.8	20.4	12.3	28.4*
Gastrointestinal	32.1	34.7	26.4	59.5*
Cardiovascular	1.6	4.1	1.2	6.8*
Neurological	1.0	1.0	0.6	2.7
Hematological	2.3	3.1	1.5	6.8*
Wound	4.9	3.1	4.8	2.7
Pain	10.8	14.3	8.1	27.0*

*$P < 0.05$ for chi-square test of differences between low- and high-risk patient groups.
[a] Based on 403, of 407 day 5 inpatients where preoperative ASA grade was known.

surgery (operation directly involving gastrointestinal tract) and least frequently after orthopedic surgery (operation site remote from the gastrointestinal tract), whereas renal morbidity occurred most commonly after urological surgery. The interaction between severity of surgery and type of surgery follows a predictable pattern: within each specialty, the pattern of morbidity is consistent but the prevalence of each type of morbidity increases in proportion to operative severity.

4.2. Limitations of POMS and this study

4.2.1. Generalizability

A potential weakness of this study is uncertain generalizability. We focused on adult orthopedic, general, and urological surgery and our study was limited to one UK teaching hospital. However, a similar prevalence study (using identical recruitment criteria for the same types of surgery) in a US teaching hospital found a similar pattern and levels of morbidity [11]. We have not demonstrated that the POMS is a valid index of morbidity for other types of surgery (e.g., vascular surgery, cardiac surgery, and pediatric surgery). We would expect to see distinct patterns of morbidity in these groups reflecting different patterns of surgical injury and underlying disease. In some cases, specific comorbidities are associated with underlying risk factors for the problem requiring surgery (e.g., increased level of ischemic cardiac disease in patients undergoing surgery for peripheral vascular disease). Separate work is underway on the development of alternative versions of the POMS that are specific to cardiac and pediatric surgery.

4.2.2. Validity

There is no criterion ‘‘gold standard’’ with which to compare the POMS as a tool for identifying postoperative morbidity. Face validity of the POMS rests on demonstration of its ability to identify clinically relevant postoperative morbidity. There was evidence that POMS captured all clinically relevant morbidity. Composite outcomes such as the POMS can have more diverse content than simpler tools and are believed to have a better chance of detecting unexpected adverse outcomes [19].

Face validity is supported by the fact that for each domain the criteria are objective and simple to assess and that they represent a significant magnitude of morbidity (e.g., parenteral opioids or regional analgesia represent a nontrivial level of pain relief). Limitations of the domain criteria are that in some cases they are dependent on administered treatment, that they are composed of variety of different types of data, and that the binary nature of the domains (presence or absence of morbidity) might result in threshold effects whereby significant morbidity would go unrecorded. These limitations are discussed below.

The definitions used in POMS may be criticized as being too dependent on administered treatment: routine prophylactic interventions might be confused with ‘‘true’’ morbidity. This is particularly true in the first 3 days after certain types of elective surgery, where, for example, there may be routine use of pain medication, urinary catheter, antibiotics, and respiratory support and in some cases withholding of oral nutrition. However, the routine use of these treatments should be rare beyond the first 3 postoperative days and morbidity identified subsequently should be ‘‘true’’ morbidity. Variation in clinician practice relating to the context of use of the POMS may also confound measurement of ‘‘true’’ morbidity (see Section 4.2.3).

Many of the POMS definitions include more than one type of data. For example, the POMS definition of renal morbidity includes a laboratory finding (increased serum creatinine [$>30\%$ from preoperative level]), a treatment (urinary catheter in situ), and a physiological observation (oliguria <500 mL/24 hr). However, this is consistent with the clinimetric approach to index development [20,21]. Strengths of this approach are that face validity is improved and that the POMS has good sensitivity and specificity for significant morbidity requiring hospital care when applied in an environment with a tightly defined discharge policy [11]. We believe that using observable treatment to define morbidity leads to high inter-rater reliability and achieves acceptable levels of sensitivity and specificity for clinically significant morbidity. Additionally, this approach eliminates much of the variation arising from subjective assessment of conditions such as wound infection, pain, and respiratory distress.

The definitions of morbidity used for each domain of the POMS will influence measured prevalence of morbidity types. For example, if the definition of pain was altered to include taking oral analgesics the measured frequency of pain would be much higher. Additionally, for some domains there may be threshold effects whereby morbidity significant to a patient is not recorded (e.g., blood loss resulting in anemia and fatigue, but not meeting transfusion triggers). However, the finding that patients in hospital without morbidity as defined by the POMS were not there because of unrecorded morbidity supports the notion that the POMS records morbidity significant to patients and clinicians. A tool more sensitive for lower levels of morbidity (e.g., mild headache or mild exercise limitation) would be a poor discriminator of postoperative outcome after major surgery.

The definitions within individual domains record phenomena, which may be pathophysiologically related. There is therefore the potential for redundancy between domains. For example, an acute myocardial infarction might be recorded under pain (parenteral opiate prescription), cardiovascular (tests for ischemia), pulmonary (supplemental oxygen), and infectious (fever) domains. Pathophysiological interactions might also result in interactions between domains. For example, the pain and gastrointestinal domains might be associated due to the effects of parenteral opiates on gastrointestinal function leading to inability to tolerate enteral diet.

4.2.3. Context of use

The POMS assumes that the institutional settings in which it is used will be competent to recognize and treat morbidity as it arises. Where this assumption is violated, the POMS may produce the paradoxical result that hospitals with lower standards of care record the lowest level of morbidity. For example, a hospital with inappropriately low parenteral opioid prescription could fail to record POMS-defined pain morbidity. It is therefore important that POMS data is always interpreted in the context of an understanding of local postoperative treatment protocols and guidelines. We expect the use of the POMS in combination with clearly defined postoperative care pathways should provide a powerful tool for quality of care and morbidity outcome assessment. Recording of POMS data during the first 3 postoperative days would provide information about routine practice as discussed above. Recording of POMS from day 5 onwards should provide an index of ''true'' morbidity.

4.2.4. Discussion of findings in light of the literature

Estimates of morbidity prevalence are always contingent on the population under study and the definitions used. Previous reports have classified postoperative morbidity using alternative approaches to that taken by the POMS. They have commonly focused on defined diagnoses (e.g., Deep Venous Thrombosis) [15] rather than looking to capture all morbidity relevant to patients. They have often not recorded morbidity that did not fit into this type of diagnostic categorization (e.g., failure-to-tolerate enteral feed). As an example, comparison with other studies assessing pain is difficult because we used an operational definition for presence or absence of pain at predefined times, whereas most pain studies use objective testing methods (e.g., visual analog scores) [22–24] and/or cumulative recording (e.g., total morphine usage) [22,25,26] yielding continuous variables rather than a point prevalence. Additionally, most previous studies, which have recorded postoperative morbidity, have not collected data such as POSSUM scores that would permit risk adjustment and meaningful comparison with this study.

Recognizing these limitations it seems that relationships between different categories of morbidity and length of stay observed in our study are broadly consistent with previous reports. Pain and gastrointestinal dysfunction were common and associated with prolonged duration of stay in hospital. In a day surgery setting prolonged length of stay was associated with postoperative nausea and vomiting, dizziness, drowsiness, pain, and cardiovascular events [27]. Other studies of outcome after surgery have shown that delayed enteral feeding is not uncommon after gastrointestinal [13,28] or nongastrointestinal surgery [29]. A study of outcome after gastroenterological surgery in patients having lower risk operations than were included in our study found 13.9% (70/503) of patients had delayed oral intake (still receiving IV fluids >1 week after surgery owing to postoperative ileus) comparable to day 8 gastrointestinal morbidity 37.3% (inability to tolerate enteral diet) [30]. However, it is notable that in our study gastrointestinal morbidity, which is by definition distressing to the patient (unable to tolerate enteral diet), is not uncommon (>15% on POD3 and POD5) even after orthopedic surgery. This suggests that much of this type of morbidity is not simply related to direct disturbance of the gastrointestinal tract but may be associated with the overall physiological disturbance consequent upon major surgery of any type: it is likely to be a marker of the whole body response to injury rather than a specific local effect. Previous attempts at recording perioperative outcome have often not recorded this dimension of patient morbidity or have recorded ''postoperative ileus'' [15,31], a much less clearly defined outcome [32].

In our study, the wound domain was not strongly associated with increased length of stay and occurred less frequently among those with a greater preoperative risk as defined by ASA grade of POSSUM. This finding was consistent across surgical subgroups. This is in contrast to previous epidemiological [33] and case-matching [34–36] studies, which have reported clinically significant ''attributable'' increases in length of stay associated with surgical site infection (SSI). The lack of association in our study is striking because the POMS definition of wound morbidity has a stricter criterion than many other reports with the result that the POMS should only identify the most serious or severe wound morbidity. However, this is not universally reported: a case series of patients after colorectal surgery did not demonstrate an association between SSI and length of hospital stay using multiple regression analysis [37].

Both cardiac and neurological domains occur infrequently (<5%) in all types of surgery. Although cardiac risks are commonly perceived to be greater, our results are consistent with large-scale surveys of the risk of major cardiac complications in noncardiac surgery [38–41] but lower than levels identified if intensive monitoring techniques (e.g., continuous ECG monitoring for ST depression) [42] or biochemical tests [43] (e.g., Troponin T) are used.

4.2.5. POMS and bed occupancy

Our study provides an opportunity for direct comparison of outcome after major surgery between a UK and a US institution [11]. The pattern and prevalence of morbidity was very similar, but the relationship between morbidity and bed occupancy was not: nearly all (>98%) patients remaining in hospital in the US hospital had identifiable morbidity [11], whereas many patients (54% on day 8) in the UK hospital did not. The observation that patients remain in hospital in the absence of a clinical indication is not new [6–9,44–48]. A recent UK report of postoperative bed occupancy reported that 31% of patients were occupying beds inappropriately [49]. Although the POMS was not designed as a bed utilization review tool, the striking difference in prevalence of ''morbidity-free'' days between the two centers suggests contrasting levels of "appropriate" bed use and emphasizes the potential for improvements in discharge efficiency in the UK hospital. Shorter hospital stay as a result of improved discharge efficiency will reduce cost per patient and increase patient throughput.

4.2.6. Further studies

The POMS has great potential as a standard outcome measure in quality of care, prognostic, and effectiveness research. As the only validated measure of postoperative morbidity, this would permit comparison of both the level and pattern of postoperative morbidity and allows comparison between different studies. Comparing outcomes that occur more frequently (e.g., morbidity rather than mortality) allows smaller studies while retaining statistical power to detect significant differences between groups. In addition, the POMS permits the separation of process and outcome assessment in prognostic and effectiveness research thereby reducing confounding by process related factors. The POMS also has utility as a tool to explore improvements in bed management efficiency and to evaluate the success of these changes when implemented. Suitable models incorporating preoperative risk profiles, surgery characteristics, and postoperative morbidity assessment could be developed which would predict surgical bed occupancy and be responsive to the level and pattern of morbidity in current inpatients.

An important element of future work will be to validate the POMS in other populations (e.g., vascular surgery, cardiac surgery, neurosurgery, and pediatric surgery). The distinct pattern of morbidity in some of these settings (e.g., neurosurgery, cardiac surgery) might be expected to require the development of a modified tool specific to this type of surgery and work is already underway to develop and validate a version of POMS specific for cardiac surgery. In the pediatric surgical population, one might hypothesize that both the pattern of morbidity and the expression of "unwellness" (e.g., different reasons for not tolerating enteral feeding) might be different to the adult population and a study is currently underway to develop and validate a version of the POMS for this group.

We would also propose a study to test the hypothesis that use of the POMS in an environment with more tightly defined and audited management pathways (in particular for the interventions included within the POMS morbidity definitions) might be expected to further improve validity and utility.

5. Conclusions

The POMS identified gastrointestinal, infectious, pain-related, pulmonary, and renal problems as the most common sources of morbidity after major surgery in a UK setting. Many patients remain in hospital despite absence of postoperative morbidity as defined by the POMS. Screening for postoperative morbidity using the POMS may be useful to identify patients remaining in acute hospital beds unnecessarily. The POMS may have utility as a tool for recording bed occupancy and for modeling bed utilization.

The POMS is a reliable and valid descriptor of short-term postoperative morbidity in major surgical patients. The POMS should not be treated in statistical analyses as though it is a unidimensional scale. We envisage the POMS as a component of an integrated system of practice evaluation incorporating tightly defined care pathways and recording of case-mix (risk) adjusters, postoperative morbidity and mortality, resource utilization (length of hospital stay, cost), and quality-of-life data. We believe that the POMS may be a useful tool to inform clinical decision making, and in clinical governance activities and effectiveness research.

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