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High-Risk Surgery: Epidemiology and Outcomes

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Surgical morbidity is a significant public health issue worldwide. It is estimated that >230 million surgical procedures are performed each year, with an estimated mortality of at least 0.4% and morbidity of between 3% and 17%. Furthermore, there are potentially far-reaching consequences of a complicated perioperative course, because perioperative morbidity is associated with reduced long-term survival. In this review, we examine the factors that are associated with surgical outcomes. Issues related to the delivery of health care, such as structure, process, and resource utilization, have been shown to vary within and between institutions, leading to differences in both morbidity and mortality after surgery. Patient-related factors, in particular comorbid illness, functional capacity, and cardiovascular health, are also related to perioperative risk, and may be assessed using risk stratification models, exercise testing, and biomarker assays. The strengths and weaknesses of each of these techniques are discussed. We also review the strengths and limitations of the measures used to assess outcome after surgery, including patient-centered variables such as mortality and morbidity scores, and patient-related outcome measures. Finally, we suggest the direction of future work, which should be aimed at improving the precision of tools for describing perioperative risk, and of the measures used to assess the outcomes and quality of surgical health care. These tools are the building blocks of high-quality clinical trials, epidemiological studies, and quality improvement programs. (Anesth Analg 2011;112:891–901)

HIGH-RISK SURGERY: EPIDEMIOLOGY AND OUTCOMES

The Scale of the Problem

An estimated 234 million surgical cases occur worldwide each year.[1] The impact of this burden on individuals, health care providers, and society as a whole is difficult to estimate, but there are data suggesting that in developed nations, surgical mortality may be between 0.4% and 0.8% and complications may occur in between 3% and 17% of patients.[2,3] All-cause mortality within 1 year after most types of surgery is higher than mortality in age- and sex-matched normal populations, reflected as increased standardized mortality ratio; this increase in mortality is more frequent in patients who are high resource consumers while in the hospital (and therefore likely to have had a complicated postoperative course).[4] These data highlight perioperative morbidity and mortality as a major public health issue.

As a result, identification of high-risk surgical patients, and development of strategies aimed at reducing perioperative morbidity and mortality, is a major challenge for anesthesiologists and surgeons. Various interventions aimed at improving surgical outcomes, e.g., perioperative goal-directed therapy,[5–9] neuroaxial blockade,[10–12] and glycemic control[13,14] have produced conflicting results in clinical trials. These inconsistencies may be explained in a number of different ways. Clearly, we may be choosing the wrong interventions to study. Equally, however, we may be choosing the wrong patient groups, based on inappropriate risk stratification for perioperative complications, or we may be choosing inappropriate outcome measures for a particular intervention. To explore these possibilities, we need to identify risk factors for adverse outcomes, related to both patient physiology and variations in health care service provision.

In this review, we examine the relationship between health care processes, resource utilization, patient-specific risk factors, and perioperative outcomes. We also appraise the various quantitative and qualitative methods of estimating preoperative risk and measuring postoperative outcomes as an indicator of quality. Finally, we suggest direction of future work aimed at improving perioperative morbidity and mortality.

The Interaction Between Structure, Process, and Outcome in Surgical Patients

More than 40 years ago, Avedis Donabedian described a structure/process/outcome model of evaluating quality in health care.[15] "Structure" refers to how health care is organized, "process" is the method by which health care is provided, and "outcome" is the state resulting from health care processes. There is increasing evidence that issues related to process in health care may have significant impact on the outcomes of surgical patients. A number of cross-sectional studies reveal a volume/outcome relationship in surgery: that is, the more operations a particular surgeon or institution conducts, the better the outcome for

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the cohort.[16] This has been demonstrated consistently and in a wide variety of surgical specialties and health care systems worldwide.[17–20] Although this may not seem surprising, longitudinal studies do not confirm a "practice makes perfect" explanation for these observations, implying that there are intrinsic differences between high- and low-volume hospitals in terms of quality and standards of care.[21,22]

Further evidence for the influence of process on clinical outcome is provided by a retrospective analysis conducted by the National Surgical Quality Improvement Program (NSQIP) in the United States. A study that examined the outcomes of >180,000 surgical cases found a significant increase in 30-day mortality for the population of patients who had their elective, inpatient surgery performed on a Friday as opposed to those who were operated on between Monday and Wednesday. This difference was only evident in patients who were admitted postoperatively to general wards, rather than day-case patients or those admitted to critical care.[23] These data may imply that reduced staffing levels in general wards on weekends are having an adverse effect on patient outcomes, a phenomenon that has been reported in patients with a wide variety of medical conditions admitted via emergency departments.[24,25] By contrast, the maintenance of normal staffing levels at night and on weekends on critical care wards may explain why patients admitted to the intensive care unit postoperatively have similar outcomes irrespective of the day of their surgery. This hypothesis is supported by previous data showing no association between the time of admission and the case mix-adjusted outcomes of unselected patients admitted to critical care,[26] but a significantly higher mortality in patients discharged from critical care to normal wards at night.[27]

Most recently, further work conducted by NSQIP revealed a significant difference in surgical mortality among institutions, despite a similar case mix-adjusted morbidity rate.[28] This "failure to rescue" in hospitals with higher mortalities is likely to be associated with structure- and process-related issues; for example, medical and nursing staffing levels may influence the timely recognition and management of patients with postoperative complications. Investigation of such issues will gain momentum in the future as health care systems worldwide focus increasing efforts on improving quality of care.

The Association Between Health Care Resource Utilization and Perioperative Outcome

Work in the United Kingdom, evaluating >4 million surgical procedures, identified a "high-risk surgical population": the relatively small proportion of patients who were in this group (12.3%) accounted for the majority of postoperative mortality (83.4%), and these patients had a significantly longer hospital stay.[29] Perioperative risk was related to increasing patient age and the complexity and immediacy of the procedure: 88.5% of patients in the high-risk category underwent emergency surgery, as opposed to just 21.3% in the "standard risk" population. Of particular interest, fewer than 15% of the patients who were in the high-risk category were admitted to critical care directly from the operating theater.[29] The authors noted that cardiothoracic patients (excluded from this study), who by definition have significant comorbidity and are undergoing complex surgery, have a relatively low population mortality[30] compared with patients undergoing certain orthopedic, general, and vascular surgical procedures.[31–34] This may be partly attributable to process-related issues because the cardiac surgical population is relatively homogeneous, allowing for more protocolized and streamlined care. However, the authors also postulated that the more intensive management afforded to cardiac surgical patients as a result of routine admission to critical care postoperatively may lead to better outcomes.

These data may reflect inaccurate preoperative risk stratification and insufficient available resources for this high-risk population. They highlight the need for the accurate identification of patients at the highest risk of surgical complications, and who may therefore benefit from higher levels of support, such as critical care admission; equally, identifying patients for whom this level of support is not required is just as important, so that limited resources are directed at those who are most likely to benefit. The next few sections of this review discuss different methods of estimating perioperative risk for individual patients.

The Relationship Between Patient Risk Factors and Adverse Perioperative Outcome

The ability to increase oxygen delivery to a patient to meet the increased demands of the perioperative period is thought to be a fundamental determinant of outcome,[35,36] and it is this principle that underpins the strategy of perioperative hemodynamic optimization. Goal-directed fluid optimization aimed at maximizing oxygen delivery, using noninvasive monitors, such as the esophageal Doppler, has repeatedly been shown to be associated with a reduction in perioperative complications and hospital length of stay in certain types of surgical procedures.[37,38] The causes of the uncoupling of oxygen supply and demand in the perioperative period relate both to the patient's comorbidities and the severity of the surgical insult.[39]

Accurate stratification of patients into "risk categories" according to their own physiological characteristics may lead perioperative physicians to modify or abandon a planned surgical intervention if the risk is seen to outweigh the benefit, particularly in diseases for which a conservative alternative to major surgery is available. Alternatively, accurate preoperative risk stratification may allow physicians to select those patients who may benefit from specific treatment strategies, such as perioperative hemodynamic optimization or an enhanced level of perioperative care. In recent years, a number of different methods of predicting perioperative risk have been developed, which include predictive models, measures or estimates of functional capacity, and serological markers of inflammation and cardiac function. Other models and investigations are available for the specific prediction of adverse cardiac events.

Risk Stratification Scoring Systems

Three of the most frequently used risk stratification systems, the American Society of Anesthesiologists physical status (ASA-PS) score, the Charlson Age-Comorbidity Index, and the Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM), are

Table 1. Comparison of Frequently Used Risk-Stratification Scoring Systems

Scoring system	Description	Original purpose	Validation	Advantages	Disadvantages
American Society of Anesthesiologists physical status (ASA-PS) score	Categorical numbered scale (I–V) based on the severity of patient comorbidities (as estimated by the impact of comorbidity on patient physical status)	First reported in 1941 as a description of "anesthetic risk" for the purposes of epidemiological study[48]	Multicenter validation for categorization of population risk[49]; not validated for prediction of individual patient risk[50]	Simple, easily applied bedside tool not requiring complex calculation	Subjective; does not differentiate among different types of patient comorbidity; subject to wide interobserver variability[51]; does not use information regarding the surgical procedure itself. Poor sensitivity and specificity for the prediction of morbidity and mortality on an individual patient basis[50]
Charlson Age-Comorbidity Index	Additive score based on the presence and severity of different patient comorbidities	First reported and validated in 1994 for the purpose of risk classification in longitudinal studies	Multicenter; international. Originally validated for long-term population mortality prediction (3–5 years postoperatively) in diabetic and hypertensive surgical patients; has since been validated for prediction of inpatient mortality and morbidity in a number of different cohorts	Relatively simple; bedside calculation possible; more accurate predictor of outcome than ASA-PS[47]; accurate predictor of population risk according to assigned score[52,53]	Uses no information regarding the surgical procedure itself; assessment of patient comorbidity may be subjective
Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM)	12 physiological and 6 operative variables; each variable is assigned a score and the total scores are entered into logistic regression equations that calculate a percentage mortality and morbidity risk	First reported in 1991 to facilitate comparative audit among surgical services (by adjusting surgical outcome data for calculated predictive perioperative risk)	Multicenter; international. Portsmouth POSSUM system[54] uses the same dataset as the original POSSUM score, but a different equation is used to calculate predicted mortality. Found to be an equivalent or superior predictor of mortality compared with the original POSSUM in different surgical settings[55,56]; Surgery-specific variants such as Cr-POSSUM (colorectal) have been validated as better predictors of outcome than both the "general" POSSUM systems[57]	Validated for prediction of individual patient risk; POSSUM and its variants have been widely validated in different patient cohorts internationally; uses objective variables (such as blood test results) in dataset, therefore reducing interobserver variability	Uses some subjective variables (such as chest radiograph interpretation and jugular venous pressure measurement), which may be subject to interobserver variability. The operative variables are not available until during or after surgery. Logistic regression calculation means that the lowest possible mortality risk is 1.08%; predictive ability limited at extremes of age and calculated risk; however, validation in local datasets may improve predictive capacity

summarized in Table 1. These systems, and the many others in existence, differ in their discriminant ability and reliability, and the types of patients, procedures, and outcomes for which they are validated. A number of derivatives of these 3 systems have been validated in different surgical cohorts. The Surgical Risk Score,[40] and the later modification of it by Donati et al.,[41] are based on the ASA-PS system, but also include details of the proposed surgical procedure; both systems demonstrate improved predictive accuracy compared with the ASA-PS system used alone. However, caution should be exerted when considering the use of any of these models for clinical decision making on whether to proceed with a proposed intervention, because they demonstrate variable predictive precision, particularly at the extremes of age[42,43] and calculated risk.[44–46] Furthermore, although a direct comparison of risk stratification models revealed POSSUM to be superior to ASA-PS and Charlson for the prediction of 30-day morbidity, none of these systems was an accurate predictor of 90-day mortality.[47]

Other tools such as exercise testing or biomarker assays, which are discussed below, may be able to provide a more accurate assessment of a patient's perioperative risk than currently available risk stratification models. However, in certain patients, especially those undergoing emergency surgery who are therefore at particularly high risk of adverse outcomes, complex preoperative investigation is unlikely to be feasible. Therefore, for those patients in particular, there is a pressing requirement to develop and validate risk stratification models with better predictive precision than those currently available. It is unlikely that a "one size fits all" risk prediction model would be able to accurately stratify patients worldwide and over time, as a result of variations in structure and process among health care systems, differences in the type of surgery that may be offered to patients for a particular disease in different regions, and changes in how patients are looked after, as medical knowledge and management improve. To address this problem, large databases of patient demographics and risk factors, such as that of the Veterans Administration National Surgical Quality Improvement Program, need to be created internationally. Such systems would enable the development of "bespoke" risk stratification models that can be modified annually to reflect regional fluctuations in patient health and perioperative practice.

Assessment of Functional Capacity

Simple direct questioning to assess a patient's cardiorespiratory fitness has long been a part of preoperative assessment by the anesthesiologist, and has been shown to correlate with postoperative outcome.[58] Formal assessment of functional capacity may be subjective (e.g., the Duke Activity Status Index [DASI]) or objective (incremental shuttle walk test [ISWT] and cardiopulmonary exercise testing [CPET]).

The DASI is a simple questionnaire that categorizes levels of exertion (for example, ability to climb stairs or complete household chores) according to the metabolic equivalent of oxygen consumption required to achieve the task. The DASI is correlated with peak oxygen uptake on exercise testing[59] and, as suggested in the American College of Cardiology/American Heart Association (ACC/AHA) guidelines,[39] may be a useful element of a wider preoperative assessment, especially in the emergency situation in which there is no opportunity for formal exercise testing. However, it is a patient-reported and subjective measure, which may therefore not always correlate with an individual patient's true functional capacity. The ISWT involves a patient walking back and forth between 2 fixed points to the limit of their exertion. It is a validated and highly reproducible measure of functional capacity, and is likely to be most valuable for the screening of patients with a sufficient level of fitness to not require further investigation.[60,61] CPET requires the patient to cycle on a bicycle ergometer at gradually increasing intensity during a "ramp" exercise protocol. The 2 main measures of interest in CPET are the peak oxygen consumption ($\dot{V}o_2$peak) and anaerobic threshold (AT), which is the point at which anaerobic metabolism starts to increase significantly because oxygen delivery to muscles is surpassed by the metabolic demands placed by exercise.[62] Studies conducted in the 1990s identified a correlation between an objective measure of poor functional capacity (AT <11 mL/kg/min) and perioperative mortality in different surgical populations.[63,64] Of note, exercise capacity was found to be a more significant correlate of outcome than the occurrence of exercise-induced ischemia; the prognosis was worse in patients who had both ischemic exercise tests and a low AT. More recent work has also found $\dot{V}o_2$peak to be predictive of outcome in a variety of other patient cohorts.[65–67]

Recent work suggests that the DASI and the ISWT are highly sensitive and specific in the identification of patients at low risk of perioperative complications; however, they may incorrectly categorize as high risk a significant number of patients who, on CPET, would be considered low risk (that is, with an AT of >11 mL O_2/kg/min or peak $\dot{V}O_2$ >15 mL O_2/kg/min).[68] Such data suggest following an algorithmic approach to the assessment of functional capacity. The DASI ± ISWT may be used as inexpensive and quick screening tools to identify low-risk patients who warrant no further investigation; patients identified as high risk by these methods may benefit from further evaluation using CPET. For those patients identified as high risk, perioperative hemodynamic optimization and postoperative critical care admission may be of benefit, although at present there are no published multicenter studies examining the impact of specific management strategies on patients who have been risk-stratified using CPET.

Serological Markers of Inflammation

The biological mechanism responsible for the development of postoperative morbidity is likely to involve an inflammatory response that may clinically manifest by the systemic inflammatory response syndrome (SIRS) or milder clinical variants.[69] Perioperative levels of some pro- and antiinflammatory markers have been found to correlate with postoperative adverse outcomes. For example, endotoxin, which is a component of Gram-negative bacteria and is normally found in high concentrations in the gastrointestinal tract, is thought to be a trigger for SIRS in the surgical setting,[69] and endotoxemia may occur as a result of gut mucosal impairment during and after major nongastrointestinal surgery or from direct manipulation of the gut during abdominal surgery. Immunological work observing the level of antiendotoxin core antibody in preoperative patients has found that patients who have lower preoperative serum endotoxin core antibody concentrations are more likely to have postoperative complications[70–72] and reduced long-term survival.[73]

High-sensitivity C-reactive protein (hsCRP) is well established as a marker of inflammation that may predict vascular and cardiac adverse events in the general population, independent of accepted risk factors such as smoking, hypertension, and diabetes mellitus.[74] It has been found to inversely correlate with functional capacity as measured by $\dot{V}o_2$peak even in symptom-free individuals,[75] and the addition of hsCRP level to risk models for the prediction of cardiovascular risk in the general population improves predictive ability.[76] More recent work has examined the relationship between preoperative hsCRP level and surgical outcome, and found an independent association between elevated hsCRP levels and adverse events in orthopedic[77] and vascular surgical patients.[78–80] Other studies show preoperative hsCRP to be independently associated with long-term outcome in a variety of cohorts with surgically treated malignancies[81–83] and patients undergoing cardiac surgery.[84,85] However, heterogeneity in the hsCRP level that was defined as high in these studies means that, based on the current data, the generalizability of this assay for patient risk stratification remains limited.

It is possible that in the future, the addition of biomarker assays and measures of functional capacity to risk stratification scoring systems will lead to improvements in accuracy of perioperative risk prediction. All of the aforementioned tools have been used to predict generic adverse events after surgery. We now focus on specific considerations regarding the investigation and management of coronary artery disease and its influence on perioperative outcome.

The Relationship Between Cardiovascular Disease and Perioperative Outcome

Considerable attention has been focused on the incidence of adverse cardiac outcomes after surgery; however, the issue of whether cardiac ischemia (as opposed to inflammation) is the dominant pathophysiological mechanism underlying postoperative complications remains unresolved. The ACC/AHA guidelines recommend a stepwise approach to preoperative investigation of cardiac disease, based on the presence of clinical risk factors, the patient's functional capacity, and the seriousness of the proposed surgical intervention.[39] It is suggested that clinical risk factors may be assessed using the Lee Revised Cardiac Risk Index, which is a widely validated and simple composite scoring system evaluating 5 risk factors for cardiac disease and the risk of the proposed surgery.[86] Functional capacity may be assessed using the DASI, as previously discussed. However, once a patient is identified as being at high cardiac risk using these simple screening tools, there remains controversy over the choice of noninvasive test that will most reliably identify significant coronary artery disease. The ACC/AHA guidelines recommend that the choice of investigation be determined by local availability and expertise because there is no clearly superior test.[39]

Whichever investigation is undertaken, the key decision in this process is determining whether the test results will influence management: that is, whether the results will help to identify high-risk patients who may benefit from specific preoperative or perioperative management interventions, such as coronary revascularization or β-blockade.[87] Furthermore, even in the case of patients in whom significant coronary artery disease is identified, the evidence in favor of particular treatment strategies is subject to debate. In patients with stable 1-, 2-, or 3-vessel disease, for example, several randomized controlled trials suggest that outcome is not improved by prophylactic revascularization. The optimal management strategy in patients in whom more significant cardiac impairment is identified (for example, left ventricular dysfunction, unstable angina, or aortic stenosis) is not yet clear.[88,89] Similarly, recent data suggest that in many patients, β-blockade may be more harmful than beneficial.[87]

Novel techniques being evaluated for the prediction of adverse cardiac events include biomarker assays such as brain natriuretic peptide (BNP). The preoperative level of N-terminal pro-BNP has been found to independently predict mortality and cardiac events after both major cardiac[90–92] and major noncardiac surgery.[93–96] There are, however, several limitations of N-terminal BNP as a biomarker that should be considered. In the general population, there are age-, gender-, and assay-specific variations in cutoff values for risk stratification.[97] Renal impairment has been shown to diminish the usefulness of the assay for the prediction of perioperative cardiac complications.[98] Nevertheless, in the future, BNP (and similar biomarkers) may prove to be a useful part of a multifactorial risk assessment. As with generic perioperative risk, the evaluation of cardiac risk is likely to involve a combination of the above strategies to achieve optimal predictive accuracy.

Perioperative Outcomes: How to Measure Quality in the Perioperative Period

The next part of this review examines the evidence for using different variables as measures of outcome, both for the assessment of benefit from clinical trial interventions and for the measurement of quality in the perioperative period.

The relative importance of perioperative complications may be classified by the impact that they have on any of the following: survival, both short- and long-term; morbidity; patient evaluation of outcome (patient-reported outcome measures [PROMs]); and measures reflecting resource utilization, such as length of hospital stay.

Mortality

Mortality is a frequently measured outcome, and has several advantages as a quality metric. It is a dichotomous variable that is objective, clinically important, and not subject to interobserver variability. Nevertheless, there are a number of issues that may limit its use as an outcome measure, or at least argue for the concurrent recording of other outcomes. Mortality definitions are highly dependent on the timeframe of measurement. Inpatient, 28-day or 1-year mortality (or survival) are frequently reported definitions but are not reliably related to each other; therefore, it is not possible to reliably compare the results of studies or audits in which different mortality definitions are used. Inpatient mortality has the advantage that the data should be easier to collect, with loss to follow-up being an infrequent problem, but confounding may occur as a result of different criteria for patient discharge. In studies that take longer-term mortality as their outcome (28-day or longer), loss to follow-up after hospital discharge may be a concern, as may the influence that the natural course of comorbid diseases has on patient survival.

Another important issue, both for the assessment of quality in surgical care and for clinical trial interventions, is the incidence of mortality in perioperative patients. As surgical and anesthetic techniques have improved over time, this is reflected in published audit data and in longitudinal studies using short-term patient mortality as an outcome.[99–101] Studies evaluating the influence of hemodynamic optimization on perioperative outcomes frequently fail to show an improvement in perioperative mortality as a result of intervention, although they consistently show an improvement in morbidity and resource utilization measures, such as hospital or intensive care unit length of stay.[6,38,102,103] The failure of such studies to demonstrate improvement in hospital survival may, in part, be responsible for the poor uptake of optimization strategies by perioperative physicians. However, accumulating evidence of an association between perioperative morbidity and long-term survival suggests that mortality data relating only to the acute surgical admission may not fully reflect the health care impact of the surgical episode.

Analysis of >105,000 patients in the NSQIP database revealed that the occurrence of any 1 of 22 perioperative complications reduced median life expectancy by 69%.[104] This impact of morbidity on long-term mortality was found to be independent of preoperative comorbidities and was still significant after deaths within 30 days were excluded from analysis. The extent to which morbidity affected long-term survival was related both to the seriousness of the adverse event and the type of operative procedure. Nevertheless, even complications that may be considered to be relatively minor (such as urinary tract or wound infection) occurring after procedures that may be considered to be relatively benign (for example, laparoscopic cholecystectomy) were shown to have an impact on long-term survival. This study is the largest to link long-term outcome with perioperative events, and is supported by a growing body of evidence in heterogeneous surgical populations.[105–109] Although there is currently no mechanistic explanation for these findings, one may hypothesize that residual effects on functional capacity or the persistence of an ongoing inflammatory process associated with a postoperative complication is responsible for long-term adverse outcomes. Whether such an inflammatory response occurs as a result of the postoperative complication, or whether the complication occurs as a result of an already existing (and unidentified) proinflammatory state, is unclear. What is clear, however, is that although short-term mortality is a required and relatively robust outcome measure, measures of perioperative morbidity should be considered with similar importance for the purposes of comparative audit and in clinical trials.

Morbidity

In general, clinical outcomes may be classified as disease specific or generic measures.[110,111] Perioperative morbidity may be considered to be a type of disease-specific measure, whereby the "disease" is undergoing major surgery, and may be defined as the occurrence of any clinically significant nonfatal complication. However, the literature is inconsistent in its definition and reporting of surgical outcomes. There is wide variability in the definition of morbidity for which various risk stratification systems have been developed and validated,[41,49,112] and further inconsistencies are evident in subsequent studies that seek to describe the generalizability of these systems in different clinical settings.

Traditionally, postoperative morbidity has been classified as either local (relating to the operative site) and general (relating to other organ systems) or specific (relating to the particular operation) and general (relating to any type of operation).[113,114] Morbidity may also be classified as early, intermediate, or late, defined by arbitrary time points. However, the classification of adverse events by any of these methods has a number of difficulties. For example, there may be significant interaction between the occurrence of a local complication (e.g., wound infection) and a general outcome (e.g., pyrexia). There may also be difficulties in attribution. Although postoperative ileus may be considered a specific consequence of gastrointestinal surgery, clinical experience shows that the etiology may be multifactorial, and therefore ileus may be considered a general complication.

A different approach would be to consider postoperative morbidity as a "syndrome," in a similar manner to how multiple organ dysfunction syndrome (MODS) or sepsis is described and now defined by specific scoring systems.[115,116]

Table 2. The Postoperative Morbidity Survey

Morbidity type	Criteria
Pulmonary	Has the patient developed a new requirement for oxygen or respiratory support?
Infectious	Currently on antibiotics and/or has developed a temperature of ≥38°C in past 24 h
Renal	Presence of oliguria (<500 mL urine/24 h) Increased serum creatinine (>30% from preoperative level) Urinary catheter in situ
Gastrointestinal	Unable to tolerate enteral diet for any reason, including nausea, vomiting, and abdominal distension Use of antiemetic
Cardiovascular	Diagnostic tests and/or treatment for any of the following in the past 24 h New myocardial infarction or ischemia Hypotension (requiring fluid therapy >200 mL/h or pharmacological therapy) Atrial or ventricular arrhythmias Cardiogenic pulmonary edema Thrombotic event requiring anticoagulation
Neurological	New focal neurological deficit, confusion, delirium, or coma
Hematological	Requirement for any of the following within the past 24 h Packed erythrocytes Fresh frozen plasma Cryoprecipitate
Wound	Wound dehiscence requiring surgical exploration or drainage of pus from the operation wound with or without isolation of organisms
Pain	New postoperative pain significant enough to require parenteral opioids or regional analgesia

A syndrome is defined as a pathological condition associated with a cluster of co-occurring symptoms, usually 3 or more.[117] Also central to the definition of a syndrome is the existence of an underlying common pathological process. The development of a SIRS is a recognized sequel of surgical intervention and anesthesia, which may ultimately lead to MODS; inflammatory markers that reflect the severity of this response may be measured and found to correlate with postoperative outcome.[118–124] One may argue that postoperative morbidity represents 1 (mild) manifestation of a disease spectrum, the most severe manifestation of which may be defined as MODS. It may therefore also be argued that a composite measure of postoperative morbidity may be a useful tool in the description of perioperative outcome for the purposes of audit and studies of clinical effectiveness and prognosis.

The Postoperative Morbidity Score was developed as a composite measure of clinically significant short-term postoperative harm,[125] and has been validated for this purpose in orthopedic, general, and urological surgical patients.[126] It classifies postoperative morbidity into 9 domains; these were derived on the basis of being complications of a type and severity that would delay hospital discharge,[127] and could be defined by data that would be easy to collect and subject to minimal interobserver variability.[126] In the future, this type of approach may be more widely adopted as a validated composite measure of the "syndrome" of postoperative morbidity (Table 2).

Patient-Reported Outcome Measures

PROMs are questionnaires that are completed by patients and measure health status or health-related quality of life. PROMs are measured before and after a clinical intervention so as to measure the change in this health status or health-related quality of life as a result of intervention; they may be disease specific or generic, and a large number of these tools have been developed and validated in different surgical cohorts. Pi-by-no questionnaires such as the Short Form-36 and EQ-5D are designed to reflect quality of life and may be particularly useful when assessing outcome in types of surgery that are aimed at improving symptoms, such as orthopedics.[127] Disease-specific PROMs such as the Oxford Hip and Knee Scores aim to assess patient health status, and demonstrate improved responsiveness in the detection of treatment effects compared with generic measures.[128] Rasch analysis is a "goodness of fit" estimation that may be used to evaluate instruments such as PROMs.[129]

There are a number of biases that limit the usefulness of PROMs for comparative audit or in clinical effectiveness studies. For example, experiences that patients may report as complications may be viewed as normal or expected by physicians (e.g., wound pain), and process issues such as the mode of administration of the questionnaire (e.g., telephone versus mailing) may affect the responses that patients give.[130] It is issues such as these that may explain why feedback from PROMs to clinicians and managers has been shown to significantly influence process in health care, but has limited impact on patient health status. Equally, however, it may be that PROMs are being used inappropriately as a result of a lack of knowledge and experience of the health care providers who are implementing them.[131] In the United Kingdom, the mandatory use of PROMs as a measure of outcome throughout the National Health Service will shortly be implemented. However, unless PROMs are developed to reflect factors that are relevant and important to patients, and are validated as tools that will capture the effects of interventions aimed at improving quality of care, their usefulness will remain limited.

Resource Utilization Measures

Length of inpatient stay and critical care stay are measures that are sometimes used as surrogates of postoperative recovery and therefore clinical outcome; however, the validity of using such measures for this purpose is limited for a number of reasons. First, there are inherent assumptions made when using length of stay as a surrogate of clinical outcome, namely, that every patient is discharged from hospital or critical care at the same level of fitness and that their discharge is not affected by factors unrelated to physiological status (such as provision of social services or availability of ward beds). Such assumptions may lead to both intra- and interinstitutional bias, because nonclinical issues affecting length of stay will vary among and within institutions depending on factors such as the provision of convalescent facilities and the patient's own social support network. Rates of readmission to hospital or critical care are also used as surrogates of clinical outcome and are similarly subject to confounding because the clinical threshold for admission and discharge will also vary among services.

Even as a measure of resource utilization alone, length of stay is of limited validity because there are different costs associated with different levels of intensity of treatment (such as critical care versus ward care). Furthermore, using hospital length of stay as a resource utilization measure assumes that the cost of treatment is consistent throughout the patient episode. This approach is unlikely to accurately reflect the true cost; for example, the cost of patient care on the first day postoperatively is likely to be much higher than the cost on the day before discharge. Finally, the actual cost of a hospital episode will differ among health care systems based on the method by which hospitals charge for their services. Despite these limitations, length of stay (both hospital and critical care) continues to be a widely used outcome measure in clinical effectiveness studies, predominantly because of the ease of measurement and the lack of interobserver variability in recording.

Suggestions for Future Work and Conclusions

All the currently used risk stratification tools and outcome measures have limitations of validity and reliability, which may in part account for inconsistencies in the results of studies aimed at identifying strategies directed at improving surgical outcomes. These limitations also present an ethical and logistical dilemma to the perioperative team, who must consider the optimal management strategy for an individual patient and even whether a proposed operation is in the patient's best interests.

Clinical experience in the United Kingdom leads us to believe that there is poor compliance with simple, evidence-based interventions that are directed at improving surgical outcomes. This may be partly attributable to the lack of evidence for a mortality benefit of such interventions, even though the literature consistently demonstrates an improvement in surgical morbidity and resource utilization measures such as hospital length of stay. In addition, the association between morbidity and reduced long-term survival may provide further incentive for the uptake of interventions that improve short-term morbidity. However, although there is no clearly validated and widely accepted definition of the high-risk surgical patient, it is possible that the true value of such interventions may not be fully elucidated. Furthermore, the generalizability of results from interventional studies leading to improvements in morbidity may be limited by organizational failings associated with worse patient-relevant outcomes, such as PROMs and short-term mortality.

To progress this clinical and academic field, we must first work toward improved precision in predicting perioperative risk. Risk prediction modeling, assessments of functional capacity, and biomarker assays all show promise as risk stratification tools in particular studies and clinical situations. Further work may include the validation of novel biomarkers in more heterogeneous patient populations and the further evaluation of functional capacity as a predictor of patient outcome by using different combinations of data measured during exercise testing. The use of a more objective dataset in risk adjustment models may result in improved predictive accuracy; the incorporation of serological biomarker assays and data relating to the patient's functional capacity may also improve discrimination. It is likely that by using these techniques in combination, initially in clinical trials, and then in epidemiological studies, more accurate risk prediction models can be developed than are currently available. Annual revision of such models would ensure that they continue to accurately predict patient risk, despite changes in population health status, structure and process in health care systems, and management of specific disease processes.

However, even if the high-risk patient could be accurately identified, elucidating and implementing the optimal clinical management strategy for such patients remains the greater challenge. It is clear that structure, process, and resource utilization issues are associated with perioperative outcomes, and as such, service reconfiguration and the expansion of critical care facilities may be at least as important as specific clinical interventions for improving the quality of surgical care. It is likely that feedback from PROMs, which has been shown to lead to changes in organizational strategy, will become an increasingly important measure of health care quality, but health care providers must be better educated in the development and implementation of these outcome measures before their true value can be evaluated and maximized. The measurement of perioperative outcomes in most of the world is currently limited to the recording of postsurgical mortality; the recognition of perioperative morbidity as a significant public health issue should drive the agenda for a more widely implemented surgical outcomes recording system. Such a system may improve the quality of surgical care and assist clinical research and the multicenter collaborative evaluation of treatment strategies targeted toward improving outcome in the high-risk surgical patient.

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