The Internet Journal of Surgery
Volume 20 Number 2

# Physiologic Modification of the American Society of Anaesthesiology Score (ASA) for Prediction of Morbidity and Mortality after Emergency Laparotomy

S Abbas, A Kahokher, M Mahmoud, A Hill

**Citation**

S Abbas, A Kahokher, M Mahmoud, A Hill. *Physiologic Modification of the American Society of Anaesthesiology Score (ASA) for Prediction of Morbidity and Mortality after Emergency Laparotomy*. The Internet Journal of Surgery. 2008 Volume 20 Number 2.

**Abstract**

Background and aims:Laparotomy is commonly performed as an emergency operation. It is often performed on elderly patients with high risks of mortality and morbidity. Currently there is no accurate scoring system to predict preoperatively mortality and morbidity in these circumstances. This study was conducted to develop a scoring system that can accurately predict the risk of in-hospital mortality and complications for these patients in the emergency department prior to surgery. Patients and methods:Middlemore Hospital data were searched for patients who underwent emergency laparotomy for an acute abdominal condition between January 1997 and December 2006. Data collected included age, gender, presenting diagnosis, indications for surgery, acute physiological parameters and also data on associated comorbidities. We categorized patients for the risk of morbidity and 30-day mortality. The risk categorization was based on preoperative existing comorbidities and acute disturbances of physiological parameters. Regression analysis was used to correlate acute laboratory parameters, patients' age and gender, clinical pre-morbid conditions and surgical procedures with the risk of mortality and rates of complications. Results:Emergency laparotomy was performed on 1712 patients. The median age was 58 and there were 896 male patients. Patients with one or two minor comorbidities had comparable mortality and complication rates to those with no comorbidities. There was high correlation between factors that denoted the onset of multiple organ failure and in-hospital mortality and complication rate; this allowed us to divide patients into four groups with increasing mortality and morbidity. Conclusions:Mortality and morbidity after emergency laparotomy is closely related to the presence or absence of severe acute physiological impairment and the presence or absence of chronic system organ failure. The SPI score is a simple scoring system for prediction of mortality and morbidity prior to emergency laparotomy.

## INTRODUCTION

Emergency laparotomy is a commonly performed operation. It is frequently performed on elderly patients with a variety of acute pathological disorders that render these patients dehydrated, hypovolemic, and suffering from a systemic inflammatory response often with incipient multiple organ failure [1,2] . Compared with elective surgery, emergency abdominal surgery is associated with a higher risk of morbidity and mortality, especially in patients over the age of 65 [3,4,5] , where 50% of these patients have significant associated comorbidities [6] . Mortality in such patients has been reported to be between 22% and 44% [3,5] , and morbidity around 50% [7] .

Mortality and complications in elderly patients undergoing emergency laparotomy for acute abdomen depend on perioperative risk factors and delay in presentation and treatment. Patients with conditions that only permit palliative surgery such as cancer and those who have acute mesenteric ischaemia, have particularly high mortality rates [5] . The acute physiological insult of abdominal pathology, added to chronic ill health, complicates the postoperative course [3,5] .

Many scoring systems have been designed to predict mortality and morbidity in surgical patients; however, these systems are complex and require the collection of several clinical and pathological parameters that may not be available before the patent is taken for emergency surgery [8,9,10] . As a result, none of these classification systems has found a place as a routine part of clinical practice in surgery.

It would therefore be very useful to have a classification system based on clinical and laboratory measures that is able to provide an objective assessment of morbidity and mortality before undertaking surgical management [11,12] . In the elective surgery setting, the ASA score is a commonly used system for prediction of morbidity and mortality; however, it is not specific to any particular procedure or specialty and does not allow for calculation of mortality and morbidity in emergency laparotomy [13,14] . It also is associated with a wide range of subjective judgments in its categorization [15] .

The body's response to intra-abdominal pathology is known as systemic inflammatory response and this may lead to multiple organ failure. These conditions are common in emergency surgery and carry high mortality rates. The typical metabolic responses are characterized by increased oxygen consumption and demand, hyperglycaemia and accelerated protein catabolism, and subclinical perfusion deficits [16] . Many patients present with incipient multiple organ failure manifested by dysfunction of one or more organs. Thus any prognostic system must take into account both the premorbid condition and also the metabolic derangement induced by the acute abdominal pathology.

This study includes a wide variety of patients admitted for conditions requiring emergency laparotomy. The aim of this study was to develop a predictive scoring system for mortality and morbidity in patients undergoing emergency laparotomy taking into account preoperative comorbidity and the physiological response to the abdominal pathology.

## PATIENTS AND METHODS

### PATIENTS

We categorized patients for risk of morbidity and 30-day mortality following emergency laparotomy. The risk categorization was based on preoperative existing comorbidities and acute disturbances of physiological parameters. The risk categorization of morbidity and mortality was derived from multivariate analysis of premorbid conditions and acute physiologic parameters. These parameters were correlated with operative findings, and postoperative morbidity and mortality. We included patients who presented with acute abdominal pathology requiring midline laparotomy during their acute hospital admission. Only the first operation was analyzed for those patients who underwent repeat laparotomy as a planned or unplanned return to theatre. We excluded patients who underwent simple appendicectomy through a right iliac fossa incision. Patients who had a ruptured abdominal aneurysm or laparotomy for abdominal trauma were not included in the study due the unique nature of these particular emergencies.

### DATA COLLECTION

The Middlemore Hospital electronic record was searched for patients who underwent emergency laparotomy for an acute abdominal condition between January 1997 and December 2006.

Preoperative data collected included age, gender, blood pressure, heart rate, temperature and urine output. We also collected preoperative laboratory data including white cell count, hemoglobin, renal function including creatinine, urea and electrolytes, liver enzymes, bilirubin, coagulation profile, serum albumin, acid-base status, oxygen saturation and blood oxygen partial pressure. We also collected data on associated comorbidities including chronic renal impairment, cardiovascular disease (hypertension, angina, cardiac failure, stroke, and coronary revascularization), asthma, chronic obstructive airway disease, liver disease, metastatic cancer, and diabetes mellitus.

Other data were collected to evaluate in-hospital outcome including surgical procedure, findings at laparotomy, final diagnosis, intensive care admission, in-hospital mortality and complications.

Following initial multivariate analysis with inclusion, substitution and exclusion of factors, the acute physiological changes were subdivided into three categories; 0 = no acute physiological derangement, 1 = mild physiological derangement (such as raised white cell count, pyrexia, electrolyte disorders, tachycardia in the hemodynamically stable patient, etc.) with no evidence of organ dysfunction; 2 = severe derangement with clinical or biochemical evidence of organ dysfunction (such as acutely raised creatinine, anuria, septic shock, respiratory distress and hemodynamically unstable patient). Parameters of organ failure are defined in table 1.

**Figure 1**

Table 1. Definitions of C2 Comorbidities

| | |
|---|---|
| Respiratory | Hypercapnic respiratory failure (type II) is characterized by a $PaCO_2$ of more than 50mm Hg<br>Hypoxemic respiratory failure (type I) is characterized by a $PaO_2$ of less than 60mm Hg with a normal or low $PaCO_2$ |
| Renal | Severe reduction in GFR (15-29 mL/min/1.73 $m^2$ ) or dialysis |
| Neurological | CNS: Stroke, other forms of cerebrovascular disease |
| Liver | Child's class C chronic liver disease |
| Cardiac | Severe coronary artery disease requiring coronary revascularization<br>New York Heart Association Class II (occurs with ordinary physical activity |
| Hematological | Hematological malignancy currently on chemotherapy for relapse |

Associated medical comorbidities were recorded on a datasheet according to their systemic nature and severity. These were graded according to severity (0= no pathology, 1= mild disease, 2= moderate to severe disease). For example patients who had mild asthma were given a score of 1 for respiratory disease and those who had chronic obstructive airway disease given a score of 2 (Table 1). Other comorbidities were categorized in a similar manner and included hypertension, ischemic heart disease, left ventricular failure, cerebrovascular accident, chronic renal impairment, liver disease, hematological and connective tissue disorders. A grade two was given to patients with moderate to severe impairment of any system resulting in a clinically evident chronic physiologic impairment such as chronic obstructive pulmonary disease, end-stage renal failure, severe coronary artery disease requiring coronary artery bypass or resulting in moderate to severe left ventricular impairment. Patients with three or more comorbidities were also given a grade two.

Primary outcomes were major complications and mortality within 30 days. Major complications were defined as postoperative continued systemic sepsis, pneumonia, requirement for vascular or respiratory support in the intensive care unit, wound dehiscence, anastomotic leak, acute renal failure, myocardial infarction, arrhythmias, bleeding, venous thromboembolization, stroke, unplanned return to theatre and gastrointestinal bleeding due to stress ulcers.

Mortality and complication rates were calculated for different surgical diagnoses, procedures and associated comorbidities. All acute laboratory parameters, clinical pre-morbid conditions and surgical procedures were correlated with the risk of mortality and the rates of complications. When it was thought appropriate, different parameters were included and excluded from the analysis to evaluate the effect of any single parameter.

Patients were finally divided into groups according to their acute physiologic status and chronic systemic condition to grade the likelihood of death or complications.

## STATISTICS

Statistical analyses were performed using SPSS® (Chicago Illinois) version 10.5. After preliminary univariate analysis of various parameters and their effects on outcome, regression analysis was performed to correlate between acute laboratory parameters, patients' age and gender, clinical pre-morbid conditions and surgical procedures with the risk of mortality and the rates of complications. We compared alternative combinations of variables to sub-categorize patients in order to produce a grading system that was reproducible and easy to use. Patients were divided into sub-groups according to their premorbid condition, acute physiology and operative intervention and calculation of morbidity and mortality difference between different groups was performed using the chi-squared test.

## RESULTS

Emergency laparotomy was performed on 1712 patients between January 1997 and December 2006. The median age was 58 and there were 896 male patients (52%).

Demographics of the patients are shown in table 1; patients were divided into diagnosis-related groups. We expect that some patients who were admitted with an acute abdomen did not make it to theatre because their condition was considered unsurvivable. Multivariate analysis of the influence of pre-existing comorbidities showed that patients with no comorbidities had less risk of death and complications compared with those who had associated comorbidities ($p<0.0001$).

Analysis performed on subgroups of patients with relation to the severity of their associated organ system dysfunction showed fewer deaths and complications in patients who were without comorbidity or those with mild controlled comorbidities compared with patients who had severe impairment of any system resulting in a clinically evident chronic physiologic impairment. There was no statistical difference in mortality between those with no comorbidities and those with controlled mild conditions ($p=0.09$), unless there was acute organ failure ($p<0.0001$).

Logistic regression was performed on parameters of acute physiological derangement. This showed a very high correlation between factors that denoted the onset of multiple organ failure with in-hospital mortality and complication rate. Including and excluding any of these factors from analysis (i.e. septic shock, anuria, elevated creatinine with documented normal recent previous levels, deranged coagulation caused by sepsis and hypoxia due to respiratory distress) showed the same risk of mortality ($p<0.0001$) (Table 2,3,4,5).

### Figure 2

Table 2. Morbidity and mortality by diagnosis

| Diagnosis | Number of patients | Mortality (%) | Complications (%) |
|---|---|---|---|
| Perforated peptic ulcer | 138 | 20 (14) | 47 (34) |
| Sepsis of unknown origin | 79 | 23 (29) | 43 (54) |
| Small bowel obstruction | 497 | 27 (5) | 130 (26) |
| Peritonitis from perforated viscus | 98 | 13 (13) | 35 (36) |
| Tubo-ovarian pathology | 62 | 1 (1.6) | 7 (11) |
| Pancreatic necrosectomy | 15 | 4 (27) | 14 (93) |
| Malignant large bowel obstruction | 112 | 19 (17) | 54 (48) |
| Mesenteric ischemia | 53 | 28 (40) | 37 (70) |
| Biliary disease | 48 | 8 (16) | 23 (48) |
| Diverticulitis | 95 | 15 (16) | 38 (40) |
| Peritoneal carcinomatosis | 86 | 14 (16) | 22 (25) |
| Bleeding peptic ulcer | 72 | 19 (26) | 37 (51) |
| Perforated appendicitis | 224 | 3 (1) | 53 (24) |
| Miscellaneous | 132 | 26 (20) | 36 (27) |

### Figure 3

Table 3. Complications

| Complication | Numbers | % |
|---|---|---|
| Bleeding | 13 | 0.7% |
| Cardiac complications<br>Infarction<br>Arrhythmia<br>Heart failure | <br>64<br>72<br>28 | 9.5% |
| Abdominal collection | 9 | 0.5% |
| Stroke | 5 | 0.3% |
| Wound dehiscence | 33 | 2% |
| Deep vein thrombosis | 5 | 0.3% |
| Pulmonary embolism | 7 | 0.4% |
| GI bleeding | 11 | 0.6% |
| GI fistula | 4 | 0.2% |
| Prolonged ileus (TPN) | 29 | 1.7% |
| Anastomotic leak | 12 | 0.7% |
| Multiple organ failure | 63 | 4.6% |
| Small bowel obstruction | 5 | 0.3% |
| Respiratory complications | 204 | 12% |
| Pseudomembranous colitis | 3 | 0.2% |
| Recurrence of small bowel obstruction<br>within 6 weeks after surgery<br>early obstruction after laparotomy | 11<br><br>5 | 1% |
| Acute renal failure | 139 | 8% |
| Systemic sepsis | 104 | 6 |

### Figure 4

Table 4. Complications by acute physiologic derangement and comorbidities

| Acute physiology | Comorbidities | SPI | Complications | P |
|---|---|---|---|---|
| Grade P1 | Grade C1=1083<br>Grade C2=350 | I | 187 (17%) | <0.0001 |
| | | II | 172 (50%) | |
| Grade P2 | Grade C1=174 | III and IV | 129 (74%) | 0.1 |
| | Grade C2=103 | | 85 (83%) | |

### Figure 5

Table 5a. Multivariate analysis (Logistic regression) for predictors of mortality

| Predicting factors | P | Odds Ratio (95% CI) |
|---|---|---|
| Acute physiological changes Consistent with at least acute one organ failure | P < 0.0001 | 29.7 (20.1 - 43.8) |
| Chronic renal failure | P = 0.3 | 1.3 (0.7 - 2.3) |
| Hypertension | P = 0.1 | 1.4 (0.9 - 2.2) |
| High cholesterol | P = 0.1 | 1.2 (0.7 - 2.4) |
| History of angina | P = 0.1 | 1.6 (0.7 - 2.6) |
| Cardiac failure | P = 0.002 | 2.2 (1.3 - 3.7) |
| Coronary disease requiring revascularization | P = 0.02 | 1.8 (1.3 - 3.7) |
| COPD | P = 0.3 | 1.2 (0.7 - 2.1) |
| Asthma | P = 0.08 | 0.6 (0.2 - 0.9) |
| Stroke | P = 0.02 | 0.4 (0.2 - 0.8) |
| Diabetes mellitus | P = 0.3 | 0.7 (0.4 - 1.2) |
| Cancer (advanced) | P < 0.0001 | 2.3 (1.6 - 3.9) |
| Any chronic system failure | P = 0.04 | 1.8 (1 - 3.3) |
| Surgery for mesenteric ischaemia or pancreatic necrosis | P = 0.002 | 4.7 (3.1 - 10.8) |
| Chronic liver disease | P = 0.0002 | 12.3 (6.9 - 15.5) |
| Age =>65 years | P = 0.0001 | 2.8 (1.8 - 4.2) |
| Gender | P = 0.09 | 1.2 (0.9 - 1.6) |

Patients with normal physiology had the lowest rate of death and complications. Patients who had mild physiologic derangement had significantly less risk of death than patients with any parameter that indicated acute organ failure. These factors included raised white cell count, raised temperature, tachycardia, electrolyte derangement and dehydration (Table 4).

Postoperative complications were seen in 573 patients (33%). Risk factors for postoperative complications in addition to acute multiple organ failure included chronic renal impairment, ischemic heart disease, chronic obstructive pulmonary disease, history of stroke and advanced malignancy. Age, controlled diabetes (no end-organ damage), gender and type of surgical procedure did not result in an increased complication rate (Tables 5 a, b and 6).

### Figure 6

Table 5b. Logistic regression analysis of the predictors of complications

| Parameters | P | Odds ratio and 95% CI |
|---|---|---|
| Acute organ failure | P < 0.0001 | 10.2 (7.4-14.2) |
| Chronic renal impairment | P < 0.0001 | 2.7 (1.7 -4) |
| Vascular disease | P < 0.0001 | 1.7 (1.3-2.3) |
| Cardiac failure | P < 0.0001 | 2 (1.4-2.7) |
| COPD | P = 0.0012 | 1.8 (1.2-2.7) |
| Stroke | P = 0.0372 | 1.4 (1-2.1) |
| Diabetes mellitus | P = 0.8557 | 1.0 (0.7-1.4) |
| Cancer | P = 0.0118 | 1.4 (1 -2) |

### Figure 7

Table 6. Mortality according to acute physiological derangement and associated comorbidities

| Acute physiology | Comorbidities | SPI | Mortality | P |
|---|---|---|---|---|
| Grade P1 | Grade C1=1083 | I | 22 (2%) | <0.0001 |
| | Grade C2= 350 | II | 43(12%) | |
| Grade P2 | Grade C1= 174 | III | 85(49%) | 0.0019 |
| | Grade C2= 103 | IV | 70(69%) | |

P= Acute physiology
C= Comorbidities
P1= Normal to mildly deranged physiology
P2= Severe physiological derangement (at least one organ failure)
C1= Normal health or mild comorbidity (such as controlled hypertension or mild asthma)
C2= Severe chronic organ impairment (see table 2)

Patients were divided in categories according to their acute physiological condition and chronic illnesses and rates of mortality and morbidity were calculated. Finally, patients were divided into four groups (SPI 1-4) for mortality and three groups (SP1-3) for complications according to the statistical difference between the groups.

## DISCUSSION

The study describes a scoring system for morbidity and mortality in emergency laparotomy based on associated comorbidities and acute physiological derangement. Mortality and morbidity increased proportional to the SPI score. This system is easy to calculate and will potentially be of clinical use in patients requiring emergency laparotomy.

The current study classifies morbidity and mortality risk according to the level of acute physiological derangement in response to the abdominal pathology and the degree of chronic systemic diseases. Despite the positive correlation between the presence or absence of advanced cancer and serious abdominal pathology with mortality, these factors are also reflected by acute physiological responses and chronic ill health. We therefore used these two factors as indicators of the severity of systemic level of function. The classification system that resulted from this analysis is practical, easy to calculate and can be utilized. It requires knowledge of past history of systemic illnesses and any evidence of acute organ dysfunction from routinely performed clinical and laboratory tests.

The importance of the acute physiological response to the abdominal pathology is due to the wide spectrum of pathological changes that take place with the systemic inflammatory response syndrome (SIRS) in individual patients. Some patients may show evidence of organ dysfunction limited to one or two organs and SIRS resolves with no consequences. Yet another group of patients develops an overwhelming inflammatory reaction rapidly after the initial insult and die of multiple organ failure within a few days [17]. For the purpose of simplicity, we used any single positive indicator of multiple organ dysfunction without sub-classifying the extent or severity of the dysfunction. Mortality with multiple organ dysfunction is proportional to the number of involved systems and varies from 30% with single organ failure to 100% in five organ failure [18].

It has proven difficult to design an ideal morbidity and mortality scoring system that is accurate, easy to calculate and reproducible and can be used preoperatively in the emergency department to predict mortality. Patient's age alone as a single risk factor to determine the risk of morbidity and mortality is not a valid predictor. Older patients have a high risk for complications and death after emergency surgery, with a mortality rate in 75 year-olds over double that of 65–74 year-olds, because they have more co-morbidities than younger patients [519]. The ASA score has consistently been shown in uni-variate and multi-variate analyses to be a good predictor of mortality in emergency surgical patients. However, the ASA classification is associated with significant inter-observer variation in a given patient [51320], which limits its utility.

Other investigators have devised scoring systems to predict morbidity and mortality in emergency surgery [210]. These systems require many parameters and special equations. None of these is currently used as part of daily surgical care. The Physiological and Operative Severity Score for enumeration of mortality and morbidity (POSSUM) was described in 1991 by Copland et al. [8] The original POSSUM score was found to overestimate risks of morbidity and mortality in emergency laparotomy [21]. It requires the calculation of 12 physiological and six operative parameters, hence it is not possible to calculate it prior to surgery. It has been modified by the p-POSSOM for emergency abdominal surgery [1021]. The APACHE II score is used in the intensive care setting and requires 12 physiological parameters over a 24-hour period for calculation; hence it is not possible to utilise before emergency surgery either [22].

The Reiss Index and the Fitness Score are other scoring systems derived by multivariate analysis of a large cohort of patients [23], and require several pre-operative data points and diagnostic information that may not be available until surgery is undertaken. The Fitness Score is easy to apply in practice and has been derived from multivariate analysis of arbitrary selection of presumed risk factors that the authors have weighted without statistical analysis [24]. Reiss et al. have developed a scoring system specific for predicting mortality in the elderly patient undergoing abdominal surgery (elective and emergency). They analysed 36 variables in a study that included 1200 patients undergoing laparotomy. They identified five significant factors by multivariate regression analysis. These were: age, urgency of surgery, ASA, surgery for malignancy and the final diagnosis. The score was validated prospectively on another study that included 200 patients [23]. The drawback of this system is that in many case the diagnosis is not known before the actual operation and hence these cases can not be scored before surgery. An emergency laparotomy where the diagnosis was unknown could not be scored with this system.

Kennedy et al. analysed 498 elderly patients over the age of 65 who were admitted for emergency surgical procedures. They described a simple scoring system, the Sickness Assessment (SA), which requires three variables: hypotension, severe chronic disease affecting any organ and whether or not the patient was functionally independent. Laparotomy in the presence of a positive SA (any positive point) was associated with a 57% mortality compared to 15% in those with a zero SA. Mortality rates in patients with one, two and three points were 52%, 60% and 100%, respectively. Hypotension (systolic BP < 100mmHg) in the emergency department was the single most powerful predictor of mortality (77% of patients undergoing laparotomy who were hypotensive on admission [25]). This is therefore a scoring system that is not applicable to all surgical patients.

In patients undergoing surgery for sepsis, in addition to the APACHE score, several other systems have been developed. These scores include the Mannheim Peritonitis Index (MPI) [26], the Multiple Organ Failure Score [27], the Simplified Acute Physiology Score (SAPS) [28] and the Sepsis Score [29]. In comparative studies, the APACHE II and MPI scores appear to offer the best prediction of outcome in patients with abdominal sepsis. The MPI score, though the best of these scores at predicting outcome, has a low specificity [30] and is also associated with a high false positive rate [31]. Combining the MPI and APACHE II scores improves specificity but these systems are mainly used in auditing outcome of surgical patients admitted to intensive care units after surgery [30].

Our series has a typical variety of emergency abdominal surgery. This variety is likely to make the results of this classification system applicable to acute general surgical services. Patients are divided preoperatively into four categories of risk depending on the presence or absence of acute physiological derangement or chronic comorbidity. This system allows for classification of patients into four groups with significantly different mortality and morbidity rates prior to surgery. Thus the SPI is simple to calculate and useful in prediction of mortality and morbidity and should be considered for wide application in emergency general surgery.

## References

1. Zimmerman JE; Wagner DP; Draper EA; Wright L; Alzola C; Knaus WA. Evaluation of Acute Physiology and Chronic Health Evaluation III predictions of hospital mortality in an independent database. Critical Care Medicine 1998; 26: 1317-1326.
2. Tekkis PP, Kocher HM, Bentley AJE, Cullen PT, South LM, Trotte GA, Ellul JPM. Operative mortality rates among surgeons. Comparison of POSSUM and p-POSSUM scoring systems in gastrointestinal surgery. Dis Col Rectum 2000; 43: 1528-1532.
3. Cook TM, Day CJ. Hospital mortality after urgent and emergency laparotomy in patients aged 65 yrs and over. Risk and prediction of risk using multiple logistic regression analysis. Br J Anaesth 1998; 80: 776-81.
4. Linn BS, Linn MW, Wallen N. Evaluation of results of surgical procedures in the elderly. Ann Surg 1982; 195: 90-6.
5. Arenal JJ; Bengoechea-Beeby M. Mortality associated with emergency abdominal surgery in the elderly. Can J Surg 2003; 46: 11-116.
6. Waldron RP, Donovan IA, Drumm J, Mottram SN, Tedman S. Emergency presentation and mortality from colorectal cancer in the elderly. Br J Surg 1986; 73: 214-6.
7. Kettunen J, Paajanen H, Kostiainen S. Emergency abdominal surgery in the elderly. Hepatogastroenterology 1995; 42: 106-8.
8. Copland GP, Jones D, Walters M. POSSUM: a scoring system for surgical audit. Br J Surg 1991; 78: 356-360.
9. Knaus WA, Zimmerman JE, Wagner DP et al. APACHE - acute physiology and chronic health evaluation: a physiologically based classificaton system. Crit Care Med 1981; 9: 591-597.
10. Mohil RS, Bhatnagar D, Bahadur L, Rajneesh, Dev DK, Magan M. POSSUM and P-POSSUM for risk-adjusted audit of patients undergoing emergency laparotomy. Br J Surg 2004; 91:500-3.
11. Jones HJS, de Cossart L. Risk scoring in surgical patients. Br J Surg 1998; 86: 149-157.
12. Fazio VW, Tekkis PP, Remzi F, Lavery IC. Assessment of operative risk in colorectal cancer surgery: the Cleveland Clinic Foundation colorectal cancer model. Dis Colon Rectum 2004; 47: 2015-24.
13. Wolters U, Wolf T, Stutzer H, Schroder T. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaesth. 1996; 77: 217-22.
14. Tiret L, Hatton F. Prediction of outcome of anaesthesia in patients over 40 years: a multifactorial risk index. Statistics in Medicine 1988; 41: 83-90.
15. Owens WB, Felts JA, Sitznagel EL. ASA physical status classification: A study of consistency of ratings. Anaesthesiology 1978; 49: 239-243.
16. Beal AL and Cerra FB. Multiple organ failure syndrome in the 1990s. Systemic inflammatory response and organ dysfunction. JAMA 1994; 271: 226-233.
17. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M, for the Early Goal-Directed Therapy Collaborative Group. Early goal-directed therapy in the treatment of severe sepsis and septic shock. New Eng J Med 2001; 345: 1368-1377.
18. Awad SS. State-of-the-art therapy for severe sepsis and multisystem organ dysfunction. The American Journal of Surgery 2003; 186/5A: 23S–30S
19. Barlow AP, Zarifa Z, Shillito RG, Crumplin MKH, Edwards E, McCarthy JM: Surgery in a geriatric population. Ann R Coll Surg Engl 1989; 71: 110-4.
20. Makela JT, Kiviniemi H, Laitinen S: Prognostic factors of perforated sigmoid diverticulitis in the elderly. Dig Surg 2005; 22: 100-106.
21. Prytherch DR, Whiteley MS, Higgins B, Weaver PC, Prout WG, Powell SJ. POSSUM and Portsmouth POSSUM for predicting mortality. Physiological and Operative Severity Score for the enumeration of Mortality and morbidity. Br J Surg 1998; 85: 1217-20.
22. Knaus WA, Draper EA, Wagner DP. APACHE II: a severity of disease classification system. Crit Care Med 1985; 13: 818-829.
23. Reiss R, Deutsch A, Nudelman I. Surgical problems in octogenarians: epidemiological analysis of 1083 consecutive admissions. World J Surg 1992; 16: 1017-21.
24. Playforth MJ, Smith GMR, Evans M, Pollock AV. Pre-operative assessment of fitness score. Br J Surg 1987; 74: 890-2.
25. Kennedy RH, al-Mufti RA, Brewster SF, Sherry EN, Magee TR, Irvin TT. The acute surgical admission: is mortality predictable in the elderly. Ann R Coll Surg Engl

1994; 76: 342-5.
26. Wacha H, Linder MM, Feldman U, Wesch G, Gundlach E, Steifensand RA. Mannheim Peritonitis Index – prediction of risk of death from peritonitis: construction of a stastical and validation of an empirically based index. Theoretical Surgery 1987; 1:.169-77.
27. Goris RJA, te Boekhorst TPA, Nuytinck JKS, Gimbrere JSF. Multi-organ failure. Generalized autodestructive inflammation? Arch Surg 1985; 120: 1109-15.
28. LeGall J, Loirat P, Alperovitch A, Glaser P, Granthil C, Mathieu D. A simplified acute physiology score for ICU patients. Crit Care Med 1984; 12: 975-977.
29. Elebute EA, Stoner HB. The grading of sepsis. Br J Surg 1983; 70: 29-31.
30. Bosscha K, Reijinders K, Hulstaert PF, Algra A, van der Werken C: Prognostic scoring systems to predict outcome in peritonitis and intra-abdominal sepsis. Br J Surg 1997; 84: 1532-34.
31. Qureshi AM, Zafar A, Saeed K, Quddus A. Predictive power of Mannheim Peritonitis Index. J Coll Physicians Surg Pak 2005; 15: 693-696.

## Author Information

**Saleh M. Abbas**
Middlemore Hospital, Auckland, New Zealand

**Arman Kahokher**
Middlemore Hospital, Auckland, New Zealand

**Maryam Mahmoud**
Middlemore Hospital, Auckland, New Zealand

**Andrew G. Hill**
Middlemore Hospital, Auckland, New Zealand