The Use of Tonometry to Predict Mortality in Patients Undergoing Abdominal Aortic Aneurysm Repair

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Objective: To assess the reliability of intramucosal pH (pHi) of the sigmoid colon, IL-6 concentration and the APACHE II score in predicting outcome in patients undergoing elective abdominal aortic aneurysm repair.

Design: Prospective study.

Methods: In 42 patients, measurements were made of the sigmoid pHi with the silicone tonometer and plasma IL-6 by enzyme linked immuno-sorbent assay (ELISA). The daily postoperative APACHE II scores were also calculated. In 29 patients a preoperative left ventricular ejection fraction was determined by gated radionuclide angiography.

Results: Four out of 42 patients who were studied died. The lowest perioperative pHi, the peak postoperative IL-6 concentration and APACHE II scores were significantly different in the survivors in comparison to the non-survivors. In the non-survivors, the fall in pHi preceded the time of patient's demise by at least 4 days. Significant correlations were observed between changes in pHi, IL-6 and APACHE II. Using receiver operating characteristic curves, pHi was shown to be the most predictive of mortality compared to the other variables. The simplicity, speed and practicality of using the tonometer adds to its superiority over the latter measurements. No relationship was found between ventricular ejection fraction, pHi and outcome.

Conclusion: Although the number of patients is small, these results support pHi as a valuable predictor of outcome and also suggest a role for the gut in initiating the IL-6 and physiological responses.

Key Words: Abdominal aneurysm, tonometer, outcome.

Introduction

The identification of those patients with a history of either acute or chronic illnesses liable to suffer a poor outcome following surgery represents a stimulating challenge for most clinicians, and more importantly management can be tailored appropriately. Various staging and scoring criteria are available, and indeed are used for conditions such as pancreatitis, trauma and sepsis, reflecting the general desire to prognosticate on the basis of objective data. These scoring systems may involve various modalities ranging from simple clinical observations to more sophisticated laboratory investigations, such as biochemical and haematological tests. Recently, the use of the silicone tonometer in predicting outcome in cardiac and abdominal aortic surgery, and in intensive care units (ICU) has been described.1-7

The tonometer measures the intramucosal pH (pHi) of hollow viscera using the technique of tonometry first described by Bergofsky.9 It consists of a semi-permeable balloon at one end of a long catheter, which allows free diffusion of carbon dioxide across its membrane. The principles of the tonometer are based on the assumption that the partial pressure of carbon dioxide within the bowel wall is similar to that of the lumen, and the concentration of standard bicarbonate within the tissues is the same as that of arterial blood. The pHi of the bowel has been shown to correlate well with both local and systemic causes of diminished perfusion once oxygen delivery falls below a critical level.9,10

The aim of this study is to assess the reliability of sigmoid pHi in predicting outcome in elective abdominal aortic aneurysm repair, and to compare its accuracy with plasma IL-6 concentrations and APACHE II scores, which are widely used in ICU.11-14 IL-6 is a cytokine produced by the immune cells in response to stress, and correlates with survival in ICU.13,14 Baigrie et al.15 found that patients who developed postoperative complications following abdominal aortic surgery have much higher
concentrations of this polypeptide than those who make an uneventful recovery. They recommended routine plasma IL-6 estimation to identify patients most likely to require careful postoperative monitoring.

**Methodology**

This study was approved by the Ethical Research Committee of the Queen's University of Belfast. Forty-two patients undergoing elective abdominal aortic aneurysm surgery were recruited and successfully studied. After routine thioptene/morphone induction and muscle relaxation with pancuronium, a sigmoid silicone tonometer was inserted digitally into the ampulla of the rectum and then advanced into a mid-sigmoid position at laparotomy. Saline (2.5 ml) was injected into the balloon and equilibrated over variable periods of time before the partial pressure of carbon dioxide within the saline was analysed. The pHi can then be calculated using a modified Henderson-Hasselbach equation if a simultaneous arterial standard bicarbonate concentration is determined.

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\text{pHi} = 6.1 + \log \left( \frac{[\text{HCO}_3^-]}{\text{pCO}_2 \times 0.03} \right)
\]

The correction of pCO2 in the saline after different equilibration durations and the actual calculation of the pHi was made using a slide rule provided by Actamed Limited, U.K. This allowed the pHi of the sigmoid colon to be calculated at regular intervals. The tonometer balloon was maintained in situ for 24 h or until it was expelled spontaneously by the patient, which in some cases was 10 h after surgery. A sealed Dacron straight or bifurcated graft was employed to replace the aneurysm depending on the findings at operation (Bard, Meadox, U.K.). Postoperatively, the patients were managed in the vascular surgery unit in beds equipped with Hewlett-Packard (HP 78560A, U.S.A.) monitors for continuous display of cardiac rhythm, intra-arterial and central venous pressures.

Blood samples were collected in pyrogen-free, heparinised tubes from an indwelling line preoperatively, during and shortly after clamping of the aorta, and at 2 h, 4 h, 12 h, 24 h, 36 h, 48 h, 72 h, 96 h and 120 h postoperatively. These samples were centrifuged at 2000 rpm at 4°C within 1 h of collection. The plasma was then aliquoted into sterile cryotubes (Nunc 36340, Intermed, Denmark) and stored at -80°C until assayed using a commercially available enzyme-linked immunosorbent assay (ELISA) (Kabi Diagnostica, Sweden).

Routine observations were made of blood pressure, pulse and temperature. Daily estimations of full blood count, liver and renal function and partial pressure of arterial oxygen were performed for 5 days postoperatively. The partial pressure of gases in solution and blood were measured using the blood gas analyser BGE (Instrumentation Laboratory Limited, U.K.) set at 37°C, and from these data daily APACHE II scores were calculated. In 29 patients, a preoperative estimation was made of the left ventricular ejection fraction by gated equilibrium radionuclide angiography using Technitium 99m petchenette.
from 7.22 ± 0.07 to 6.98 ± 0.03 (p<0.0001). The lowest pH occurred within 6 h of surgery in the majority of patients, both in the survivors and non-survivors. In the latter group this was much sooner than the actual time of demise, which occurred from the fourth to 13th day postoperatively (Table 1). Interleukin-6 concentrations rose gradually in all the patients, reaching a peak between 2 h and 48 h postoperatively, and then declined towards baseline afterwards. There were significant differences between survivors and non-survivors in the lowest perioperative pH, in peak interleukin-6 concentrations, and in worst postoperative APACHE II scores (Table 2). Of the 29 patients who underwent estimations of ventricular ejection fraction as part of their cardiac assessment, two died. The ejection fraction in the non-survivors (71 ± 3%) was much higher than the survivors (52 ± 2%, p<0.05), even though one was a cardiac death.

Significant correlations were observed between pH and IL-6 (r = -0.37, p = 0.01), pH and APACHE II (r = -0.44, p<0.005), and IL-6 and APACHE II (r = 0.42, p<0.005). No correlation was found between pH and left ventricular ejection fraction. The correlation between IL-6 and volume of blood transfused (r = 0.33, p = 0.05) was weak. pH, IL-6 and acute physiology score all showed some ability to predict mortality, but ROC curves indicated that pH measurements were superior to the other two (Fig. 1). None of the preoperative morbid states such as the presence of cardiac, respiratory and renal impairments were useful as predictors of outcome. Although certain variables showed significant predictive value individually, a final solution was not found by multiple logistic regression analysis, probably because of the small numbers in the non-survivor group.

### Discussion

Despite advances in anaesthesia and intensive care, the operative mortality rate of surgery for abdominal aortic aneurysms can be high. The elective repair of the abdominal aortic aneurysm carries an operative mortality of 10% and higher, although increasingly, and with better patient selection, fatality may be less than 5%. These variations in mortality statistics between centres may be influenced not only by different risk factors and clinical considerations, such as the availability of intensive care unit management after surgery, but also by the “shelving” of high risk patients.
patients, by data enhancement, and in certain centres by a failure to differentiate between elective and acute surgical cases.\(^\text{15}\)

In the ideal world, all patients undergoing elective abdominal aortic aneurysm repair should be cared for postoperatively by experienced staff in well resourced intensive care units. Realistically, this level of supervision may not be possible in most centres, due to limited resources which may be reserved solely for patients judged to be of high risk on the basis of their medical history, clinical findings and investigations. In some general surgical wards the postoperative management of patients after aneurysm surgery may be relegated to junior staff inexperienced in critical care. In this era of financial constraints, a reliable predictor identifying the most vulnerable patients would be of immense value in targeting scarce resources.

Certain pre-existing medical conditions, such as ischaemic heart disease, chronic pulmonary disease, renal failure, hypertension and diabetes, particularly when several of these are present, are associated with a higher incidence of morbidity and mortality.\(^\text{21}\) In many reports over half the patients undergoing elective abdominal aortic aneurysm repair suffer one or more complications due to atherosclerosis.\(^\text{19,22}\) Although age is undeniably an important factor, a good measure of success is achievable even in octogenarians.\(^\text{26,27}\) Recently, high plasma concentrations of IL-6 were found to presage a poor outcome.\(^\text{15}\) Patients in an intensive care unit with grossly elevated concentrations of IL-6 had a higher mortality in comparison to those with low concentrations.\(^\text{13,14}\) Others have shown that estimations of pH\(\text{I}\) of the sigmoid colon following abdominal aortic aneurysm surgery is of value as a predictive index not only of bowel ischaemia, but also of infection from intestinal organisms and the development of multiple system organ failure.\(^\text{1,2,4,6}\) The development of intramucosal acidosis of the stomach following cardiac bypass surgery is associated with a higher incidence of morbidity and mortality, and tonometric measurements of gastric pH\(\text{I}\) are now an accepted means of monitoring systemic oxygenation and outcome in ICU patients.\(^\text{17}\) Sustained acidosis of the gastric and sigmoid mucosa, beyond 2 h, were demonstrated to be highly sensitive in forecasting mortality and the occurrence of major complications in elective and emergency aortic aneurysm patients.\(^\text{28}\)

In this group of patients, sigmoid pH\(\text{I}\) monitoring was found to be superior to gastric pH\(\text{I}\) measurements, even though both were feasible. The pH\(\text{I}\) changes may act as an early warning to an impending complication, and therapy guided by pH\(\text{I}\) may improve outcome significantly in critically ill patients in ICU.\(^\text{26,29}\)

The data demonstrates clearly that pH\(\text{I}\) of the sigmoid colon was the most reliable of all the variables in predicting perioperative mortality in patients undergoing elective abdominal aortic aneurysm repair. The changes in pH\(\text{I}\) occurred much earlier than those of IL-6 or APACHE II score, and were of greater importance in identifying patients who required more intensive monitoring or an alteration in their management regimen, especially when high risk patients can be identified days before the fatal event. The delay in response of IL-6 and APACHE II score in comparison to that of pH\(\text{I}\) measurement and the significant correlation between them suggest that the latter is a more immediate and direct pointer to tissue injury. It has been pro\(\text{posed, in fact, that the colonic response may be driving the systemic reactions.}\(^\text{6,30}\)

A correlation has been drawn between the amount of blood transfused and peak IL-6 concentrations in abdominal aortic surgery, and may be related to the severity of stress.\(^\text{15}\)

Another important criteria which supports the tonometer as a better tool for identifying high risk patients is its practicability. pH\(\text{I}\) is much easier to measure than IL-6 or APACHE II score. After placement of the balloon, each measurement takes no more than 30 min to perform, and does not require the involvement of a second or third participant. IL-6 measurements are also time consuming and require the services of a well equipped laboratory unit and technical staff. Furthermore, the need to involve departments of various disciplines, and the necessity to gather different modalities in calculating the APACHE II score, adds to the disadvantages of its use. A drawback of the tonometric technique is that a little skill and patience is required to manoeuvre and accurately place the balloon in the sigmoid colon. Frustrations and disappointments initially encountered in positioning the tonometer were quickly overcome, and in general added no more than 10 min to operation time. The reason for the fall in the pH\(\text{I}\) is unclear, and is probably caused by a combination of factors such as local reduction in colonic perfusion during clamping of the infrarenal aorta, ligation of the inferior mesenteric artery, hypovolaemia or cardiac insufficiency. Whatever the cause, those patients who developed intramucosal acidosis of the colon suffered a worse outcome.

Unfortunately, no definitive pH\(\text{I}\) cut-off point is available to predict the risk of mortality, which is why the receiver operator curves were plotted to compare the accuracies of the three putative prognosticators. However, taking a sigmoid pH\(\text{I}\) of 6.86 as the lower limit of normal, many workers have shown a sensitivity of 100% in the prediction of ischaemic colitis. In
this study a pH of 6.80 would provide a 100% sensitivity and 89% specificity of identifying patients at increased risk of suffering a fatal complication. Therefore, at this level, less than 20% of all aneurysm patients may require intensive monitoring, allowing better bed occupancy in the intensive care unit. At lower pH values, better specificity is obtained at the expense of sensitivity.

Conclusion

Although the number of patients studied is small, these data demonstrate that tonometric pH measurement of the sigmoid colon is a valuable technique in predicting outcome in patients undergoing elective abdominal aortic aneurysm repair. It provides a simple means of identifying patients at most risk of dying, and towards optimising cardiac performance and fluid therapy during the perioperative period. However, a larger sample of patients would be needed to resolve convincingly any uncertainty regarding this proposition.

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References


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