The treatment objective for any anaesthetist and intensivist is to provide the best and most safe treatment for any patient in his or her care. However, sometime this may be a little difficult or confusing if there are different alternatives for the recommended treatment. The patients clearly hope that they will have trouble-free safe anaesthesia and post-operative recovery. The single most important element of monitoring during anaesthesia must be the continuous presence of an expert anaesthetist for the duration of the operation, and so long as that doctor is awake, observant and competent then the patient is likely to have the best possible chance of survival. Over the last 25-50 years there is good evidence that the incidence of death directly attributable to anaesthesia has fallen but despite this the overall incidence of death following surgery has remained almost unchanged. In the mid-1950’s a number of studies suggested that the postoperative mortality solely associated with anaesthesia was approximately 1 in 2500 (1, 2, 3). However over the following 30 years this death rate was greatly reduced, due partly to improvements in anaesthesia but more probably due to the training and quality of anaesthetists and so by 1987 Buck et al. (4) showed that the death rate following surgery attributable solely to anaesthesia was now approximately 1 in 185000. Much more significantly their study showed that the post operative death rate due solely to the quality of surgery had not changed in the same 30 years. Furthermore the United Kingdom confidential enquiries in to peri-operative deaths (NCEPOD) 1989-2003 showed that surgical post operative mortality hardly changed in the 20 years following the publication of the first report (5, 6). In a recent study by PEARSE and colleagues (7) the outcome following surgery in 94 National Health Service hospital in the United Kingdom over a five year period. They studied over 4 million operations. 2.8 million of these were elective surgery and 1.2 million were emergency operations. The death rate following elective surgery was 0.44% and the death rate following emergency surgery was 5.4%. However, this information was more shocking as it was possible from the data they studied to identify a group of patients who were at high risk of post operative death (within 28 days of surgery) and post operative complications and in this group the post operative death rate was 12.3%. Furthermore, this accounted for 83.8% of all postoperative deaths even though they only account for 12.5% of hospital surgical admissions. This same population, of high risk patients, had a prolonged hospital stay (median 16 days inter-quartile range 9-29 days). Worse they also found that less than 15% of these patients at high risk from death and serious complications post-operatively were admitted to an intensive care unit or high dependency unit or other critical care area after their operation. Given that there are 3.3 million surgical operations per year in the United Kingdom and approximately 25,000 deaths then from this and the data from PEARSE et al. (7) it would suggest that there are approximately 166,000 patients per year undergoing major surgery who are a high risk of post operative death or serious complication. With 250 hospitals in the UK then this would mean that the average general hospital undertakes major surgery on 12-13 patients per week who are at high risk of post operative death or serious complications.

The patients who are at high risk of post operative death and complications are well recognised and easy to identify. They are patients with advanced aged, significant medical co-morbidities and are undergoing major surgery. Most have significant cardiovascular disease. We are all well aware of the patients who make up this high risk group. Shoemaker and colleagues studied a several thousand patients undergoing operations in the United States in 1970s (8, 9) and 1980s (10) and was able to determine the physiological patterns of those patients who survived and those patients who died despite having apparently the same operation. The work by Shoemaker and colleagues has been confirmed by other authors. Farrow and colleagues (11) showed the incidence of death following major surgery was less than 5% for patients with normal physiology but that this death rate rose to over 20% in patients who were known to have
severe ischaemic heart disease, chronic obstructive pulmonary disease or congestive cardiac failure prior to surgery. Mella and colleagues (12) have shown that in a study of 3520 patients that following surgery for colorectal cancer the overall post operative mortality was 7.6% but that this rose significantly to 21% for those at high risk or undergoing emergency surgery. Shoemaker and colleagues were able to refine their data collection from all their studies to suggest criteria for identifying patients at high risk of post-operative death from their pre-operative medical status (Table 1).

Having recognised that they were able to identify a group of patients prior to major surgery that were at high risk of post operative death and complications Shoemaker and his colleagues (13) then determined to see if they were able to reduce the incidence of death and complications by deliberately enhancing the patients cardiorespiratory performance during the perioperative period with goals of their therapy being the cardiorespiratory physiological performance seen in the patients who survived without complications following similar surgery. To enable them to undertake such a study they examined 37 criteria these included the most commonly measured physiological variables during the perioperative phase. Variables such as heart rate, blood pressure, temperature, urine output. They found however that most of these do not vary significantly between survivors and non-survivors. However, they noted that those variables that were related to tissue oxygen delivery and tissue oxygen consumption (most notably cardiac output and blood flow) were linked to the patient’s survival. They noted that patients with a tissue oxygen delivery of greater than 600 mL/min/m² body surface area or a tissue oxygen consumption of less than 170 mL/min/m² body surface area or a cardiac index of less than 4.5 L/min/m² tended to survive the perioperative period and have significantly fewer complications after surgery. These findings suggested that one possible cause of the high death rate seen in these patients may be due to the development of tissue hypoxia during and immediately after surgery. It is well recognised (14) that hypoxia can cause failure of energy dependent membrane ion channels with subsequent loss of membrane integrity, changes in cellular calcium homoeostasis, and changes in cellular enzyme activity. Tissue death may not occur as rapidly as in highly hypoxic sensitive tissues but delayed diagnosis will have equally serious consequences. Furthermore intra-operative surgical stress may markedly increase adrenergic nerve activity and plasma catecholamine concentrations, which causes peripheral vasoconstriction and decreased tissue oxygen partial pressure possibly leading to tissue hypoxia (15). Pain, as well as intra-operative surgical stress, leads to an autonomic response that markedly increases adrenergic nerve activity and plasma catecholamine concentrations (16). This will lead to peripheral vasoconstriction, reduced perfusion, and decreased tissue oxygenation tissue hypoxia (17, 18).

Shoemaker postulated that major surgery and illness (and in particular shock) was associated with significant tissue hypoxia leading to an increased oxygen demand from the tissues and that if this was unmet because of the patient’s poor cardiorespiratory performance during this phase then an oxygen debt was developed. This led to an amplification of the inflammatory process which then led to organ dysfunction and eventually organ failure which in turn was the cause of the high perioperative death rate. This corresponded well with the clinical picture where it was noted that post operative death does not occur immediately after surgery but is reported continuously for over 30 days after surgery and is often associated with gradually organ dysfunction and then failure leading to multi-organ failure and then death. NCEPOD (6) reports have consistently shown that perioperative deaths are still occurring over 30 days after surgery with the median day of death being the sixth day after surgery. Shoemaker and colleagues (19) subsequently

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**Table 1**

Criteria for identifying patients at high risk of post-operative death and complication undergoing major surgery (Shoemaker et al. (13), 1988)

- Previous cardiorespiratory illness (including myocardial infarction or stroke within previous six months, evidence of significant obstructive airways disease, evidence of congestive heart failure, evidence of organ dysfunction)
- Late-stage vascular disease
- Age greater than 70 with limited physiological reserve
- Acute abdominal catastrophe with haemodynamic instability: peritonitis, perforated viscus, pancreatitis.
- Acute massive blood loss (more than 8 units transfused intra-operatively)
- Septicaemia, with positive blood culture requiring admission to ICU prior to surgery in patients with limited cardiorespiratory reserve
- Respiratory failure (PaO₂ less than 8.0 kPa or FiO₂ greater than 0.4 or mechanical ventilation prior to surgery)
- Extensive surgery for carcinoma; oesophagectomy, gastrectomy, pelvic exenteration in elderly patients with limited cardiorespiratory reserve.
- Acute renal failure with onset immediately prior to surgery (urea greater than 20 mmol/L or creatinine greater than 260 mmol/L)
calculated the oxygen debt developed during surgery in his cohort of patients. They then showed how long their patients took to eliminate this oxygen debt following surgery. They found that those patients who repaid the oxygen debt within 2 to 6 hours of surgery survived with no complications. Those patients who repaid their oxygen debt within 24 hours of surgery survived but had significant complications and those patients who did not repay the oxygen debt at all died. See Figure 1.

Shoemaker and his team then undertook to examine whether by increasing the oxygen delivery in the patients at high risk of death to the median values seen in patients who survived, then would this improve outcome and reduce the death rate. In 1988 Shoemaker et al. (13) published the results of a study where they deliberately increased the oxygen delivery in patients at high risk to goals achieved by survivors. They chose as their targets an oxygen delivery of 600 mL/min/m² or a cardiac index of 4.5 L/min/m² (the median values of the survivors in their previous studies). The results of this early goal directed study were very encouraging. The mortality in the control group was 33% but in the group who underwent the goal directed therapy the mortality was only 3%. However, the study was small and the patient groups were not well matched and the precise protocol used in the goal directed therapy group was not clear.

In a larger double-blind randomised controlled study Boyd and colleagues (20) involving a similar technique of perioperative goal directed therapy (using a combination of intravenous fluid therapy and doxapine to achieve the goals of therapy) were able to show a reduction in mortality from 23% in the control group to 5.7% in the protocol group. Two further similar studies have been undertaken and show similar results. A study by Wilson and colleagues (21) in the United Kingdom showed a reduction in rate of death from 17% to 3% between the control group patients and those treated with goal directed therapy as suggested by Shoemaker. A more recent study by Lobo and colleagues (22) showed an even greater improvement in outcome between the control group patients and those receiving goal directed therapy with a mortality of 50% in the control group and only 15.7% in the goal-directed therapy group.

If, therefore it is true that one of the causes of post-operative death and complications is the intra-operative development of tissue hypoxia and a subsequent tissue oxygen debt, then it is self evident that any therapy that confronts this problem should result in an improvement in outcome for the patients. The question is how do we recognise the tissue hypoxia and how do we, as anaesthetists, help patients to overcome this oxygen debt? Shoemaker and colleagues (19) demonstrated very clearly that the usual physiological parameters that we monitor in anaesthesia and surgery (such as blood pressure, pulse rate, urine output) do not vary very much between those patients who undergo surgery and survive and those patients who undergo surgery and do poorly or even die. Thus it is clear that if we are going to influence outcome we will first have to monitor those physiological variables that give an indication of the increasing oxygen debt and then to deliberately improve our interventions to target these variables with the intention of keeping them sufficiently enhanced to ensure a good outcome.

Goal Directed Therapy. Early studies (13, 20, 21, 23) all suggested that the patients who were at risk should be admitted to intensive care prior to surgery. That they should then have their cardiorespiratory systems deliberately “optimised” to induce a supranormal (for those patients) state which was then maintained as best as possible throughout surgery and into the post operative period. Furthermore, these studies all used pulmonary artery catheters to monitor the cardiovascular changes and to direct the therapy. This was time consuming and also put the patients at a certain risk (from the insertion of the pulmonary artery catheter) and relied on the availability of sufficient

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numbers of intensive care beds. However, there have now been a number of studies (24, 25, 26, 27, 28, 29, 30) using the oesophageal Doppler to direct therapy to produce “Goal Directed Therapy” in this group of patients in the intra and post-operative periods. Six of these studies used the oesophageal Doppler during surgery to direct therapy and one has used the oesophageal Doppler during the post operative period. An example of the algorithm used to produce the goal directed therapy utilising the oesophageal Doppler intra-operatively is shown below in Figure 2.

These studies were in a mixture of general patients, orthopaedic patients and cardiac patients. In total the studies involved 618 patients. Most of the studies showed a reduction in mortality (Odds ratio 0.91) and all of the studies showed a reduction in hospital stay ($P < 0.00001$) a shorter length of Hospital stay by 2.94 days with less crystalloid administered by 167 ml and more colloid administered by 661 ml.

More recently a number of studies have investigated the application of this goal-directed therapy in these high-risk surgical patients in the immediate post operative period. BISHOP and colleagues (31) studied 140 young trauma patients all with severe penetrating injuries. They aimed to ensure that their patients in the protocol group had a tissue oxygen delivery of at least 600 ml/min/m² body surface area immediately after the patients returned from the operating theatre. The found that this reduced the incidence of major organ failure by 50% and reduced the mortality of these patients following surgery from 37% to 18%. In 2006 PEARSE and colleagues (32) showed in a randomized controlled double-blind placebo controlled trial that it was possible to improve outcome in this high-risk group of patients if goal directed therapy was commenced only in the post-operative period. Using the LiDCO pulse contour analysis cardiac output monitor they studied 122 patients. The patients were returned to critical care following major surgery and randomly allocated to either a treatment group or a treatment group. The patients in the goal-directed therapy were allocated to have their oxygen delivery enhanced to attain an oxygen delivery index of 600 ml/min/m² for just eight hours immediately post-operatively, whereas the control group were allocated to conventional treatment. Patients were followed up for 60 days. The goal-directed therapy group received more intravenous fluids and intravenous colloids. However, they developed fewer post-operative complications (44% v 68%). Their mean duration of hospital stay was reduced by 3 days. This application of goal-directed therapy only in the post-operative phase has also been studied in cardiac surgery. POLONEN and colleagues (33) studied over 400 patients. All patients had a pulmonary artery catheter sited pre-operatively but the goal-directed therapy did not start until return to ICU after surgery. In the protocol group of patients the circulation was enhanced to ensure that these patients all maintained a mixed venous saturation of greater than 70% and a blood lactate of less than 2.0 mmol/L in the eight hours following surgery, both of these variables being markers of tissue perfusion. The results showed a reduction in mortality and complications following cardiac surgery. This group followed their patients for a year after surgery and the reduction in mortality continued to be significant even at one year after surgery.

Clearly therefore there is very good literature suggesting that there are methods for monitoring the at-risk surgical patient during anaesthesia and in the peri-operative period. By use of the correct monitoring technique it is possible to ensure that the patient’s cardiovascular and respiratory performance is enhanced to allow the best possible outcome. Unfortunately this monitoring is not the usual monitoring undertaken by anaesthetists for...
that this high risk group of patients represent less diac surgery, orthopaedic surgery. It would appear including vascular surgery, colorectal surgery, car-

fit may be obtained in a wide range of surgery, this high risk group. Studies have shown that bene-
vasa state improved prior to surgery if this is possible but certainly they should be admitted immediately post-operatively and goal-direct-

therapy instituted.

b. If the cardiac index > 4.5L/min/m² and/or oxygen delivery > 600 mL/min/m² then further goal-directed surgery will not be necessary intra-

c. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then further goal-directed surgery may be indicated prior to

d. If despite these measures cardiac index is < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then consider the use of additional ino-
r. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then.

increase intravenous fluids: direct therapy using flow-directed monitoring (i.e. monitor cardiac output and oxygen delivery and mixed

venous saturation by whatever method you have available in your hospital).

iii. Maintain adequate haemoglobin concentration (probably above 10 g/dL) by blood transfusion if necessary.

iv. Maintain blood oxygen saturation at 95% or greater if necessary by artificial ventilation or other respiratory support.

d. If despite these measures cardiac index is < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then consider the use of additional ino-

tronic therapy. A number of different inotropic agents have been used but the best results seem to have been achieved with dopexamine but
dobutamine or epinephrine are both suitable alternatives. The dose should be increased slowly and incrementally until the patient achieves

the goals of therapy or until there is a rise in heart rate of 20% above base line or a change in the ECG suggesting iscaemia. If either of the

last two are seen then the inotropic therapy should be reduced until they have gone and it will have to be accepted that in that particular

patient’s the goals of therapy will never be due to very poor underlying myocardial disease.

e. Maintain this goal-directed therapy for at least eight hours after surgery or until the serum lactate is less than 2.0 mmol/L or the mixed venous

saturation has returned to normal.

Guidelines for undertaking peri-operative goal-directed therapy in patients at high risk of post-operative death and complicati ons

1. Identify the appropriate patient. Please see Table 1 of this text. These Shoemaker criteria relating to the patients at high risk can be easily mod-
ingified to suit each institution. The important factor is that these will usually be elderly patients with limited cardio-respiratory reserve or evidence

of previous significant cardiac disease who are about to undergo major surgery.

2. Identify the appropriate operation. Goal directed therapy is of maximum benefit in patients undergoing major operations probably lasting longer

than one and a half hours and would usually be admitted to a critical unit after the operation. It is important to recognise the patient and ensure

that their post-operative course included a period in a critical care unit and not allow these high-risk patients to be returned to the ward to satisfy

surgical expediency or other administrative priorities.


a. Assess the patient pre-operatively. Perform cardiovascular measurements to assess the degree of cardiorespiratory reserve. Measure cardiac

output and/or oxygen delivery prior to surgery.

b. If the cardiac index > 4.5L/min/m² and/or oxygen delivery > 600 mL/min/m² then further goal-directed surgery will not be necessary intra-

operatively but it may be required post-operatively.

c. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then further goal-directed surgery may be indicated prior to

surgery, during surgery and certainly immediately following surgery. The patient should be admitted to a critical care area and their cardio-

vascular state improved prior to surgery if this is possible but certainly they should be admitted immediately post-operatively and goal-direct-

ed therapy instituted.

i. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then.

ii. Increase intravenous fluids: direct therapy using flow-directed monitoring (i.e. monitor cardiac output and oxygen delivery and mixed

venous saturation by whatever method you have available in your hospital).

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iv. Maintain blood oxygen saturation at 95% or greater if necessary by artificial ventilation or other respiratory support.

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e. Maintain this goal-directed therapy for at least eight hours after surgery or until the serum lactate is less than 2.0 mmol/L or the mixed venous

saturation has returned to normal.

References


DO I NEED MORE MONITORING TO IMPROVE OUTCOME

Table 2

Guidelines for undertaking peri-operative goal-directed therapy in patients at high risk of post-operative death and complications following major surgery

1. Identify the appropriate patient. Please see Table 1 of this text. These Shoemaker criteria relating to the patients at high risk can be easily mod-
ingified to suit each institution. The important factor is that these will usually be elderly patients with limited cardio-respiratory reserve or evidence

of previous significant cardiac disease who are about to undergo major surgery.

2. Identify the appropriate operation. Goal directed therapy is of maximum benefit in patients undergoing major operations probably lasting longer

than one and a half hours and would usually be admitted to a critical unit after the operation. It is important to recognise the patient and ensure

that their post-operative course included a period in a critical care unit and not allow these high-risk patients to be returned to the ward to satisfy

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output and/or oxygen delivery prior to surgery.

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operatively but it may be required post-operatively.

c. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then further goal-directed surgery may be indicated prior to

surgery, during surgery and certainly immediately following surgery. The patient should be admitted to a critical care area and their cardio-

vascular state improved prior to surgery if this is possible but certainly they should be admitted immediately post-operatively and goal-direct-

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i. If the cardiac index < 4.5L/min/m² and/or oxygen delivery < 600 mL/min/m² then.

ii. Increase intravenous fluids: direct therapy using flow-directed monitoring (i.e. monitor cardiac output and oxygen delivery and mixed

venous saturation by whatever method you have available in your hospital).

iii. Maintain adequate haemoglobin concentration (probably above 10 g/dL) by blood transfusion if necessary.

iv. Maintain blood oxygen saturation at 95% or greater if necessary by artificial ventilation or other respiratory support.

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References


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surely similar to the work in the 1960’s and 1970’s when anaesthetists were gradually persuaded to improve monitoring during anaesthesia to include, basic minimum monitoring of ECG, Blood pressure and urine output. The consequence of that great movement was that nowadays we monitor ECG continuously, blood pressure, pulse rate, oxygen saturation and end tidal carbon dioxide in virtually all operations where general anaesthesia takes place. As a result the mortality due to anaesthesia has fallen from 1 in 2500 to less than 1 in 200,000 (1, 2, 3). That is a fantastic improvement in the safety and outcome following anaesthesia. It remains to be seen whether over the next decade we can persuade all anaesthetists to invest the extra time that this simple technique requires to improve the outcome or whether it will be forced upon us when the routine audit of surgical outcome demonstrates that the technique will reduce post-operative mortality, complications and hospital stay.

References


