Clinical trials of monitoring in anaesthesia, critical care and acute ward care: a review

D. Young* and J. Griffiths

Nuffield Department of Anaesthetics, John Radcliffe Hospital, Headley Way, Oxford OX3 9DU, UK

*Corresponding author. E-mail: duncan.young@nda.ox.ac.uk

During anaesthesia monitoring is used as part of a complex feedback-control system to keep the patient in a safe physiological 'envelope' and so is central to the conduct of a modern anaesthetic. The utility of basic monitoring is universally acknowledged and will never be assessed using randomized controlled trials. However, each time a new monitoring device is introduced, it can be assessed to see if it adds to the safety and effectiveness of anaesthetics. This review highlights some of the studies that have assessed new monitors in anaesthesia, critical care, and other areas of acute care.

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‘Not everything that counts can be counted and not everything that can be counted counts’

...Albert Einstein attributed (1879–1955)

Continuous electronic patient monitoring may not always be beneficial. Rapid recognition of abnormal physiology may alert the clinician that the patient is deteriorating, but this knowledge will only benefit the patient if there is an effective treatment for the underlying cause. Even if a treatment is available, early recognition of physiological mischief is only of value if the treatment is more effective when delivered quickly. To display data which cannot influence the patient’s outcome might increase our knowledge of disease processes, but does not directly benefit the monitored patient. Nor is it harmless, more information brings with it more ways to misunderstand and mistreat. Detailed evaluation of the benefit to the patient of monitoring physiological variables is therefore appropriate.

In anaesthetic practice ‘monitoring’ usually refers to transduction and display of several of the patient’s physiological variables, combined with variables assessing anaesthetic machine function. This combination of patient and anaesthetic machine monitoring is well illustrated by the minimum monitoring standards issued by the Association of Anaesthetists of Great Britain and Ireland (AAGBI). These suggest that the patient is monitored with a pulse oximeter, a non-invasive blood pressure monitor, an ECG and a capnograph and the anaesthetic machine with an oxygen sensor, an anaesthetic vapour monitor and a capnograph.

However the Oxford English Dictionary suggests a broader definition of monitoring, that to monitor someone or something is ‘to observe, supervise, or keep under review; to keep under observation; to measure or test at intervals, especially for the purpose of regulation or control’. This encompasses both the technical process of monitoring, and its purpose, which under anaesthesia is primarily ‘regulation and control’ as part of a complex feedback and control system.

Why do we suggest that the primary purpose of monitoring under anaesthesia is ‘regulation and control’ when physiological monitoring of patients is usually justified not because it is central to the process of anaesthesia, but by suggesting it reduces serious adverse events? For example, the AAGBI promotes minimal monitoring standards because ‘...there is substantial evidence that it (monitoring) reduces risks of incidents and accidents both by detecting the consequences of errors, and by giving early warning that the condition of a patient is deteriorating for some other reason’. During anaesthesia the patient, the anaesthetist and the monitors all form part of a complex feedback loop. The monitors display physiological variables to the anaesthetist, who also receives information on other variables such as the stage of the operation, and processes these data along with parameters such as the patient’s medical history to decide whether any actions are needed. If actions are needed, the anaesthetist implements them (for example a fluid bolus) and then measures the effect, to determine if any repeat or further actions are needed. So, in the majority of cases, the monitoring is used as part of a complex feedback-control system to keep the patient in a safe physiological ‘envelope’, and not primarily as a warning system to alert the anaesthetist when the patient’s physiology strays outside the ‘envelope’. Thus capnographs are mostly used to adjust artificial ventilation to achieve normocarbia, and not primarily to detect exhaustion of the soda-lime, and...
ECG and blood pressure measurements are primarily used to adjust the depth of anaesthetic or circulating volume, not to monitor for unexpected dysrhythmias.

The similarities between pilots and anaesthetists are often overstated, but an analogy may be useful here. Pilots of light aircraft fly along an invisible flight path. They receive information about their position in three-dimensional space from the altimeter, compass or other navigational aids. Adding data on the weather, cross winds, barometric pressure, aircraft characteristics and airspeed, they use these data to adjust the heading and control surfaces to stay on course at the right height. At the same time they monitor the aircraft function using fuel gauges, engine temperature and the like. Whilst their instruments will all indicate if a serious adverse event occurs, their primary use is to keep the aircraft on course.

Basic monitors are now central to the conduct of modern anaesthesia, and are part of a complex man–machine interaction. The idea that their utility overall or individually can be assessed using the core ‘evidence-based medicine’ tool, the randomized controlled trial, is probably unrealistic as it would be impossible to find a group of anaesthetists willing to give anaesthesia to a group of patients without one or all of the monitors recommended by their professional bodies. To stretch an analogy rather too far, no-one would suggest the utility of an altimeter was assessed by a randomized controlled trail of altimeters vs no altimeters with aircraft accidents as an outcome measure. Thus if we wish to determine the utility of monitoring we really only have two options. We can find studies looking at the trends of anaesthetic mishaps over time which try to correlate these with trends in monitoring, but the best opportunities to evaluate monitors occur when a new technique is introduced and conventional monitoring with or without the new device can be compared in a clinical trial.

Monitoring is used in many other environments other that operating theatres. It is used extensively in ‘level 3’ (critical care units) and ‘level 2’ (high dependency units) care areas. Its use on ‘high-risk’ patients is increasing in acute medical and surgical wards. However as the acuity of care reduces from level 3 care, through level 2 care to ward care, the function of monitoring subtly changes. In operating theatres, and usually in level 3 care areas, there is a continuous one patient/one clinician (anaesthetist or highly trained nurse) relationship. In the critical care setting the clinician uses the data from the monitors to adjust inotropes, fluid balance, ventilator settings and sedatives, and in the operating theatre to adjust the anaesthetic. The continuous presence of a trained clinician ensures these adjustments are made quickly and their effect rapidly assessed. As the acuity of the patient decreases, so does the tendency to physiological derangement, and so fewer staff react at longer intervals to slower changes. On the general ward, monitors are not usually used primarily for measuring and titrating treatment at all, but to alert staff to catastrophic changes in the patient’s physiology. In this circumstance, monitoring does not primarily drive decisions on the amount and type of treatment, there is no consensus on the use of monitoring and no data on its utility, and so clinical trials of monitoring in this setting are both possible and ethical.

In this (narrative) review we will cover the studies of monitoring that have been undertaken in anaesthesia, and then go on to discuss some studies undertaken in high and low acuity areas outside the operating theatres.

Studies of monitoring in anaesthesia
Many anaesthetists cite improved monitoring as one of the reasons for a reduction in anaesthetic-related mortality over the years. This is based on the apparent coincident increased use of monitoring and decrease in perioperative morbidity and mortality rates. The number of deaths attributable to anaesthesia almost certainly declined for at least 25 yr starting in the mid 1950s, from 1 death in 2680 anaesthetics in the 1950s to 1 death in 10 000 anaesthetics in the 1980s. The National Confidential Enquiry into Perioperative Deaths based on data collected in 1985 gave an even lower figure for anaesthetic-related mortality rate of 1 death in 185 056 anaesthetics. However, since the 1980s the mortality resulting from anaesthesia may have stayed constant (or even worsened). Danish studies in the 1990s identified a cardiac arrest rate because of anaesthesia of 15 per 20 082 anaesthetics and death solely or partly because of anaesthesia of 1 in 2500–3000 anaesthetics. Thus the downwards trend in anaesthetic mortality seems to have stopped about the same time as modern, digitally based monitoring and especially pulse oximetry started to increase. The ‘coincident’ increased use of monitoring and decrease in anaesthetic mortality may not be as clear as first suggested.

Comparing point estimates of mortality derived using different methodologies in many countries is probably not going to produce a reliable estimate of trends over time. However single centre studies also show a reduction in adverse incidents during anaesthesia over time. For example, in the period 1969–88 in a single large American hospital, the ‘anaesthetic’ cardiac arrest rate more than halved from 2.1 arrests per 10 000 anaesthetics in the first decade from 1969–78 to 1 per 10 000 anaesthetics in the second decade 1979–88. The reduction in arrests was mostly due to a reduction in respiratory complications. The authors concluded that the reduction in cardiac arrests was primarily because of improved respiratory monitoring, and specifically in the second decade to the introduction of pulse oximetry. However, even in this single centre study there were many other factors that could have influenced anaesthetic mortality other than monitoring over a 20 yr period. These include changes in anaesthetist’s training, a change in the population anaesthetized as a result of changes in surgical practice or population patient characteristics, or changes in the anaesthetic agents used.
Anaesthetic monitoring had evolved slowly until the mid 1980s, with no ‘step changes’ in technology that would allow either a randomized controlled trial of ‘conventional monitoring vs conventional monitoring plus the new technology’, or which would provide a step change in standard monitoring practice to allow a clear ‘before and after’ comparison. This situation changed when pulse oximetry first became available in the 1980s. A pair of studies where patients were all monitored with pulse oximeters, but the data were only available to a randomly selected 50% of their anaesthetists, showed that in children and adults the pulse oximeter was far better than the anaesthetist in recognizing arterial hypoxaemia, with the anaesthetists missing nearly two-thirds of desaturation episodes in children. Giving the anaesthetist information from the pulse oximeter reduced hypoxaemic episodes significantly. A third study in children was undertaken using a factorial design to evaluate both oximetry and capnography, showed similar results, with little added benefit from capnography. These initial studies were reasonably small (152, 200 and 402 patients, respectively), and were the equivalent of ‘phase 2’ drug studies, in that they showed the oximeters did function as predicted, and were better than clinical assessment. What they did not answer was whether the additional detection of hypoxaemia that these devices allowed translated into any benefit to the patient. In 1993, Moller and colleagues tried to answer this question. They randomly assigned 736 patients to either pulse oximetry or conventional monitoring without oximetry, and measured postoperative cognitive function, on the basis that avoidance of hypoxia might result in less postoperative cognitive dysfunction. Although 7.8% of the ‘no oximeter’ group, compared with 0.5% of the oximeter-monitored group, experienced one or more hypoxic episodes, no difference in outcome could be detected. The definitive study was published in 1993. Moller and colleagues used a trial design that was part way between a conventional randomized controlled trial and a cluster randomized trial, assigning conventional monitoring plus a pulse oximeter or conventional monitoring without a pulse oximeter, to each operating theatre in five hospitals each day. They recruited 20 802 patients. Although the oximeters altered clinician’s actions (more oxygen and more naloxone were used), and 80% of anaesthetists felt ‘more secure’ with an oximeter, serious adverse events, mortality and hospital stay were all unchanged, though post hoc analysis did suggest pulse oximetry may have reduced the incidence of myocardial ischaemia. However, given the low mortality in the control group (11 per 10 000) even with 20 802 patients the study would have only reliably detected a 35% reduction in mortality (to 7.5 per 1000). Moreover, as most deaths presumably occurred as a result of the primary disease or non-anaesthetic factors like pulmonary emboli, they could not have been influenced by the presence of a pulse oximeter.

A published Cochrane review attempted to identify the adverse outcomes that might be prevented by the use of pulse oximetry. The four trials highlighted provided data from a total of 21 773 patients. The reviewers noted that although the studies confirmed that pulse oximetry could detect hypoxaemia and related events, there was little evidence that it affects the outcome of anaesthesia and perioperative morbidity and mortality. They concluded that the value of perioperative monitoring with pulse oximetry is unproven. An alternative interpretation of the same data is that oximetry may be beneficial but the number needed to treat to avoid one adverse event is very large.

A second ‘step change’ in monitoring occurred more recently when depth of anaesthesia monitoring using the processed EEG signal became sufficiently simple to be used as routine monitoring. Nearly all studies in this area have used the bispectral index (BIS) monitor. BIS monitoring was generally but not universally found to modestly reduce the amount of hypnotic used during anaesthesia, though the cost savings made were entirely cancelled out by the cost of the disposables required for the monitoring. No advantage in terms of time to discharge fitness or time in the post anaesthetic care unit were demonstrated. However, a large study in Australia (the B-Aware study) clearly demonstrated that the use of BIS monitoring reduces, but does not prevent, awareness, with a number needed to treat 138 patients (the number of patients who would have to be monitored to prevent one case of awareness). Depth of anaesthesia monitoring is covered in more detail in another review in this issue of the Journal.

The third ‘step change’ has been the development of simple, relatively non-invasive devices to measure cardiac output and stroke volume in anaesthetized patients. The device that has been studied in randomized controlled trials is the oesophageal Doppler cardiac output monitor. This is an ultrasound probe which when placed in mid-oesophagus insonates the descending aorta and measures blood velocity. The velocity information can be processed to give an indication of stroke volume and an indirect measure of inotropy and peripheral (systemic) vascular resistance. As with many monitoring devices in anaesthesia it is used as part of a feedback process, to assess fluid status and replace circulating volume to a ‘target’ stroke volume, cardiac output or corrected flow time. When used in a randomized, controlled trial to guide fluid replacement during surgery for proximal femoral fracture more fluid was given (about 30% more colloid per unit time, or an average of 750 ml per case) during the operation in the monitored group. Although mortality was unchanged, the monitored group had a mean hospital length of stay of 12 days, whereas the control group had a 20 day length of stay. This was an enormous benefit to both patients and hospital for the modest cost of the disposables for the monitor and two bags of colloid plasma expander. However, 5 yr later a similar study,
again in patients with proximal femoral fracture did not show a reduction in hospital length of stay when fluid replacement was guided either by central venous pressure monitoring or oesophageal Doppler, though the Doppler group were considered ‘medically fit’ for discharge earlier than the control group. These two studies are the subject of a Cochrane review, which concludes that they are not conclusive and more research will be needed to address the question of the benefit of oesophageal Doppler-guided fluid treatment in patients undergoing surgery or fractured proximal femur. A modest benefit was seen when patients undergoing abdominal surgery were studied, with a 1.5 day reduction in length of stay brought about by a 500 ml increase in colloid use in the group with the Doppler monitor. In a fourth study involving patients undergoing bowel surgery, hospital length of stay was the same in those monitored with the oesophageal Doppler and the control group, but 5 out of the 28 control patients needed intensive care unit (ICU) admission whereas none of the 29 monitored patients were admitted.

The link between intraoperative fluid management and time to discharge is usually made by suggesting that intraoperative fluid administration reduces organ hypoperfusion and hence reduces late complications. This link between an additional 500–750 ml of intraoperative fluid and delayed hospital discharge a week to 10 days later is a bit tenuous especially as additional intraoperative fluid may have deleterious and beneficial effects, and a study where additional intraoperative fluid was given without monitoring during surgery for proximal femoral fracture has shown no benefit.

In very high-risk patients, intraoperative fluid management based on monitoring with a pulmonary artery catheter has been studied. These studies fall into two groups, where patients received intraoperative monitoring only, and studies where preoperative ‘optimization’ using a pulmonary artery catheter was undertaken before surgery. In brief, none of these studies show any survival benefit. A systematic review containing details of all these studies will soon be published online as part of the monograph describing the PAC-Man trial (the NHS Health Technology Assessment Programme at http://www.hta.nhsweb.nhs.uk/).

So, despite a limited ‘evidence base’ to support basic monitoring in anaesthesia, as new monitoring techniques have been introduced they have only been evaluated to limited degrees. Though there are many barriers to research evaluating monitoring devices in anaesthesia, the large number of patients anaesthetized during office hours using reasonably homogeneous techniques means that access to a suitable patient population is not one of them.

Studies of monitoring on the ICU
Many continuous or intermittent cardio-respiratory monitoring techniques have been evaluated in critically ill patients. The monitoring device that has been studied in considerable detail, and which teaches us the most about evaluating monitoring in critical care units, is the pulmonary artery (or Swan-Ganz) catheter. Bedside pulmonary artery catheterization was first introduced in the 1970s, and gradually became accepted as the gold standard method to measure cardiac output and other haemodynamic variables. The view that detailed knowledge of haemodynamics in critically ill patients would translate to a survival advantage was widely held, and so pulmonary artery catheterization became a standard of care without any real evaluation of its clinical effectiveness.

In 1996, a review of all clinical trials involving pulmonary artery catheterization was published. Thirty-four studies were identified, but only one was considered high-quality evidence. This showed no benefit for treatment aimed at achieving ‘target’ values for haemodynamic variables in a mixed intensive care population. In the same year a large, non-randomized, case-controlled study by Connors and colleagues suggested an increase in 30-day mortality in patients managed with a pulmonary artery catheter in the first 24 h following admission to ICU, and increased utilization of resources. In 1997, MacKirdy conducted a similar risk adjusted comparison of patients managed with and without a pulmonary artery catheter using data from the Scottish Intensive Care Society Audit Group (SICSAG), and presented (but not published) similar results.

These studies caused considerable concern. Rather than benefiting patients, the use of a monitoring device with no direct therapeutic benefit was apparently causing harm. Several randomized controlled trials of pulmonary artery catheterization in patients treated in ICUs were undertaken to try and answer this question. In the UK the PAC-Man study examined the effects of pulmonary artery catheterization in a mixed ICU population of 1014 patients. In France, Richard and colleagues studied 676 patients with shock or ARDS, and a single centre study in London studied 201 patients with shock or acute respiratory failure. The results of another study in the United States (Fluid and Catheter Treatment Trial or FACTT) have yet to be published. The completed studies, and a meta-analysis combining the studies (Harvey S, Young D, Brampton W. et al. Pulmonary artery catheters for adult patients in intensive care. Cochrane Database Syst Rev 2006; issue 2, in press) have all shown the same result; there is no survival advantage conferred by the use of a pulmonary artery catheter, and no reduction in hospital length of stay. However, a cost-utility analysis of the PAC-Man trial data, using a different statistical approach from the primary analysis, concluded that there was a good case to avoid using pulmonary artery catheters based on a modest survival advantage at a modest cost.

The lack of benefit in these studies of pulmonary artery catheter use in general intensive care patients could be explained by statistical chance, by widespread ‘inappropriate’ use of the catheter in patients who could
not benefit from its use, by misinterpretation of haemodynamic data being presented to clinicians, by correct interpretation of data but formulation of incorrect treatment plans, by the whole paradigm by which we use haemodynamic data being incorrect, or because there is no additional advantage being gained from a more detailed knowledge of haemodynamics however used. The last two possibilities are arguably the most worrying, because they imply it is not just the pulmonary artery catheter that is ineffective, but also all the flow measurement devices that are used in intensive care, such as pulse contour devices, indicator dilution techniques, oesophageal Doppler devices and impedance-based devices.

There are studies which might be taken as evidence that if haemodynamic data obtained from pulmonary artery catheters are used correctly patient benefit results. These are studies of ‘pre-optimization’, where high-risk surgical patients are given fluids, inotropes and vasoactive drugs before surgery to achieve ‘targets’ or ‘goals’ which are commonly based on global tissue oxygen delivery (essentially the product of cardiac output and haemoglobin concentration) or stroke volume, measured using a pulmonary artery catheter. A good example is Wilson and colleagues’ study published in 1999. High-risk patients received either standard care, or pre-optimization with a pulmonary artery catheter and fluids and inotropes. The mortality in the standard care group was 17%, in the treatment group it was 3%. Superficially there was benefit from monitoring a patient with a pulmonary artery catheter. However, the patients in the treatment group were admitted to ICU prior to their operation (the controls were left on the ward), and so received a much higher staffing ratio before the operation, and presumably any other treatments (oxygen, etc.) that the ICU clinicians thought they required, and full ICU monitoring, as well as the optimization treatment and pulmonary artery catheterization. The individual effect of the pulmonary artery catheter in this large package of treatment cannot be assessed, so it is not appropriate to suggest they are studies of monitoring. When pragmatic, effectiveness studies of perioperative care with a pulmonary artery catheter have been undertaken, no benefit has been seen.43

The pulmonary artery catheter studies demonstrate very well that even monitoring that is safe and reliable, and whose results are acted upon using pathophysiological concepts and data from a lot of observational studies, may not in the final analysis benefit the patient. Medical electronics now makes automated continuous or near continuous non-invasive measurement and display of some or all of these physiological variables, and a measurement of arterial haemoglobin oxygen saturation using pulse oximetry, simple, accurate and relatively economical. Monitoring is believed to lead to earlier recognition and correction of physiological abnormalities,14 15 22 27 which unrecognized would lead to adverse outcomes, such as increased length of hospital stay, poor functional outcome, cardiopulmonary arrest and even death.34 44 Yet in spite of widespread use of continuous electronic monitoring in acute medical and surgical wards the effect of even traditional manual vital sign measurement, let alone continuous electronic vital sign monitoring, on patient outcome remains uncertain.15

We recently completed a trial to compare continuous electronic vital sign measurement and traditional vital sign measurement in high-risk surgical and medical patients in acute care wards. During the planning phase of the study we tried to undertake a systematic review of primary studies of the effect of electronic, automated, non-invasive, vital sign monitoring on patient outcome. We failed to find any studies comparing any form of continuous electronic vital sign monitoring with intermittent manual vital signs recording on adult patients in acute wards. Given the increase in ward-based monitoring, with worldwide sales of monitors rising at 9% a year from a global market of £4.2 billion in 2003, it is a little surprising that some measurement of their benefit has not been undertaken.

There are, however, two areas where there are considerable bodies of evidence for a benefit arising from specific types of monitoring on well-defined patient populations in two ‘high-dependency’ areas. The first is fetal monitoring in labour, where the evidence has been summarized in three Cochrane systematic reviews. Fetal heart rate monitoring (cardiotocogram or CTG) with or without ECG waveform analysis has been used since the 1960s to monitor fetal well-being in labour. The concept behind continuous fetal monitoring in labour is very simple. The fetal response to hypoxaemia is bradycardia, and so by monitoring fetal heart rate, an at-risk group can be defined and delivery expedited, thereby hoping to reduce the risks of birth asphyxia. This has led to the use of electronic fetal monitoring in three out of four hospital deliveries in the USA. A Cochrane review by Thacker and colleagues48 identified nine published, valid studies of routine electronic fetal monitoring in labour, with a total patient population of 18 651 pregnant women, and control groups where intermittent auscultation of fetal heart rate was used. A meta-analysis showed no effect of routine electronic fetal monitoring on any indices of fetal well-being except neonatal seizures, which were reduced from 1 in 201 infants in the control groups to 1 in 401 infants in the monitored group. This improvement in seizure rate came at a (possibly predictable) price, the Caesarean section rate was 1:20 in the monitored group, but 1:29 in the control group and the vaginal operative deliveries increased from

Continuous electronic monitoring on the ward

Outside critical care areas ‘vital sign’ measurement traditionally involves manual recording of pulse rate, respiratory rate, temperature and blood pressure at intervals that generally decrease with an increasing severity of the illness.
the delivery of anaesthesia, and we will never be able to avoidContinuous electronic physiological monitoring is core to the use of fetal pulse oximetry. Overall the use of fetal ECG analysis or fetal pulse oximetry conferred no benefit over heart rate monitoring alone, and no comparisons were made with intermittent auscultation.

These studies give a very clear message. The benefits of simple electronic fetal monitoring are not improved by the additional information obtained from waveform analysis and oximetry, in essence the extra information is redundant. They also give a very clear indication that electronic fetal monitoring is sensitive enough to pick up some cases of fetal hypoxia early enough to reduce the seizures that it causes, but not specific enough to avoid a large increase in operative deliveries. The elements of the risk–benefit decision for a labouring mother are clear, does she want to decrease the chance of a neonatal seizure in her child by 50% by running a 50% increase in the risk of operative delivery? In the UK detailed guidance on fetal monitoring based on published evidence has been published by the National Institute for Clinical Excellence.

The second area where monitoring is well studied is in coronary care units or similar areas where patients are cared for following myocardial infarction or acute coronary events. In these circumstances the conditions we outlined at the beginning of this article that allow a patient to benefit from monitoring are all in place. Recognition of abnormal cardiac rhythms by trained staff alerts the clinicians that the patient has acutely deteriorated, especially in the case of ventricular tachydysrhythmias. There is an effective treatment available, defibrillation, with trained staff available to administer it. Numerous observational studies have shown that the efficacy of defibrillation deteriorates rapidly if delayed, and so early recognition of ventricular tachydysrhythmias does alter outcome. As a result those patients who suffer a cardiac arrest resulting from a ventricular tachydysrhythmia in a monitored site are defibrillated more quickly, and have a considerably better survival. Finally, a trial where patients were randomly assigned to a general ward or a coronary care unit after myocardial infarction almost halved mortality. In this case simple ECG monitoring, in areas with reasonably high numbers of trained staff, and an effective treatment for abnormalities that are detected by the monitoring, saves lives. This cascade from monitor through to patient benefit is difficult to show in many other are as where monitors are used.

Conclusion
Continuous electronic physiological monitoring is core to the delivery of anaesthesia, and we will never be able to evaluate our minimal monitoring standards using a randomized controlled trial. New monitoring modalities can be tested as they are introduced, and the results are not always as expected; very few anaesthetists would have predicted that it would not be possible to show a benefit arising from pulse oximetry in over 20 000 patients. In critical care, the ‘gold standard’ haemodynamic monitor has been shown to be virtually valueless, and the challenge now is to find out if this is because the data it provides are of value and our response is flawed, or if detailed haemodynamic data cannot be converted to patient benefit. Finally, our obstetric colleagues have clearly shown that large, well-conducted studies of monitoring can be undertaken even in the emotive area of childbirth.

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