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A cost analysis of a treatment policy of a deliberate perioperative increase in oxygen delivery in high risk surgical patients

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Abstract *Objective:* To investigate the cost implications of a treatment policy of a deliberate perioperative increase of oxygen delivery in high risk surgical patients.
Design: A cost-effectiveness analysis comparing 'protocol' high risk surgical patients in whom oxygen delivery was specifically targeted towards 600 ml/min/m^2 with 'control' patients.
Interventions: In a randomised, controlled clinical trial we previously demonstrated a significant reduction in mortality (5.7% vs 22.2%, $p = 0.015$) and morbidity (0.68 ± 0.16 complications vs 1.35 ± 0.20, $p = 0.008$) in 'protocol' high risk surgical patients in whom oxygen delivery was specifically targeted towards 600 ml/min per m^2 compared with 'control' patients. This current study retrospectively analysed the medical care and National Health Service resource use of each patient in the trial. Departmental purchasing records and business managers were consulted to identify the unit cost of these resources, and thereby the cost of treating each patient was calculated.
Results: The median cost of treating a protocol patient was lower than for a control patient (£6,525 vs £7,784) and this reduction was due mainly to a decrease in the cost of treating postoperative complications (median £213 vs £668). The cost of obtaining a survivor was 31% lower in the protocol group.
Conclusion: Perioperative increase of oxygen delivery in high risk surgical patients not only improves survival, but also provides an actual and relative cost saving. This may have important implications for the management of these patients and the funding of intensive care.

Key words Cardiac output · Complications · Cost · Dopexamine · High risk patients · Intensive care · Morbidity · Mortality · Oxygen delivery · Resource use · Surgery

Introduction

Developed nations are spending increasing proportions of their gross domestic product on health care, and an increasing percentage of this on intensive care, although there are wide variations in the actual amount spent per capita in different countries. All too often there is little direct evidence that this increased expenditure leads to any improvement in patient outcome in terms of survival, reduced morbidity or even quality of life. Therefore, new pharmacological agents and treatment protocols must increasingly be placed in context by considering their impact on the use of National Health Service resources [1]. This may be particularly important when considering new treatments for patients on intensive care as they can be prohibitively expensive [2], may increase the length of stay on intensive care and costs can escalate rapidly [3, 4].

One area where clinical studies have shown benefit by 'prophylactic' intensive care is in the management of the high risk surgical patient. Each year approximately 3.3 million operations are performed in England alone [5]. Recently it has been shown that at least 22,000 deaths occur within 30 days of operation [6]. Eighty-four percent of these deaths occur in patients aged 60 years or over, and the median day of death is 6 days postoperatively [6]. The costs for specific operative groups, and specifically for the patients who die, are unknown. However, advances in surgical possibilities and the growth in the elderly population mean that these costs are likely to increase significantly in the future.

One possible treatment approach has been to increase perioperative cardiac output and tissue oxygen delivery, aiming for the values naturally obtained by the survivors of surgery [7]. This is a so-called 'goal orientated' approach to management. Studies have shown a decreased mortality following very early intervention in the course of illness or prior to surgical intervention, although similar results have not been obtained in patients in the later stage of their illness [8, 9]. Randomised, controlled trials in high risk surgical patients [10, 11], patients with hip fracture [12] and trauma patients [13], have all shown reductions in mortality; and reductions in morbidity have been seen in patients undergoing peripheral vascular surgery [14] and following gun-shot trauma [15]. Trials using historical controls have shown similar results [10, 16–18].

In the largest trial of high risk surgical patients, we previously demonstrated a significant reduction in mortality (5.7% vs 22.2%, $p = 0.015$) and morbidity (0.68 ± 0.16 complications vs 1.35 ± 0.20, $p = 0.008$) in 'protocol' high risk surgical patients in whom oxygen delivery was specifically targeted towards 600 ml/min per m^2 compared with 'control' patients [11]. This current study retrospectively analyses the cost implications of the results of our earlier work. We are not aware of any studies that have attempted to analyse the cost implications of intensive care interventions in this way.

Methods

The financial costs of the treatment programmes were analysed and compared in three stages. Firstly, the clinical records of the 107 patients recruited in the trial [11] were reviewed in order to identify use of National Health Service resources; secondly, the unit cost of the individual resources were used to obtain a total cost for each patient; thirdly, the patients treated with a goal orientated approach were compared with the control patients.

Identification of the use of resources

As part of the documentation for the clinical trial, data on preoperative and postoperative intensive care stay, and postoperative surgical ward stay were collected. The clinical trial records were reviewed to obtain these data, together with those details pertaining to the therapy that was given in addition to the clinical trial interventions on the intensive care unit, particularly in respect of treatment of postoperative complications. The clinical trial records and hospital notes made it possible to identify and quantify the National Health Service resources that were used to manage the complications, and for investigations, interventions and drug treatments. The individual cost of treating each complication in each patient who had a complication was calculated on a per patient basis.

Cost of resources used

The cost of each resource was obtained at 1993/4 prices from St George's Hospital, London. The costs of investigations were obtained from the departments concerned. The cost of disposable equipment was obtained from the purchasers. The cost of drugs used was obtained from the hospital pharmacy, and although the dopexamine used for the clinical trial was provided free for the duration of the trial, we have included its acquisition cost. Hotel costs for the surgical ward and intensive care stay were obtained from the hospital business managers. The use of most capital equipment was included in the 'hotel' costs for intensive care and surgical ward stay. However the use of additional capital equipment that was required specifically as part of the treatment used, and the maintenance of this equipment, were costed separately. The cost for the surgery undertaken was not included in the total cost, as this study considers the cost implications of the perioperative management, not the surgery. If a further operative procedure were included as part of the management of a complication then this surgery was charged at the hourly rate obtained from the operating theatre business manager.

Comparison of the resources used

A comparison of cost was made between the two groups in the clinical study in terms of total cost, and in respect of different phases of treatment (i.e. preoperative, postoperative on intensive care, postoperative on the ward, and with regard to treatment of complications). Cost-effectiveness analysis took into account the mortality outcome data from the clinical study. A cost for obtaining a survivor (by dividing the total cost for each group by the number of survivors) was therefore calculated and compared. A sensitivity analysis to evaluate the impact of clinical outcomes where there was an element of doubt (i.e. those that were non-significant) was also carried out.

Results

Identification of resources used

The clinical trial documentation combined with the inpatient hospital records enabled National Health Service resources used by the patients to be quantified.

Cost of resource use

Contact with purchasers and business managers enabled the cost of the resources under consideration to be calculated for all cases. Table 1 shows the unit cost of capital equipment and the maintenance of this equipment. Only equipment that was considered as an additional requirement for participation in the study

over and above what would normally be required for running an intensive care unit is included. Thus monitoring equipment for each bed is included but a blood gas analyser, which would be required for the running of any intensive care is not, and is, instead, included in the hotel costs (Table 2). The daily use of monitoring equipment was obtained by considering its purchase price and life-expectancy, giving an average cost of £82.19 per day. Table 2 shows the unit cost of consumables used during the study, including 'hotel' costs for intensive care and ward care.

Table 1 Costs of capital equipment and maintenance

Capital equipment	Cost (£)	Life-expectancy (years)
Monitoring equipment on intensive care	150,000	5
Syringe driver	1,000	5
Volumetric pump	700	5
Ventilator	20,000	12
Lactate analyser	4,000	5
Maintenance of equipment (per day)	14	

Comparison of study groups

The study groups were compared at the different phases of their routine perioperative management, i.e. preoperative intensive care management, post-operative intensive care management and post-operative ward management (Table 3). Since there was very little difference in the routine study treatment for the two patient groups, the differences in costs result from differences in length of intensive care and ward stay. The infusion of dopexamine that was required in some of the 'protocol' patients to increase oxygen delivery contributed negligibly to the total costs.

The cost of management of complications was considered separately. Table 4 shows the costs of treating specified complications in the control and protocol groups. Because each patient was considered individually, the costs of treating each individual complication was not necessarily the same for control and protocol patients. Indeed 12/18 complications were found to be more expensive to treat in the control patients and 4/18 were more expensive in the protocol patients. Also, the occurrence of a complication did not mean that an additional cost was incurred in treating that complication. For example, acute myocardial infarction required no specific treatment to be given to three patients, as this was thought to be a terminal event by the surgical teams in direct charge of the patients' management. Also, it should be noted that specific treatment for a complication may already have been given as part of a treatment for another complication incurred by the same patient – such treatments were not counted twice, leading to some apparent anomalies in Table 4, such as the apparent cost of treatment for acute myocardial infarction being zero. Not included in the cost of treating complications is any additional hospital stay required as this was already included in the hospital costs in Table 3. The median cost for treating complications in the two groups was £212.96 for protocol patients and £668.40 for control patients. This difference was due both to the higher incidence of complications in the control group and the higher cost of treating individual complications in this group.

Table 2 Costs of consumables

Consumable	Cost (£)
Blood count	2.80
Clotting screen	2.50
Biochemistry	11.00
Chest X-ray	13.62
ECG	30.00
Blood cross-match (per unit)	4.67
Blood grouping	9.00
Two channel pressure monitor	16.97
Pulmonary artery catheter, cardiac output set and insertion set	120.51
16G cannula	14.23
20G cannula	10.29
Line site dressing	2.00
Lactate analysis (syringe etc)	0.30
Blood gas measurement (syringe etc)	0.25
Colloid (500 ml)	3.34
Crystalloid (1000 ml)	0.76
Dopexamine hydrochloride (50 mg/5 ml)	21.00
Syringe (50 ml for drug administration)	0.33
Red cells (unit)	30.65
Platelets (unit)	135.38
Fresh frozen plasma (unit)	28.16
Cryoprecipitate (unit)	28.77
Morphine (10×1 ml)	6.25
Propofol (5×20 ml)	22.28
Surgery (h)	1000.00
Intensive care hotel costs (h)	33.00
Ward care hotel costs (day)	309.00

The total costs for patients in the two groups are shown in Table 5. Table 5 also gives details of an estimate of cost-effectiveness by presenting the overall costs in terms of the surviving patients in each group. In the protocol group, both the total cost spent on patients and the cost per survivor were less. The differences in costs arose as a result of differences in the significantly improved survival and reduced complications, and due to the non-significant decreases in intensive care and ward stay among patients in the protocol group previously reported [11] (Table 6). These outcomes are the cost drivers for the two groups. Since the differences in intensive care and ward stays between the

Table 3 Costs (£) of preoperative, additional intraoperative and postoperative care for protocol and control patients. Median, 25th and 75th centile range

	Protocol patients	Control patients
Preoperative costs	576.83 (576.83, 576.83)	569.93 (569.93, 569.93)
Intraoperative costs*	7.80 (7.80, 7.80)	0
Postoperative hospital costs	5,640.19 (3,316.27, 17,248.16)	6,458.23 (3,334.19, 15,487.32)

* Attributable to the cost of dopexamine

Table 4 Costs (£) of treatment of individual complications in protocol and control patients, see text for details. Median (range)

Complication	Protocol	Control
Respiratory failure	159 (80–558)	160 (80–957)
Acute renal failure	980 (12–1844)	631 (6–5040)
Sepsis	261 (261)	261 (261–5,987)
Cardiorespiratory arrest	131 (0–393)	392 (0–472)
Pulmonary oedema	173 (21–173)	144 (0–182)
Pleural fluid	27 (0–161)	1,090.50 (0–2,181)
Wound infection	85 (85–2,126)	85 (85–2,127)
Disseminated intravascular coagulation	445 (445)	693.50 (445–942)
Acute myocardial infarction	0 (0)	0 (0)
Abdominal abscess	–	278 (278)
Postoperative haemorrhage	2,845 (2,845)	1,340.50 (278–2,304)
Gastric outlet obstruction	89 (89)	–
Cerebrovascular accident	–	253 (228–278)
Pulmonary embolism	–	117 (65–169)
Chest infection	160 (160)	160 (160)
Psychosis	91 (91)	91 (91–116)
Distal ischaemia	1,044 (87–2000)	2,413 (186–2513)
Other	61 (61)	47 (47)

Table 5 Total costs, cost savings and cost-effectiveness analysis for patients in the protocol and control groups of the study. Median, 25th and 75th centile

Cost (£)	Protocol	Control
Total cost/patient	6,525.38 (4,201.46, 17,468.92)	7,784.17 (4,660.13, 16,155.72)
Cost/surviving patient	6,916.90 (4,453.55, 18,517.05)	10,008.22 (5,991.59, 20,771.64)

two groups were not significant, a sensitivity analysis was performed.

The analysis in Fig. 1 shows the impact on potential cost savings as a result of different lengths of intensive care and ward stay among protocol patients. If the length of hospital stay for protocol patients were to be increased from 40 h to 46 h in the intensive care and from 12 days to 14 days on the ward, as was the case for control patients, then the cost saving per protocol patient would be reduced from £1,259 to £422 and the cost saving per surviving protocol patient would be reduced from £3,091 to £2,205. The sensitivity analysis also shows that a protocol patient would cost the same as a control patient if their length of hospital stay were to be increased to 49 h in the intensive care unit and 15 days on the ward. Similarly, a surviving protocol patient would cost the same as a surviving control patient if their length of hospital stay were to be increased to 60.5 h in the intensive care unit and 19 days on the ward. Hence, the length of hospital stay for a protocol patient would have to be substantially increased before potential cost savings were no longer made.

Discussion

This study evaluates the cost implications of perioperatively increasing oxygen delivery in high risk surgical patients, by retrospectively comparing the costs of protocol and control patients in our previously published clinical trial [11]. The evaluation demonstrates that the

Table 6 Major results from the randomised controlled trial of a deliberate increase in oxygen delivery in high risk surgical patients [11]

	Protocol	Control	*p*
Mortality (%)	5.7	22.2	0.015
No. of complications (mean ± SE)	0.68 ± 0.16	1.35 ± 0.20	0.008
Intensive care stay, hours (median, 25th and 75th centile)	40 (19, 120)	46 (20, 98)	0.58
Ward stay, days (median, 25th and 75th centile)	12 (7, 40)	14 (7, 37)	0.63

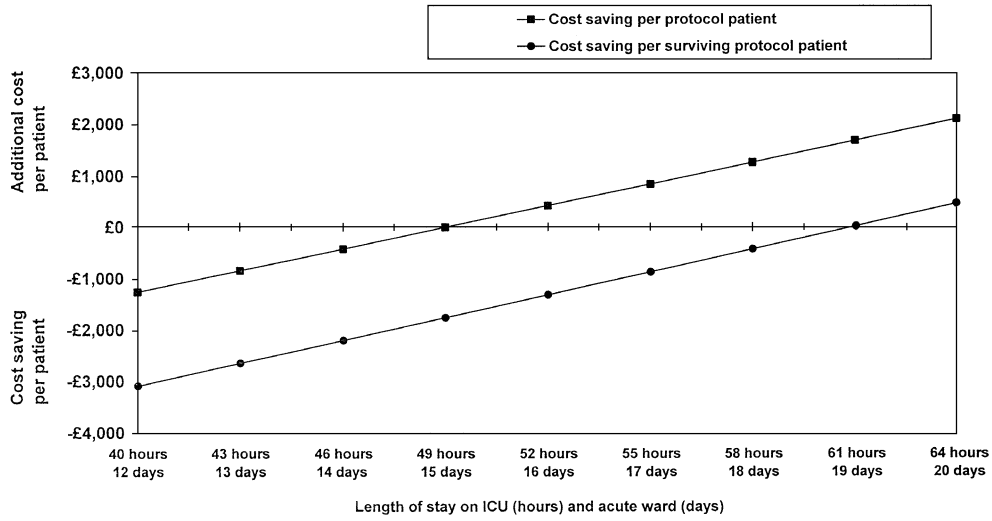

Fig. 1 Impact of variation in length of hospital stay on the potential cost saving per protocol patient

median total cost for patients in whom oxygen delivery was deliberately increased towards a target value of 600 ml/min per m^2 was £6,525.38, compared with £7,784.17 for control patients. Most of the difference was due to the non-significant difference in hospital stay and to the significant difference in treating complications between the two groups. Cost-effectiveness analysis showed that there was a 31% reduction in costs for obtaining a survivor in patients in whom oxygen delivery was deliberately increased, from £10,008.22 to £6,916.90. Break-even points for the non-statistically significant cost drivers would require protocol patients to stay 4 h longer on the intensive care unit and 1.5 days longer on the ward than control patients, quite the opposite to the results of the original study (Table 6).

There are very few studies that have investigated the effects of new research on cost. Shoemaker showed that costs were significantly reduced in his study in the group in whom oxygen delivery had been specifically increased [10]. Although these results show a similar trend to our own, they are difficult to compare directly as there is no detail given of what was included in the final figure or how this was arrived at; presumably costs were based on charges made to patients. Recently, the large variations between charges and actual costs that arise due to variations in hospital pricing policies, have been emphasised [19]. In our study, although some of the costs included were based on charges made by one service, e.g. radiology, to another, e.g. surgery, we considered direct healthcare costs incurred at St George's Hospital, rather than the prices charged to purchasers.

In estimating the costs in the current study a number of assumptions have been made. Not included in this analysis was 'routine' preoperative care on the surgical ward. This care was the same for both study groups and standard for this type of surgery. Also, there are varying lengths of preoperative stay that were not documented and were multifactorial in cause. Furthermore, surgery costs have not been included, except for the costs of re-operation for the treatment of a complication, because this analysis is concerned with the cost effects of the perioperative care and not the surgery.

There are a number of limitations to this study. Firstly, the analysis is based on clinical data censored at 28 days postoperatively. Secondly, the analysis does not consider the impact of increased survival on future healthcare costs. Thirdly, the study concentrates on direct healthcare costs to the National Health Service. The evaluation did not include direct costs to patients, their families and non-healthcare providers, indirect costs due to lost productivity, and other intangible costs. Fourthly, the valuation of costs used in this study is based on St George's Hospital in London, UK for the year 1993/94. Differences in costs between St George's Hospital and other institutions, and variations among patients, may necessitate modification of the actual costs presented in this study before they are applied to other institutions. However, the costs identified as part

of this study are very much in line with those used in other studies [20–22]. Furthermore, it would require a large and unexpected difference in the cost of a particular resource before the conclusions of this study became invalid.

There are now a number of randomised, controlled clinical trials that have investigated the hypothesis that increasing oxygen delivery in the perioperative period might lead to improved outcome. Studies on perioperative patients have all shown an improved outcome in the treatment arm of the study [10–12, 14]. In studies of high risk perioperative patients Boyd and colleagues [11], and Shoemaker et al. [10], both showed a significant reduction in postoperative mortality. Earlier, Schultz et al. showed a significant reduction in mortality among patients undergoing operation for fractured neck of femur, but the treatment used in this study is not absolutely clear [12]. In a study of patients undergoing vascular surgery, Berlauk and colleagues [14] showed a reduction in perioperative and postoperative cardiac events, but the reduction in mortality did not reach statistical significance. Studies of trauma patients have shown reduced post-trauma organ failure [15] and improved survival in elderly patients [13]. However, when trying to rationalise these research findings with current clinical practice it is often perceived that there will be increased financial costs. This study demonstrates that this is not necessarily so, and shows that the increased financial cost of improved therapy can ultimately result in net cost savings due to the reduced costs of treating complications and of a shorter hospital stay.

In conclusion, this study shows that a treatment policy aimed at deliberately increasing oxygen delivery in the perioperative period in high risk surgical patients results in reduced hospital costs and, as we have shown previously, reduces mortality. Findings such as these have important implications for the direction of future research, the management of high risk surgical patients and the funding of intensive care.

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