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# Economic analysis of the implementation of autologous transfusion technologies throughout England

**Simon Dixon**
*University of Sheffield*

**Virge James**
*National Blood Service (Sheffield)*

**Daniel Hind**
*University of Sheffield*

**Craig J. Currie**
*University of Wales College of Medicine*

**Objectives:** This study aims to provide the first estimates of the costs and effects of the large scale introduction of autologous transfusion technologies into the United Kingdom National Health Service.
**Methods:** A model was constructed to allow disparate data sources to be combined to produce estimates of the scale, costs, and effects of introducing four interventions. The interventions considered were preparing patients for surgery (PPS) clinics, preoperative autologous donation (PAD), intraoperative cell salvage (ICS), and postoperative cell salvage (PoCS).
**Results:** The key determinants of cost per operation are the anticipated level of reductions in blood use, the mean level of blood use, mean length of stay, and the cost of the technology. The results show the potential for considerable reductions in blood use. The greatest reductions are anticipated to be through the use of PPS and ICS. Vascular surgery, transplant surgery, and cardiothoracic surgery appear to be the specialties that will benefit most from the technologies.
**Conclusions:** Several simplifications were used in the production of these estimates; consequently, caution should be used in their interpretation and use. Despite the drawbacks in the methods used in the study, the model shows the scale of the issue, the importance of gathering better data, and the form that data must take. Such preliminary modeling exercises are essential for rational policy development and to direct future research and discussion among stakeholders.

**Keywords:** Autologous transfusion, Surgery, Cost

In the United States, the uptake of blood sparing technologies for surgery has led to a slight reduction in blood use in recent years (2). However, the utilization of these technologies is currently low in the United Kingdom, with only 19 percent of hospitals using acute normovolemic hemodilution, 37 percent using cell salvage, and 51 percent using predeposit autologous donation (6). Even these figures are deceptively high, as only 6 percent of those hospitals undertaking predeposit autologous donation used more than 20 units, 4 percent undertaking acute normovolemic hemodilution used more than 20 units, and 8 percent of those using cell salvage transfused more than 100 units.

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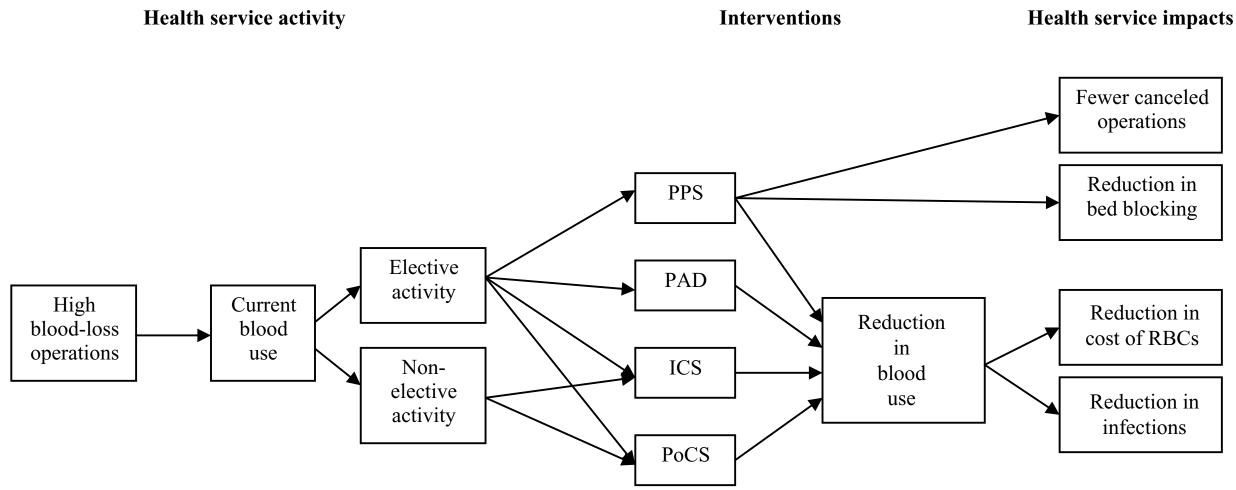


**Figure 1.** Structure of the model. PPS, Preparing patients for surgery; PAD, Pre-operative autologous donation; ICS, Intra-operative cell salvage; PoCS, Post-operative cell salvage; RBCs, Red blood cells.

Interest in the potential role of blood sparing technologies in the United Kingdom has increased recently due to the increasing cost of pursuing "zero risk" transfusion; a unit of blood costs around £100. Also, there are concerns that, if a test for variant Creutzfeldt–Jakob disease is developed, donors will stop giving blood as a positive test would be distressing and may preclude them from life insurance and mortgage applications (8). Consequently, a contingency planning exercise was undertaken to assess how the United Kingdom National Health Service (NHS) could respond to a severe, prolonged shortage of blood (7). This work was undertaken in support of the National Blood Service (NBS) contingency planning exercise.

A recently published systematic review was used in the choice of the most promising interventions to be considered (10). The interventions chosen were as follows:

- Preparing patients for surgery (PPS) clinics. Such clinics would provide a much more rigorous assessment of patients together with presurgery treatments (e.g., iron supplementation).
- Preoperative autologous donation (PAD). This process involves the patient donating blood on three occasions in the month before surgery, thus reducing the need for allogeneic blood.
- Intraoperative cell salvage (ICS). This process involves blood lost during surgery being "recycled" and filtered for use again in the patient.
- Post-operative cell salvage (PoCS). This process is applied in knee replacement patients, and involves blood being collected postoperatively from around the site of the operation, and being "recycled" and filtered for use again in the patient.

The aim of the study was to support the policy-making process, and in particular, produce national estimates of the following: scale of potential implementation, costs of implementing the various interventions, reduction in blood use, and reduced length of stay associated with reductions in infections. Other impacts, such as reductions in the number of canceled operations, were ruled out of the analysis.

## METHODS

A model was constructed to describe health service activity, the interventions, and their effects. A schematic representation of the model is shown in Figure 1.

### Identification of High Blood-Loss Operations

To generate cost estimates, a list of operations that would be suitable for the target interventions was required. The source of the list that was agreed upon was the Maximum Blood Ordering Schedule (MBOS) for North Glasgow University Hospitals NHS Trust (www.ngt.org.uk/transfusion/appendix7/htm). It was decided to focus on five specialties described in the MBOS: General surgery, Vascular surgery, Orthopedics, Cardiothoracic surgery, and Obstetrics and Gynecology. Transplant surgery was added to this, as it was considered an important recipient of these technologies. The operations were classified into four-digit OPCS codes by the NHS Information Authority and generated over 500 operation codes.

### Identification of Health Service Activity

Once the operation codes for the target operations were known, annual activity figures for 2000–2001 were taken from the United Kingdom Hospital Episodes Statistics. For the purposes of this study, we needed:

- Number of operations by operation code.
- Number of elective and emergency operations by operation code. This distinction is required as some of the interventions can only be used for elective operations.

- Average length of stay by operation code. This is required to assess potential reductions in length of stay associated with the interventions.

## Identification of Current Blood Use for Target Operations

A data set covering 8 years of transfusions at a large teaching hospital (Cardiff and Vale NHS Trust, Cardiff) was identified, and a data request was granted. The mean blood use for each operation as described by its OPCS code was calculated. Mean blood use is defined as total blood use over the entire patient stay and includes episodes where no blood was used.

## Identification of Resources Required to Deliver the Intervention

Data on resource use was gathered using a modified Delphi approach with fifteen experts on autologous transfusion technologies, by means of postal survey. This method took the following format:

- Health-care professionals involved in the NBS process would be asked for their opinions on the costs of implementation of the technologies and the likely impact on blood use, length of stay, and canceled operations. The basis of their estimates would also be elicited (e.g., literature, personal experience, opinion).
- These data would be processed and the results sent back to members showing the responses of the group with the reasons for divergent opinion. Respondents would then be asked to modify their estimates in light of these data and justify their position.
- This process would be repeated until no further movement in the position of members was achieved.

A questionnaire was constructed and piloted using local Clinical Hematologists. The revised questionnaire was then sent out to the health-care professionals involved in the NBS process. A total of five responses were received (33 percent response rate), together with a complete questionnaire from a pilot survey. Due to the late arrival of most of the questionnaires, the iteration of responses using the modified Delphi approach was not possible.

Consequently, few data were available to generate unit costs for the four interventions; therefore, it was decided to use simple unit costs taken from existing studies or estimated using known cost of consumables or the cost of the necessary hospital visits. The unit costs used were as follows:

- Preoperative assessment clinics = £ 74. This value is based on the average national cost of a "generic" outpatient attendance, taken from hospital financial returns.
- Preoperative autologous transfusion = £ 222. This value is based on three generic outpatient attendances.

**Table 1.** Model Parameters Taken from Expert Opinion

| | Blood reduction | | | | Patients eligible | |
|---|---|---|---|---|---|---|
| | PPS | PAD | ICS | PoCS | PAD | PoCS |
| Orthopedics | 10% | 30% | 20% | 30% | 40% | 50% |
| Cardiothoracic surgery | 20% | 10% | 30% | n/a | 30% | n/a |
| Vascular surgery | 10% | 40% | 45% | n/a | 30% | n/a |
| General surgery | 20% | 20% | 20% | n/a | 20% | n/a |
| Gynecology | 15% | n/a | n/a | n/a | n/a | n/a |
| Transplant surgery | 5% | n/a | 45% | n/a | n/a | n/a |

PPS, preparing patients for surgery; PAD, preoperative autologous donation; ICS, intraoperative cell salvage; PoCS, postoperative cell salvage; n/a, not applicable.

- Intraoperative cell salvage = £ 150. This value is based on the median cost of disposables used per procedure in the five hospitals participating in the Trent Cell Salvage Pilot Study (3).
- Postoperative cell salvage = £ 60. This value is based on the purchase price of a 2-unit bag used to collect blood postoperatively (Dr. Virge James, personal communication).

## Identification of Reductions in Blood Use and Length of Stay

Satisfactory estimates of blood reductions were not available from a recent systematic review as its scope was too narrow to estimate the potential impact of the technologies across hundreds of different operations (10). Consequently, these data came from the modified Delphi exercise described above. The six questionnaire responses were used to produce estimates of reduction in blood use for each intervention and the likely eligibility of patients for PAD and PoCS (Table 1). Not all interventions can be used for both elective and emergency operations, and so the following assumptions were made:

- PPS clinics can be used for elective operations only.
- PAD can be used for elective operations only, and within these, for patients deemed eligible.
- ICS can be used for all operations.
- It is assumed that PoCS is just used for revision of knee prostheses and total knee arthroplasties only.

Estimation of the reduction in infection rates and length of stay were taken from a study that had investigated the effects of allogeneic blood (12). The study investigated 487 patients undergoing colorectal cancer resection and identified a statistically significant increase in length of stay of 1.3 percent associated with each additional unit of red blood cells after adjusting for 20 confounding factors.

## Analysis

The model was constructed in a spreadsheet format and aimed to produce the following outputs; level of activity associated with the technologies, gross cost (i.e., excluding potential savings), reduction in the number of red blood cells used, and net cost, including reductions in blood use and length of stay associated with reduced infection. Costs are estimated at 2001/2002 prices. Sensitivity analysis was undertaken to assess the robustness of the model estimates to changes in key variables.

## RESULTS

PPS is shown to be potentially the most widely used intervention within the chosen specialties, with over 750,000 operations potentially benefiting from it (Table 2). General surgery is estimated to show the greatest reduction in blood use for PPS, although orthopedic surgery is expected to have the greater reduction in bed days used. Overall, applying this technology to cardiothoracic surgery appears to be the most cost-effective, with it saving £ 33 per patient, whereas gynecology appears to be the most expensive.

PAD is the least cost-effective technology, with an average cost per patient of £ 133, although this value hides considerable variation between specialties (Table 2). In particular, it is potentially cost-saving within vascular surgery. PAD was not considered appropriate for gynecology or transplant surgery.

ICS is potentially cost saving in four specialties, with its use in vascular surgery and transplant surgery particularly cost-effective. Its high cost in orthopedics, however, means that its overall cost per patient is higher than for PPS (Table 2).

PoCS is only applicable to knee replacement surgery; therefore, the scale of implementation is relatively small at just 52,000 operations. However, it is estimated to save 23,264 units of red blood cells and 2,898 bed days, with a net cost of £ 1 per patient.

Overall, the analysis shows that the technologies could be applied to around 1.6 million operations, which in turn, would reduce the number of units of red blood cells used by 783,000 (Table 2). This strategy would require around £ 191 million of funding, although £ 100 million would be generated in savings associated with reductions in blood use and bed days. Vascular surgery, transplant surgery, and cardiothoracic surgery appear to be the specialties that will benefit most from the technologies.

The results of the sensitivity analysis show that blood reductions need to be lowest in cardiovascular surgery and transplant surgery in order for the technologies to be cost neutral. In contrast, unrealistic reductions in blood use of over 70 percent are required for PAD to become cost neutral (Figure 2).

## DISCUSSION

Very little is known about the potential costs and effects of implementing blood sparing technologies in the United Kingdom. This study provides the first estimates of the costs and effects of the large scale introduction of these technologies

**Table 2.** Scale of Possible Implementation of Technologies and Their Associated Impacts

| | PPS | | | | PAD | | | | ICS | | | | Total[a] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of operations | RBC saved | Bed days saved | Cost per patient | Number of operations | RBC saved | Bed days saved | Cost per patient | Number of operations | RBC saved | Bed days saved | Cost per patient | Number of operations | RBC saved | Bed days saved | Cost per patient |
| Orthopedics | 232,583 | 55,210 | 6,877 | 43 | 93,033 | 66,252 | 8,252 | 129 | 371,010 | 176,140 | 21,940 | 88 | 748,155 | 320,866 | 39,967 | 73 |
| Cardiothoracic surgery | 52,580 | 41,677 | 6,070 | −33 | 15,774 | 6,252 | 911 | 168 | 55,555 | 66,053 | 9,620 | −11 | 123,909 | 113,981 | 16,601 | 3 |
| Vascular surgery | 29,777 | 11,949 | 2,184 | 16 | 8,933 | 14,338 | 2,621 | −10 | 38,826 | 70,108 | 12,815 | −110 | 77,537 | 96,395 | 17,619 | −50 |
| General surgery | 175,966 | 84,056 | 6,830 | 17 | 35,193 | 16,811 | 1,366 | 165 | 189,602 | 90,570 | 7,359 | −93 | 400,761 | 191,438 | 15,555 | 66 |
| Gynecology | 260,369 | 52,894 | 1,583 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 260,369 | 52,894 | 1,583 | 52 |
| Transplant surgery | 823 | 229 | 59 | 29 | 0 | 0 | 0 | 0 | 2,853 | 7,157 | 1,841 | −257 | 3,676 | 7,387 | 1,900 | −193 |
| Total | 752,098 | 246,015 | 23,602 | 34 | 152,933 | 103,653 | 13,150 | 133 | 657,846 | 410,028 | 53,574 | 68 | 1,614,407 | 782,960 | 93,224 | 56 |

[a] Also includes postoperative cell salvage, which can be applied to 51,530 operations, saves 23,264 units of red blood cells, 2,898 bed days, with a net cost of £ 1 per patient. PPS, preparing patients for surgery; PAD, preoperative autologous donation; ICS, intraoperative cell salvage; RBC, red blood cell.

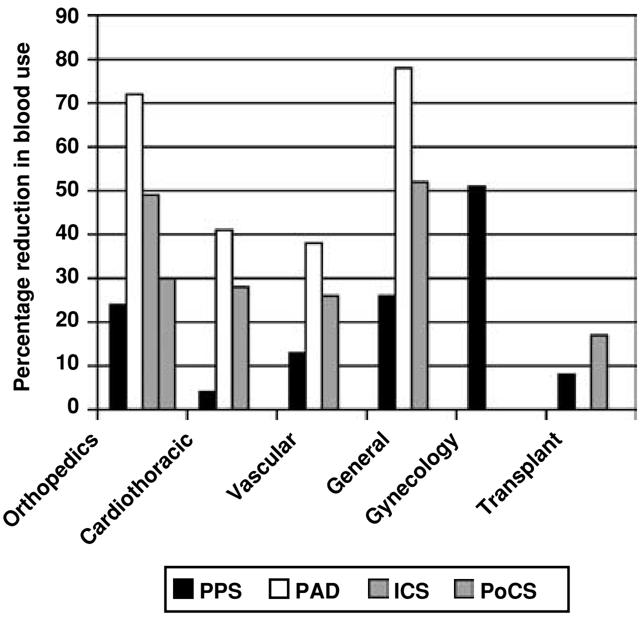


**Figure 2.** Reductions in blood use required for each technology to become cost neutral. PPS, preparing patients for surgery; PAD, preoperative autologous donation; ICS, intraoperative cell salvage; PoCS, postoperative cell salvage.

into the NHS. The results show the potential for considerable reductions in blood use. The greatest reductions are anticipated to be through the use of ICS (410,000 units per annum) and PPS (246,000 units per annum).

The estimate of total reductions in blood use across all technologies is 783,000 units, and this estimate is associated with a predicted reduction in the number of bed days of 93,000. However, these figures are likely to be overestimates as they do not take into account interactions between the technologies being used on the same patients.

Several simplifications were used in the production of these estimates and should be addressed in future research. These simplifications are as follows:

- Limited number of specialties. Other specialties are candidates for the limited use of these technologies.
- Limited number of interventions. Other techniques that may reduce the need for allogeneic blood are available, such as hemodilution and patient warming, but have not been considered.
- Limited consultation on the operations suited to each technology. The list of operations was based on practice at a single hospital.
- Use of blood use data from a single hospital. Blood usage is known to vary dramatically between hospitals; therefore, we do not know whether our data reflect the pattern of blood use throughout England or beyond the United Kingdom (4;5;9;11).
- Simple cost data were used for each intervention and reductions in length of stay.
- Estimates of the reduction in hospital stay based on a single study.
- Blood reduction based on professional opinion. Clearly, this is a severe limitation; however, provisional estimates from the Trent Cell Salvage study show that they are reasonable and perhaps even conservative (3).
- Reduced rate of canceled operations and improved discharge resulting in less bed blocking have been ignored. These are two potential operational improvements that may be generated by PPS.
- Other clinical benefits of the interventions have not been factored into the analysis. Once again, PPS may generate other benefits such as screening and treating comorbidities, which have not been included in this study.

Problems with data availability were compounded by the failure of the modified Delphi exercise to generate sufficient data to estimate accurately the costs of the various technologies and their impacts on the health service. This experience points to the problems in eliciting complex, quantitative data through postal surveys even from a well-motivated group of experts involved in the decision-making process.

The interpretation of the "cost savings" needs to be undertaken carefully, as many of them will not be realized. Reductions in length of stay will not generate savings, as the free beds will be filled immediately with other patients. The "savings" associated with reduced length of stay are best interpreted as improvements in efficiency, or savings that are immediately re-invested in the provision of hospital care.

Some consideration also needs to be given to the implementation of the interventions. Some will have consequences for training and the organization of the health service more generally. The most important issue, however, is considered to be the capacity of hospitals to provide the additional PPS clinics and PAD sessions. Table 2 shows that around 752,000 elective operations could be eligible for PPS in the six specialties examined, which equates to around 17,000 staffed outpatient clinics (assuming 15 patients can be seen in a 3-hour session). Likewise, our analysis shows that 152,000 operations could be eligible for PAD (Table 2) in the six specialties examined, which equate to around 460,000 donor sessions (assuming three sessions per operation).

The model produced was not aimed at producing detailed estimates of cost-effectiveness or cost per quality-adjusted life years. Such a model would need to be more detailed and would necessarily be more focused on a smaller set of operations. The aim of this model was quite different; it was to support the policy-making process by estimating the potential scale of implementation and the magnitude of reduction in red blood cells. Such an approach requires a much broader view of all operations that will potentially benefit from the technologies, while requiring a shallower, or less detailed, analysis of their precise outcomes. This distinction is absolutely central to assessing the value of this modeling approach, and we consider it to be "fit for purpose."

Finally, the figures produced in this study should be considered as preliminary estimates. Improvements to the estimates can be made incrementally, as more reliable figures are produced and would ideally be guided by a value of information analysis (1). Despite the drawbacks in the methods used in the study, the model forms a basis for amalgamating the data necessary to make informed decisions. It also shows the scale of the issue, the importance of gathering better data, and the form that data must take. Such preliminary modeling exercises are essential for rational policy development and direct future research and discussion among stakeholders.

### Policy Implications

The widespread adoption of the four most promising autologous blood interventions can significantly reduce the NHS's dependence on blood donations; however, this study shows that it will cost around £191 million pounds to implement in England. Cost offsets in the form of reduced blood use and lower lengths of stay produces a net cost of around half this level. Targeting each technology at those specialties where they are most cost-effective will help reduce the costs of implementation and will allow time for further research to produce more accurate estimates of cost-effectiveness. As well as the traditional form of economic evaluation that looks at one intervention in one patient population, policy-based analyses of the kind described here are essential.

## CONTACT INFORMATION

**Simon Dixon**, MSc (s.dixon@shef.ac.uk), Senior Lecturer, School of Health and Related Research, University of Sheffield, 30 Regent Street, Sheffield, South Yorkshire S1 4DA, UK

**Virge James**, DM (Oxon) (virge.james@nbs.nhs.uk), Consultant Hematologist, National Blood Service (Sheffield), Longley Lane, Sheffield, South Yorkshire S5 7JN, UK

**Daniel Hind**, PhD (d.hind@shef.ac.uk), Research Associate, School of Health and Related Research, University of Sheffield, 30 Regent Street, Sheffield, South Yorkshire S1 4DA, UK

**Craig J. Currie**, PhD (currie@cardiff.ac.uk), Research Fellow, Department of Diabetes, Endocrinology, and Metabolism, University of Wales College of Medicine, Heath Park, Cardiff, South Glamorgan CF14 4XN, UK

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