TECHNICAL COMMUNICATION

Economic Analysis of an Intraoperative Cell Salvage Service

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In the United States, the cost of erythrocyte transfusion exceeds 1.3 billion dollars annually. The fear of viral disease transmission popularized intraoperative salvage to reduce the use of banked blood. Although the economics of this technique have been questioned, the financial variables in providing an intraoperative autotransfusion service have not been analyzed. We designed mathematical models to determine the most cost-effective strategy based on hospital caseload. Four models were analyzed with a spreadsheet to project costs of an intraoperative autotransfusion service when fully or partially outsourced, performed by a full-time technician employee, or performed by a cross-trained employee. The Partially Outsourced model was more economical than the Fully Outsourced model when the annual caseload exceeded 185 cases. The New Employee model became more economical than the Fully Outsourced model when the annual caseload exceeded 110 cases. The Cross-Trained model was the most economical when annual caseload exceeded 55 cases.

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In the United States (US), the cost of allogeneic erythrocyte transfusion exceeds 1.3 billion dollars annually (1). This estimate does not include the costs of treating transfusion-related complications, including transfusion reactions, viral diseases, and infections possibly caused by immunosuppression. The fear of viral disease transmission popularized intraoperative salvage and washing to reduce the use of allogeneic blood. Several authors have questioned the cost-effectiveness of this technique (2–9). However, these studies did not examine the financial variables in providing an intraoperative autotransfusion service (IATS). Training an anesthesia technician as a cell salvage technician may be an economical means of obtaining an IATS. Given the importance of economics-based medicine as a subset of evidence-based medicine, mathematical models of IATS variables were designed to determine the most cost-effective strategy based on a hospital's caseload.

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Methods

With institutional approval, four models were analyzed with a spreadsheet (Excel2000®; Microsoft Corp., Redmond, WA) to obtain annual cost projections. These four models were designed to test the relative cost of an IATS when fully outsourced to an outside company, partially outsourced, run by a new full-time technician employee, and when an existing employee was cross-trained on the IATS equipment and procedures. The Fully Outsourced model assumed that the entire service (machine, disposables, technician) was obtained entirely by outsourcing. The Partially Outsourced model assumed that the hospital provided the machine and disposables but contracted the services of a technician. The New Employee model assumed that the hospital provided the machine and disposables and hired a full time technician whose sole responsibility was cell salvage. The Cross-Trained model assumed that the hospital provided the machine and disposables, but cross-trained a current employee as a cell salvage technician. This employee was compensated for this additional duty with a bonus. It is assumed that the IATS duties do not impinge upon the technicians' duties to the extent that a new full-time employee is required.

The Fully Outsourced fee per case was obtained by averaging the regional US rates of one contractor, whereas the Partially Outsourced rate was the estimate obtained from another contractor and was consistent with rates in the greater Washington, DC metropolitan area.

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The costs of equipment and disposables were the averages of four manufacturers' list prices, although permission to release their names was not obtained (Table 1). The machine costs were prorated over an estimated lifespan of 8 yr (10), and calculations included an annual machine maintenance fee.

Cost assumptions also included a maximum of one case per day, 250 working days in the year, and a flat fee per case without adjustment for case duration, shift, or number of processed units of cell salvage blood. The cost of transfer bags for processed blood was estimated at $12 per procedure, and based on one supplier's price for 2 bags. The median surgery technician's salary (year 2000) and average benefits package (year 2002) data used in the analysis were the most recent available from the US Department of Labor (11,12). The arbitrarily selected bonus amount for the Cross-Trained model was $15,000 per year.

The total annual costs for these models were determined by a sensitivity analysis of the projected annual cost of an IATS to the annual caseload. Other variables were held constant in each of the models as they represent costs that would be reasonably expected for the services and/or supplies.

Total projected annual cost and cost per case were generated using the equations listed in Table 2.

The accuracy of the Cross-Trained model was assessed by comparing it with data from the National Naval Medical Center's (NNMC) IATS database. The model was modified (Modified Cross-Trained model) to accommodate for shift, multiple simultaneous cases, number of units processed, and standby service. (Standby service is defined as collection with insufficient blood loss for processing.) Cases that occurred on weekends or outside weekday times of 0800 to 1600 were considered overtime cases and subject to a time and a half shift premium. Hourly wage was calculated from the median surgery technician's salary based on a 40-h workweek for 52 wk per year. Per unit charges (equal to the cost of a transfer bag) were also applied. Standby service in the Modified Cross-Trained model billed $90 for disposables when provided by the hospital. Additional simultaneous cases were billed at the Fully Outsourced Rate regardless of shift, duration, or number of units processed to simulate the cost of fully outsourcing when the in-house service is already in use. Fully Outsourced standby case fee was assumed at $300 per case, also regardless of shift or duration.

The NNMC database was queried for data from 2000 through 2002. Costs were calculated using the Modified Cross-Trained model as described in Table 2. The cost projections of the Modified Cross-Trained model were then compared with the others using linear regression analysis.

Table 1. Cost Assumptions for Intraoperative Autotransfusion Service

Cost of machine	$37,374 (±3038)
Lifespan of machine	8 yr
Prorated machine cost	$4672/yr
Annual maintenance	$3045 (±981)
Contract service	$623/case (±47)
Tech time	$300/case
Disposables	$217/case (±20)
Technician salary	$29,020/yr
Technician benefits	27.8% of salary
Technician bonus	$15,000/yr

All costs estimated in United States dollars and reported as mean (±SD) when available.

Table 2. Equations for Cost Analysis Models

Fully Outsourced = $n\,(c_1)$
Partially Outsourced = $n\,(c_2 + d) + m + s$
New Employee = $n\,(d) + c_3 + m + s$
Cross-Trained = $n\,(d) + b + m + s$
Modified Cross-Trained = $n(d) + b + m + s + h(13.95) + c_4$
Where:
b = cross-trained technician's annual bonus
c_1 = fully outsourced fee per case
c_2 = contracted technician fee per case
c_3 = new employee's full time salary + benefits
c_4 = multiple simultaneous case fee
d = disposables cost per case
h = hours overtime
m = machine cost per year
n = number of cases per year
s = machine maintenance service cost per year

Results

The Partially Outsourced model became more economical than the Fully Outsourced model when the annual caseload exceeded 185 cases (Fig. 1). The New Employee (hospital employed) model became more economical than the Fully Outsourced model when the annual caseload exceeded 110 cases. The Cross-Trained model became the most economical model when the annual caseload exceeded 55 cases. Cost per case decreased with increasing caseload for all but the Fully Outsourced model (Fig. 2).

The demographics of actual data from the NNMC IATS are summarized in Table 3.

Linear regression analysis demonstrated close correlation between the costs based on actual case data (Modified Cross-Trained model) and those of the theoretical Cross-Trained model (Fig. 3). Specifically, the regression line for the Cross-Trained model versus Actual Cost (CT = $1.1x - 2172$) more closely matched the equation for ideal correlation ($y = x$) than did any other model. This Modified

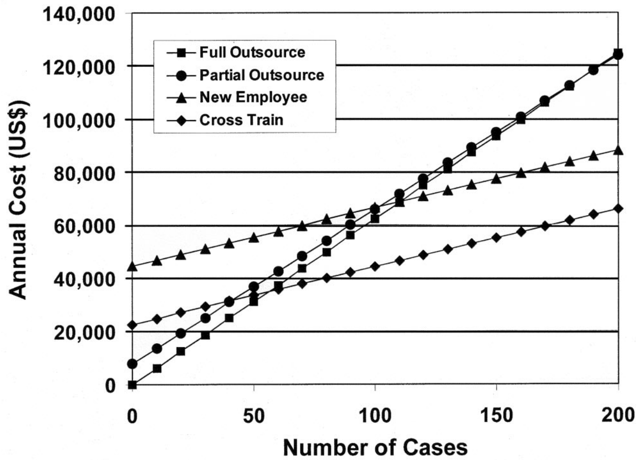

Figure 1. Annual intraoperative autotransfusion service costs.

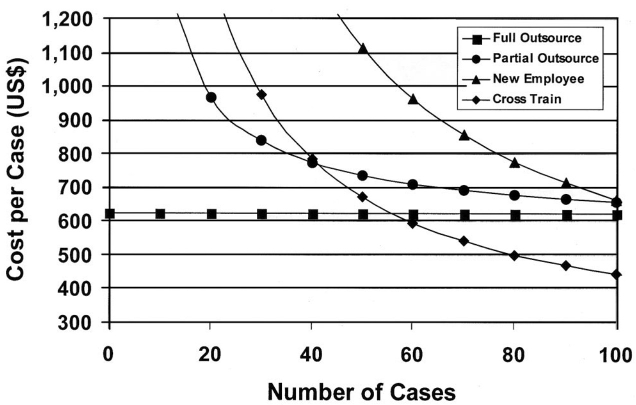

Figure 2. Intraoperative autotransfusion service cost per case.

Table 3. Summary of Actual Case Data by Year

	Year		
	2000	2001	2002
Total cases	49	77	84
Fully outsourced	0	2	5
In-house standby	2	23	36
Outsourced standby	0	2	4
Case duration (min)	236 (±138)	235 (±156)	219 (±145)
Overtime (h)	11.9	44.3	16.0
Units processed	133	177	156

Data reported as mean (±SD) when applicable.

Cross-Trained model was more economical than the Fully Outsourced model when annual caseload exceeded 55 cases, and closely matched the prediction of the Cross-Trained model.

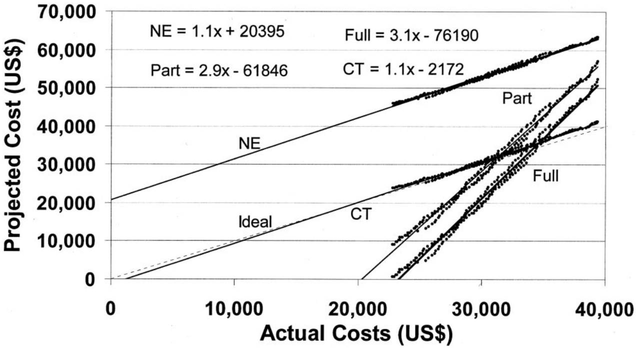

Figure 3. Projected versus actual intraoperative autotransfusion service costs. Full = fully outsourced, part = partially outsourced, NE = new employee, CT = cross-trained, ideal = fits equation of ideal fit y = x.

Discussion

The cost of perioperative allogeneic blood is significant (1) and has led to the development of techniques to reduce allogeneic transfusion. These strategies have included preoperative autologous blood donation, induced hypotension, hemodilution, pharmacological drugs such as aprotinin and erythropoietin, and perioperative salvage both with and without washing. However, these techniques have risks, unclear benefit, and/or are expensive. Fibrin split products in unwashed blood may activate both coagulation and fibrinolysis (13). Hemodilution may be beneficial (14–16), but does not help in acute, unanticipated hemorrhage. Autologous predonation exceeds the costs of allogeneic blood, and requires time, planning, and patient cooperation (17). Aprotinin costs approximately $1000 per dose and is associated with allergic reactions upon re-exposure (18) whereas recombinant erythropoietin can cost 4 times as much (17). Intraoperative salvage is an attractive alternative because it is available quickly, is free of viral contamination, and does not suppress the immune system. However, this expensive service requires dedicated personnel and equipment.

Many investigators (2–9) have questioned the value of an IATS because of this expense and the perceived safety of contemporary blood banking (19). Although one of these studies considered the additional costs of treating transfusion-related complications (4), the analysis only included transfusion reactions and viral disease transmission. Treating bacterial infections related to transfusion-induced immunosuppression was not analyzed, but two studies (20,21) have reported increased hospital costs of $300 to $1000 per unit of allogeneic blood transfused. Furthermore, these studies did not question whether there were more economical means of obtaining an IATS.

The presented analysis, although timely given contemporary medico-economics, has limitations regarding several cost and complication assumptions. The price anonymity is not scientifically satisfying, although an economic (and, perhaps, legal) necessity. Also, these price assumptions may be subject to geographic, volume, and shift-premium discrepancies that were not considered in the projections. However, these additional fees did not alter the accuracy of the model when applied to actual data from the NNMC IATS with shifts and multiple cases considered.

The assumption of one case per day may seem unrealistic, especially to a hospital with a large surgical volume, but it still provides a useful starting point for cost comparisons. If operating room managers consider an IATS service analogous to other essential pieces of surgical equipment and services (such as laparoscopic equipment, neuromonitoring, intensive care unit bed availability, and transesophageal echocardiography), then flexible scheduling of elective cases makes this assumption more realistic, and is substantiated anecdotally by the IATS data from the NNMC. Although all these differences may alter the efficiency of the presented models, adjusting the variables accordingly still helps a hospital determine its best strategy for obtaining an IATS, which was an objective of this study.

This analysis also did not consider the costs of training technicians, of their loss to their primary workspaces, and of their medical direction. Device manufacturers may include training as part of the machine purchase price. Inability to perform primary duties while cross-covering as an IATS technician is a valid concern. However, IATS duties require approximately 10–15 minutes each for equipment setup and breakdown, plus approximately 10 minutes to process each unit of cell salvage blood. It is not unrealistic to postpone or have another person temporarily cross-cover the other, less critical duties. And, although the salary of the medical director would impact the overall cost of an IATS, medical direction is required by the American Association of Blood Banks (22) regardless of the model chosen. Therefore, this salary is validly negated from each model without affecting their relative cost effectiveness.

This analysis did not consider rebates offered by manufacturers. As reported by Green (23), device manufacturers may lend machines (or discount list prices) as part of a disposables purchase agreement. Either of these rebates would further improve the efficiency of all but the Fully Outsourced model.

Related to the costs of equipment are the issues of machine lifespan and discounting the costs over time. The authors chose eight years as the lifespan of these machines, which was both arbitrary and consistent with another study (10). As machine lifespan increases, the costs of all but the Fully Outsourced model decrease. Likewise, discounting the machine costs over the eight-year projected lifespan would decrease costs in all but the Fully Outsourced model. Discounting was not applied in these (year 1) models because the discount rate does not apply to the year 1 costs (24).

This study did not consider the costs of treating complications caused by allogeneic or cell salvage blood. A major benefit of an IATS is avoiding the infectious complications associated with allogeneic blood. Although analyzing the costs of treating bacterial infections attributed to allogeneic transfusion is interesting, data have only been reported for hip arthroplasties (20) and colorectal resections (21) and are not easily extrapolated to the entire case-variety and patient population of an individual hospital. The better-documented cost of treating viral diseases also was not considered. These costs, fascinating from the standpoint of global health system economics, may be better quantified with a quality adjusted life year analysis (25). This technique was not used in this study because the results may not practically affect an individual hospital's decision to obtain an IATS unless that facility was absorbing the costs of these complications. Finally, no complex medical procedure, including those of an IATS, is risk free. However, there are no published data on the incidence of mishaps with these devices. A study of the incidence of these complications, their costs, and a comparison to those associated with allogeneic blood is long overdue, and could possibly impact a hospital's decision to obtain an IATS.

Cross-training a current employee with bonus compensation is the most efficient model when annual caseload exceeds 55 cases per year. Anesthesiology technicians can ideally fill this role. Two of the authors (DFS and PSP) have successfully managed IATS with this model. Anesthesiologists are ideally positioned to lead autotransfusion services because of their operating room presence and transfusion therapy experience. Physician leadership of a hospital's IATS, mandated by the American Association of Blood Banks (22), is consistent with the concept of the perioperative physician providing a "value-added" service (23). Physician leadership and the establishment of detailed guidelines are essential to the quality assurance of intraoperative erythrocyte salvage—a service described in an editorial as a "largely unregulated cottage industry" (26).

In summary, cross-training a current employee with bonus compensation is the most efficient IATS model when the annual caseload exceeds 55 cases. The Fully Outsourced model is more efficient with smaller caseloads. The financial assumptions for the cross-training model quickly break down if the case volume is large enough to necessitate hiring an additional technician. When case volume increases to this point, the costs become those of the New Employee model. Avoiding nonviral and bacterial infections associated with allogeneic transfusions may be of even greater value than this simple "make versus buy" analysis demonstrates, but this hypothesis requires further research.

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