

Estimating the cost of blood: past, present, and future directions

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Understanding the costs associated with blood products requires sophisticated knowledge about transfusion medicine and is attracting the attention of clinical and administrative health-care sectors worldwide. To improve outcomes, blood usage must be optimized and expenditures controlled so that resources may be channeled toward other diagnostic, therapeutic, and technological initiatives. Estimating blood costs, however, is a complex undertaking,

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surpassing simple supply versus demand economics. Shrinking donor availability and application of a precautionary principle to minimize transfusion risks are factors that continue to drive the cost of blood products upward. Recognizing that historical accounting attempts to determine blood costs have varied in scope, perspective, and methodology, new approaches have been initiated to identify all potential cost elements related to blood and blood product administration. Activities are also under way to tie these elements together in a comprehensive and practical model that will be applicable to all single-donor blood products without regard to practice type (e.g., academic, private, multi- or single-center clinic). These initiatives, their rationale, importance, and future directions are described.

Key words: blood; blood products; economics; transfusion.

INTRODUCTION

Delivering health care at a reduced cost while maintaining or improving the quality of care is a challenging global quest. From societal and payer perspectives, collecting and maintaining a blood supply free of potentially infectious viruses, bacteria, and prions is enormously costly.¹ For example, detecting HIV and HCV with nucleic-acid testing (NAT) exceeds the acceptable limit to gauge cost-effectiveness benchmark (\$80,000 per-quality of life-year [QALY] gained) by 72- to 105-fold.² With blood donor pools shrinking owing to population aging, restrictions on blood donor eligibility^{3,4}, and operative procedures rising to increase demand, recruitment efforts need to be reinforced to replace deferred donors, resulting in increasing incremental cost for each additional unit donated.⁵ Implementing appropriate checks to ensure that transfusions are administered safely without laboratory, clerical, managerial, screening, or administration errors⁶ is associated with costs still to be estimated.⁷

Transfusion-related adverse events, both short- and long-term, are among the costliest contributors to health care expenditures.⁸ Costs associated with long-term consequences are among the hardest to quantify.^{4,9-14} Pharmacoeconomic analyses are complex because of uncertainties with calculating the probabilities of illness, projecting future outcomes, and discounting.¹ Lost wages and adverse events that have an impact on quality of life add to indirect costs of blood product transfusions, but these factors have rarely been incorporated into quantitative cost-analyses.^{15,16} Adding increased liability and regulatory (i.e., haemovigilance) issues to the list, blood product costs will continue to trend upward.

Despite the increasing cost of blood, transfusion practices remain quite liberal^{17,18}, variable from institution to institution¹⁹, and are often inappropriate.^{20,21} The percentage of costs attributable to inappropriate blood transfusion ranges between 9% and 44%.²¹ Frequent transfusions are also linked to poorer outcomes, including increased patient mortality^{22,23}, a higher incidence of nosocomial infections²⁴, multi-organ failure^{25,26}, and increased length of hospital and ICU stays.^{23,27,28}

How is the cost of blood to individuals, health-care providers, and society determined? Unless all contributing cost elements are accounted for, beginning with blood collection, continuing through pretransfusion preparation and transfusion administration, and lasting throughout follow-up, the cost of blood is very likely to be underappreciated. That premise forms the rationale and basis of this manuscript. Past attempts to ascertain the cost of blood and the shortcomings of studies will be reviewed, as well as the progress made by the Society for the Advancement of Blood Management (SABM) toward estimating what blood really costs from a societal perspective. We

also examine our expectations about how these estimates and descriptions of cost elements can serve as benchmarks and roadmaps that institutions worldwide can use to examine their processes, optimize blood usage, and save valuable resources.

PAST: EVALUATIONS OF BLOOD AND TRANSFUSION COSTS

Studies on the economics of blood have been conducted in oncology patients^{29–32}, in the perioperative and ICU setting^{21,33}, in neonates³⁴, and in patients who require chronic transfusions (e.g., sickle cell anaemia, thalassaemia, chronic renal disease).^{35–37} Cost analyses have been used to compare red blood cell (RBC) administration to transfusion alternatives.^{15,36,38,39} Although these studies provide useful information, several shortcomings exist. First, transfusion-related costs are captured with varying degrees of rigor. Second, many studies estimate costs associated with RBC transfusions but may not consider costs associated with the handling of specialty products. Third, although a societal perspective is preferred because a more complete picture is provided, the health-care providers' perspective is more commonly applied.¹

The simplest way to examine blood costs is by cost per unit of allogeneic RBCs (Table 1). However, even when considering this least common denominator, cost estimates are not easily compared because the premises and perspectives adopted by each investigator differ. From there, establishing the cost of blood becomes increasingly more complex. One reason is that allogeneic RBC transfusions comprise only 75% of blood product transfused. Over 11 different types of RBC products are available (including washed white blood cell [WBC]-reduced, filtered WBC-reduced, pediatric units, frozen-deglycerolized cells, CMV-negative) whose incremental costs are considerably higher than the base unit.²⁹ For example, examining several recent price lists from US and European blood services, the cost of specialty-processed blood units can be 40%–230% higher per unit than that of a standard, nonleukodepleted packed RBC unit.

Studies about the cost of blood have typically separated direct and indirect costs and further divided these into variable and fixed costs. Direct variable expenses are those associated with materials that vary with usage, i.e., the RBC units and administration sets, costs of labour and of laboratory tests.³¹ Overhead (generally a fixed cost) contributed 46% to the price of a unit of blood, whereas material, fixed, and variable labour costs each contributed 19%, 18%, and 17% to total costs, respectively, as estimated by Cremieux et al.³² In addition to the cost of the blood unit itself, laboratory test kits, administration materials, institutional overhead, and labour costs of handling blood are incorporated into most models.^{29,32} Some have included costs associated with blood wastage, especially blood collected for autologous use, which contributes significantly.^{40,41}

PRESENT: ELEMENTS CONTRIBUTING TO BLOOD COST

Blood costs will generally depend on the number of steps it takes to deliver the transfused unit; simply stated, more steps translate into higher costs. Process flow diagrams (e.g., Figure 1) can help illustrate the complexities involved in administering blood transfusions after the decision to transfuse is made.^{31,32} Although it generates valuable information, this approach does not include cost elements incurred before a unit is ready to be transfused, i.e., beginning at donor recruitment and continuing through collection, screening, blood processing, donor notification, transport from the collection facility to the transfusion center, and costs related to inventory.⁴²

Table 1. Prior estimates of costs of allogeneic red blood cells.

Citation (reference year \$)	Acquisition Cost (% of total)	Total Cost per Unit ^a	Methods
Forbes et al. 1991(1989 \$) ²⁹	37%	\$350.49	Total: Direct costs included acquisition, handling, laboratory, administration in a mixed population.
Etchason et al. (1995)(1992 \$) ⁴⁰	50% (includes labor and equipment for collection)	\$269.00	Direct: Labor, equipment, infectious tests, processing, inventory management, and compatibility tests in mixed surgical population. Indirect: Discarded, crossover cross-match, treatment of complications Total: Direct + Indirect
Cantor et al. ^b (1998)(1995 \$) ³¹	15%	\$429.22 ^c	Outpatient transfusions administered to oncology patients. A process flow model was used to determine costs per step. Direct: Direct variable (blood, supplies, tests) + direct fixed (clinical personnel, managerial, facility, capital) Total: average direct + indirect fixed (support services, facility and general administration) unit costs for solid tumor, hematologic tumor patients
Creemieux et al. (2000)(1998 \$) ³²	18%	\$780.59	Outpatient transfusions administered to oncology patients. A process flow model was used to determine costs per step. Direct: Direct material (products, kits, administration sets, screening for viruses) + variable direct labor (personnel) + fixed (administrators) Total: average direct + overhead unit costs for solid tumor, hematologic tumor, and complex patients

^a Adjusted for inflation from (reference year \$) to (2005 \$) based on Consumer Price Index for Medical Care Services per the US Department of Labor, Bureau of Labor Statistics available at: www.bls.gov Accessed 10/26/06.

^b May be significantly underestimated since Cantor et al.³¹ provided costs per 2 units of RBC transfused, and the cost per unit may actually be higher than that of 2 units divided in half.

^c Non-bone marrow transplant solid tumor estimate.

Cost elements associated with long-term adverse events may be missed. Interdependence among tasks and how one sector affects another are almost never considered. For example, if screening for viruses after donation becomes more stringent, more donors will be deferred. This can lead to the need to increase recruitment efforts to replace deferred donors, counselors to work with donors who are made aware they have a virus, reporting requirements, stepped-up haemovigilance efforts, look-back notifications, etc.

Seeking to develop an all-inclusive reference methodology that can be used to calculate the societal cost of single-donor blood components, applicable across

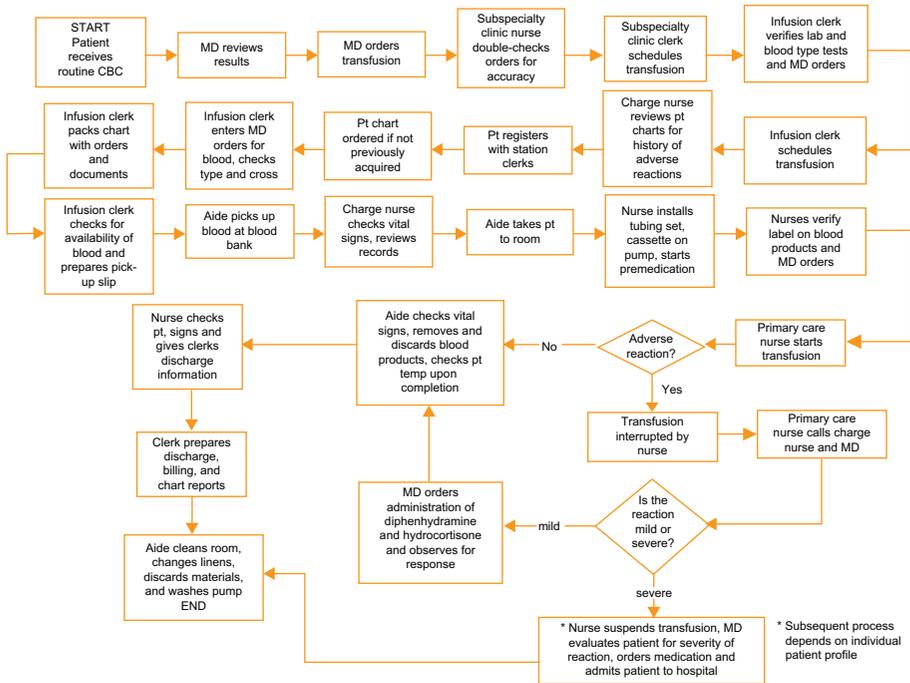


Figure 1. Process flow of outpatient RBC transfusion administration. This flow chart is part of a larger process, comprising a limited portion of cost elements (i.e., Steps 7 & 8 in Figure 2). (Reprinted from Cantor, et al³¹ with permission from the American Society of Clinical Oncology.)

institutions, payer types, delivery systems, and countries, SABM organized the first cost-of-blood consensus conference (COBCON 1). Consisting of 17 experts from blood collection facilities, government agencies, academia, hospitals, and practitioners in transfusion medicine, the group used the model first proposed by the Lewin Group⁴³ and then defined key cost elements and interdependencies associated with whole blood collection, transfusion processes, and follow-up (Figure 2).⁴²

Direct costs of preparing and delivering blood products distinct from simple allogeneic RBC units can also affect the bottom line.⁴⁰ For example, allogeneic RBC units are the least costly to prepare (Table 2), but pose higher risks of viral and bacterial transmission and immunological consequences. Predonated autologous units are 33% more expensive per unit to collect and process and only eliminate some, but not all, blood transfusion risks. Although 33% seems a reasonable premium to improve upon blood safety⁴⁰, predonated autologous blood costs escalate dramatically when wastage of unused units is included. Modeling surgical procedures in which up to 66% of self-donated blood was wasted⁴¹, incremental costs of substituting autologous for allogeneic units were \$68 to \$4,783 per unit. The highest costs were associated with the lowest probability of using the predonated autologous units. In another study, of all the blood collected for autologous or directed donations, 52%-57% (~4% of the US blood supply) was discarded, even after correcting for blood transferred into the allogeneic blood supply.⁴⁴ The COBCON panel recognized the importance of accounting for discarded units in their working model.

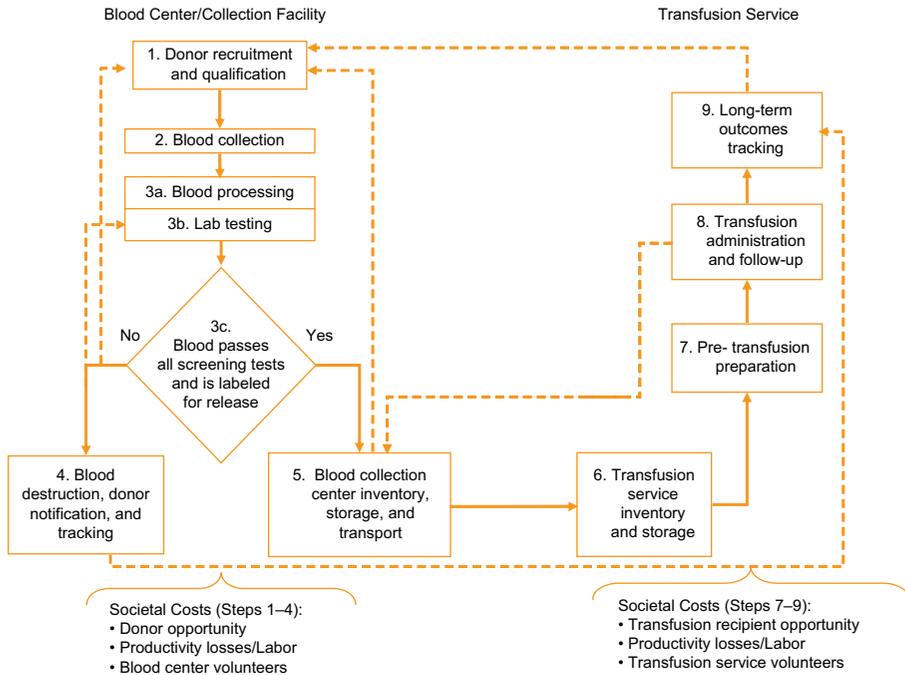


Figure 2. Blood collection and transfusion flow chart. (Reprinted from the Cost of Blood Consensus Conference participants⁴² with permission from Elsevier.

Additional steps and costs are incurred if collected blood is processed into specialty blood products.²⁹ Leukodepletion by filtration or washing to avoid alloimmunization and other immunomodulatory effects^{45,46} adds to the direct costs of blood (\$39/unit adjusted for inflation to 2005 [AFI₂₀₀₅]).⁴⁷ Dzik and colleagues estimated this cost to total \$600 million (\$667 million AFI₂₀₀₅) in the US alone.⁴⁸ Given that standards for implementing such testing differ from country to country, a tool is needed to estimate these costs according to the standards that apply.

Item	Cost per Unit (US Dollars)		% Higher
	Autologous	Allogeneic	\$ (Auto-Allo)/\$ Allo
Collection	129.42	84.91	51.9
Infectious disease testing	24.27	24.27	0
Blood processing and inventory management	28.16	25.03	12.5
Compatibility testing	16.19	16.19	0
Total	198.04	149.80	32.2

Adapted from Etchason, et al⁴⁰

COST-EFFECTIVENESS EVALUATIONS OF BLOOD TRANSFUSIONS

Strategies to improve blood safety are resource-intensive. In some cases, pharmacoeconomic principles have been applied and cost-effectiveness studies performed to help determine whether society can afford to pay for the added safety benefit. Value is assigned to variables measured in health units, i.e., years of survival gained, number of infections avoided, or hospital length of stay (LOS) shortened. In cost-utility analyses, incremental benefits are adjusted to common units, i.e., the quality-adjusted life year (QALY).¹ If the dollar value assigned to QALYs exceeds \$50,000 to \$80,000, the intervention will typically be less acceptable from a financial perspective.

Autologous versus allogeneic blood

In one of the first economic studies comparing predonated autologous to allogeneic blood, the number of dollars per QALY varied from \$235,000 to over \$23 million, causing the authors to conclude that autologous donations were not cost-effective.⁴⁰ Birkmeyer and colleagues examined low transfusion risk versus high transfusion risk surgical procedures and estimated dollars per QALY ranging from \$40,000 (high risk) to over \$1 million (low risk) for autologous donations, reflecting that wasted units produce the highest costs.⁴⁹ These investigators also demonstrated that autologous programs in patients undergoing coronary artery bypass graft (CABG) surgery would cost between \$508,000 and \$909,000 per QALY. An even higher estimate of \$26 million to \$300 million per QALY was projected to prevent one HIV transmission in pregnant women delivering term infants using an autologous blood program.⁵⁰ Unfortunately, none of these estimates compare favourably to cost-effectiveness benchmarks, ranging from \$6,000 to \$79,000 per QALY for procedures such as CABG in coronary artery diseased patients with angina, cervical cancer screening every 4 years, adjuvant chemotherapy for breast cancer, kidney or heart transplants, treatment with captopril for mild to moderate hypertension, or hemodialysis for end-stage renal disease.⁵¹

A cost analysis of autologous blood processed using cell-salvage machines versus allogeneic blood transfusions indicated that cost equivalence of the two products would be reached if using autologous blood could theoretically reduce the hospital LOS by between 0.3 and 2 days.⁵² Their analyses did not include infection risk or other immune consequences; larger studies to determine cost-equivalence were recommended. Blumberg and Heal⁵³ considered the cost associated with managing immunological sequelae and calculated total hospital charges associated with giving 1 to ≥ 3 allogeneic transfusions were \$5,000 to \$11,000 higher than those in patients who received up to 5 units of autologous blood. The public health impact of autologous blood and whether it is worth the incremental cost warrants further study.

White blood cell reduction

Leukodepletion has had positive effects on mortality in specific patient populations⁵⁴⁻⁵⁶ and some transfusion reactions⁵⁷, and it is mandatory practice in many countries, however, this practice has still not been universally adopted.^{47,58} Cost-effectiveness evaluations of leukoreduced blood products have revealed that the cost per QALY due to leukoreduction is highly sensitive to infection risk, ranging from \$2,470 if risk is high (1.85 relative risk) to \$3.4 million if there is no infection risk. Thus, in order for this

practice to be fiscally acceptable, leukoreduction must actually reduce the incidence of infection, cancer, or other immunologic-related consequences.

This issue of benefit has been intensely debated.^{59–61} In the US, universal WBC reduction is not mandated but is estimated to be applied in the vast majority of hospitals. Many reports assert that leukoreduction is cost-effective^{53,62,63}, and that LOS or hospital charges are sufficiently reduced to justify higher costs.⁵⁸

Older blood

Especially in critically ill patients, deleterious effects and increased mortality have been associated with administration of older blood.⁶⁴ Decreased deformability of RBC membranes owing to oxidation, diminished 2,3-DPG levels impairing O₂ delivery, decreased pH, diminished oxygen-carrying capacity, decreased number of viable cells per unit, and an increase in inflammatory cytokines released by contaminating leukocytes are some of the characteristics that RBCs express when nearing their expiration date.⁶⁵ Any of these characteristics can negatively affect the anticipated benefit of a transfusion, especially in a critically ill patient.⁶⁶ Additionally, the incidence of nosocomial infections may increase with the length of RBC storage.^{67,68}

To date, no studies have attempted to quantitate cost or outcomes of providing fresh versus older blood. Since 2 of 14 million units per year outdate⁶⁹, it may be very costly for society to adopt strategies to direct fresh blood supplies to certain populations. Improving the efficiency of blood banking systems, or expanding geographical areas served by individual blood banks to better utilize existing blood inventories may be warranted but will certainly add many cost elements.

More stringent blood collection and testing paradigms

More stringent and extensive screening during blood collection has made the blood supply safer, but has also made blood more difficult to acquire. Donors are more often rejected because of increasingly stringent standards.^{70,71} The Food and Drug Administration (FDA) final rule on testing human blood for transmissible infections⁷² does *not* require screening of autologous blood provided that the collection center does not transfer blood collected for autologous use to the allogeneic blood supply. Cost was one of the FDA's primary considerations when deliberating the recommendation to test all blood.^{72,73}

The use of NAT for detection of viral RNA or DNA has added to blood costs.⁷⁴ Individual unit testing reduces risk^{75,76} and the reagents used are relatively inexpensive; however, indirect costs, especially the impact of higher donor disqualification or discard rates, have not been examined. The concept of testing pooled batches versus individual units may reduce costs somewhat, but could also result in false negatives with potentially harmful outcomes.⁷⁷ The QALYs per infection detected have been estimated at \$1.3 and \$1.8 million dollars for pooled versus individual testing, respectively.^{78,79}

Pathogen inactivation

Processes and chemical agents designed to eliminate viral and bacterial infectious risks have been in clinical development as a potential alternative to NAT screening.⁸⁰ Many unknowns related to disposal, neutralization, processing, and logistical or administrative tasks exist.^{81,82} It will be important for cost estimates of untreated blood to be robust so that these new technologies can be adequately evaluated.

Quality management and quality control

Technologic improvements for administering transfusions and monitoring transfusion practices have been made^{83,84}, including safeguards against clerical and management errors that can lead to adverse events.^{85–87} Blood collection, blood-banking, administering transfusions, and all blood-related activities are highly regulated and require adequate training, standard operating procedures and protocols, and stringent controls.⁸⁸ Under the umbrella of administrative monitoring are processes for lookback-notifications of transfused patients for the risks of contracting HIV and HCV, estimated to cost approximately \$14.50 (AFI₂₀₀₅) for each transfused patient.⁸⁹ Computerized systems are necessary to manage the vast quantity of transfusion-related data. Development and implementation of efficient computer systems contribute to overhead costs.

COSTS OF TRANSFUSION-RELATED ADVERSE EVENTS

Medical implications

Any evaluation of the cost of blood must consider the costs of treating and managing adverse events that can result from transfusions, of which there are many.^{4,10} The costs of some adverse consequences found in the literature provide some perspective (Table 3).^{90–95} The probability of sustaining an adverse event is usually factored into any decision-tree analysis; most risks occur with low probability.⁹⁶ For example, death immediately following or directly linked to transfusions is rare, resulting from haemolysis, pulmonary injury, bacterial contamination, graft versus host disease (GVHD), delayed haemolysis, and infusion of incorrect, contaminated, or damaged product.^{4,14,97} Transfusion-acquired infections, also rare, still represent a risk that will never be 100% eliminated.^{4,12,98–100} Of all transfusion-related fatalities reported to the FDA (1986–1991), 16% to 26% were related to bacterial contamination.¹⁰⁰ Viruses that are undetectable due to lack of screening tests also remain a health concern.⁴

Although the immunologic consequences of blood transfusion are incompletely understood, these can result in poorer outcomes.^{4,10,45,46,54,101,102} Other severe events, e.g., transfusion-related acute lung injury (TRALI), transfusion-associated GVHD, or transfusion errors may go undiagnosed and are left underreported^{14,103–105}, and their costs are not always attributed to transfusion. Some of the more commonly recognized related expenditures addressed in cost studies include treating nosocomial infections^{106,107}, increased hospital charges to manage the immunological consequences of allogeneic versus autologous transfusions⁵³, increased costs due to prolonged hospital and ICU lengths of stay^{27,99,107,108}, lost time from work¹⁶, costs of treating serious medical sequelae (sepsis, acute respiratory distress syndrome, systemic inflammatory response syndrome [SIRS])^{108,109}, and increased mortality.¹⁰⁹ Chelation therapy for iron overload secondary to chronic transfusions is also costly.³⁵

Legal implications

An important consideration often omitted from cost of blood studies involves the costs of litigation and damages awarded. Transfusion medicine is a very highly regulated sector of our medical system, and legal issues surrounding patient and donor consent and litigation relating to transfusion adverse events can have significant economic consequences. A few pertinent examples of negligence convictions incurring monetary

Table 3. Estimated costs of managing transfusion-related sequelae.

Potential Event	Costs of Events	References
HIV infection (CD4 count <200)	\$318/month	McCarthy et al ⁹⁰ ; Hellinger et al ⁹¹
Symptomatic AIDS	\$6,970/month	
Lifetime cost HIV	\$119,000	
Hepatitis infection and related sequelae	\$1,106/1st year (acute) \$2,340/hospitalization (acute) \$3,085/1st year (chronic) \$287/year > 1st year (chronic) \$1,700/year for cirrhosis \$20,900/hepatocellular carcinoma (one-time cost)	Sonnenberg et al ⁹² ; Wong et al ⁹³
Lost earnings/ productivity	\$74/day for patient \$133/day for employer	Denton ¹⁵ ; Barnett et al ¹⁶
Bacterial infection	\$12,900–\$14,000/per event	Sonnenberg et al ⁹² ; Carson et al ⁹⁴
Hemolytic transfusion reactions	\$100 (minor)–\$1,000 \$112,578 (fatal)	Sonnenberg et al ⁹² ; Denton ¹⁵ ; Birkmeyer et al ⁴⁹
Nosocomial infection	\$16,309 (converted from Euros) \$66,302 higher hospital costs (2-fold) than noninfected controls in patients with end-stage renal disease	Liu et al ¹⁰⁶ ; Orsi et al ¹⁰⁷
Chelation therapy for iron overload	\$12,719 to \$24,845 per patient/year	Wayne et al ³⁵
ICU costs	\$1,246/day (fixed + variable; converted from £)	Dickie et al ⁹⁵
Hospital costs	\$1,551/day × 10.3 days nontransfused; \$1,682/day × 16.7 days transfused in colorectal cancer patients	Vamvakas et al ²⁸
Sepsis	\$877/day Canadian (survivors) \$1,724/day Canadian (non-survivors) \$22,100/case	Letarte et al ¹⁰⁸ ; Angus et al ¹⁰⁹
Sequelae related to immunomodulation	\$5,000–\$11,000 incremental hospital charges if allogeneic vs autologous	Blumberg & Heal ⁵³

damages, each up to \$500,000, include missing documentation, inadequate quality controls, lack of shipping records or temperature controls, insufficient tests performed to ensure safety, type and cross-match errors, and inadequately executed informed consent. In some cases, criminal prosecutions have resulted, which would further impact costs from society's perspective.^{86,110}

Haemovigilance

Systems in place to ensure the safety of the blood supply vary considerably from country to country.¹¹¹ At the present time, no information exists about what

haemovigilance systems cost in terms of personnel and administration or what their economic impact might be. The ability to input haemovigilance costs by country or region as applicable would seem to be more useful than any broad generalization.

FUTURE: COBCON 2

The importance of establishing a baseline cost of any particular blood product from which all future cost-effectiveness analyses could be determined cannot be overemphasized. In light of the foregoing discussion, we can now unequivocally assert that arriving at a dollar figure for the cost of blood is a complex undertaking. Moreover, for such a baseline to be meaningful, it should be customized for individual circumstance. Building upon the work product initiated by COBCON 1, a subset of individuals (COBCON 2) continue to pursue development of a widely applicable and practical cost-calculating tool, using activity-based cost methodology previously described.¹¹² From a societal perspective, the cost of blood should include the following:

1. Cost incurred to donors
2. Cost of producing blood components for transfusion
3. Cost of transfusion logistics and preparation within hospitals
4. Cost of administering and monitoring actual transfusions
5. Cost of treating adverse transfusion events
6. Cost of treating transfusion transmitted disease
7. Cost of litigation (claims of contaminated victims)
8. Cost of lost productivity
9. Cost of organizing and maintaining nationwide/continental haemovigilance systems.

Using the economic expertise available to COBCON 1 (Axel Hofmann, Medical Society for Blood Management), a basic cost-equation has been constructed (Figure 3) and, at present, is being populated with actual dollar values. A preliminary estimate of more than \$1,400 per unit (based on European transfusion volumes in 2004) has been calculated, representing a minimum to which costs associated with elements 1, 4, 6, 7, 8, and 9 listed above have yet to be added. Even though these costs still need to be incorporated, the dollar figure is nearly twofold more than any previous cost of blood estimate AFI₂₀₀₅ (Table 1).

The data emerging from COBCON 2 confirm what the experts from COBCON 1 suspected, namely, that the cost of blood has been seriously underestimated in previous studies. This knowledge could stimulate change in the way that transfusions are used and how transfusion alternatives are evaluated. It may also help administrators justify appropriation of funds to reduce and optimize transfusion usage.

Economic opportunities afforded by blood conservation strategies

The principles underlying optimization of blood usage include correcting anaemia before surgery, avoiding or minimizing intraoperative blood loss, and, with an understanding of the individual's physiological tolerance of anaemia, use more restrictive transfusion triggers when appropriate.¹¹³ Considering these principles, the Austrian Study Group for the Advancement of Blood Management (formally SABM-Austria), in the name of the Austrian Federal Structural Fund and the Federal Ministry of Health and Women, conducted a benchmarking evaluation to predict savings that might

$$C_{txn} = \frac{C_1X_1+C_2X_2+C_3X_3+C_4X_4+C_5X_5+C_6X_6+C_7X_7+C_8X_8+C_9X_9}{X_4} = \frac{\sum_{n=1}^9 C_n X_n}{X_4}$$

Where:

C_{txn} = total cost per unit transfused from a societal perspective

X_4 = total number of units transfused

C_1X_1 = average cost incurred per donor x number of donations = total donor cost

C_2X_2 = average cost per unit produced x units produced = total production cost

C_3X_3 = average cost per unit prepared for transfusion x units prepared = total hospital transfusion preparation cost

C_4X_4 = average cost of administering per unit transfused x units transfused = total hospital cost of administering transfusion

C_5X_5 = average cost per adverse transfusion event (short-term) x events = total cost of treating adverse events

C_6X_6 = average cost per transfusion-transmitted case of illness (long-term) x cases = total cost of transfusion-transmitted illness

C_7X_7 = average cost of litigation per case x cases litigated = total cost of litigation

C_8X_8 = average cost of lost productivity per day x hospital and rehabilitation stay days = total cost of lost productivity

C_9X_9 = average cost per haemovigilance case x cases = total cost of haemovigilance

Figure 3. Basic cost equation.

accrue if transfusion practices were optimized. In 18 randomly selected Austrian hospitals, transfusion practices varied widely (Table 4). However, by reducing the variability among centers, lowering the average transfusion rate and number of units transfused per patient to that of the lowest five consuming hospitals, the study group identified an opportunity to save 32% to 62% of units transfused.

Acute normovolaemic haemodilution, also a potential cost- and blood-saving alternative, produced 2.5-fold cost savings, using 2.3-fold fewer RBC units in patients undergoing radical retropubic prostatectomy.¹⁴

Table 4. Evaluation of potential blood cost-savings at 18 Austrian hospitals.

Type of Surgery	% of Patients Transfused	Units Transfused per Patient	Potential Savings if Transfusion Practices were Optimized % ^a
THR	16–84	0.3–2.9	59.4
TKR	12–87	0.3–2.8	62.1
CABG	37–71	0.9–2.9	32.1

^a Optimized defined as follows: 1) reduce the average % of patients transfused across all 18 sites to the average % of patients transfused at the five least-consuming sites for total hip replacement (THR) and total knee replacement (TKR) and the two least-consuming sites for coronary artery bypass graft (CABG); 2) reduce the average number of transfused units per patient to the average at the five least-consuming out of 16 sites for THR and TKR and at the two least-consuming out of 6 sites for CABG.

We must acknowledge that interventions to conserve blood are also associated with costs.^{33,51,52,115,116} For example, reinfused RBCs salvaged during joint arthroplasty as compared to allogeneic transfusions would incur an estimated \$5.7 million per QALY.^{33,117} Another strategy commonly employed to reduce transfusion requirements is to administer erythropoietic stimulating agents (ESAs). If anaemia due to surgery¹¹⁸, cancer, or other causes can be anticipated in advance^{119–124}, administration of ESAs may reduce the need for transfusions, but are they worth the extra cost? In one recent study of the cost-effectiveness of epoetin alfa as a transfusion alternative in ICU patients, costs per QALY were between \$34,088 and \$47,149, most sensitive to the risk of nosocomial bacterial infections per RBC unit. In this setting, assuming that RBC transfusions increase infection risk, epoetin alfa was cost-effective.¹²⁵ In another study, eliminating transfusions offset the direct costs of epoetin alfa by 25% to 50%, even without considering the cost-benefit of improving outcomes, and avoiding transfusion risks and the costs for their management.³⁷ A robust and comprehensive evaluation of the cost of blood is essential so that the questions are appropriately posed and outcomes are rigorously assessed. The work undertaken by COBCON 1 and 2 will be of value to economists who conduct such studies.

CONCLUSIONS

Blood, from its acquisition to transfusion through follow-up, is costly to society. Blood is not a resource to be taken for granted, used liberally without accountability, or wasted. Determining the cost of blood from a societal perspective is a complex undertaking that requires consideration of all relevant cost elements, many of which have not been identified previously. At a minimum, we estimate that the cost of blood to society is twofold higher than calculations derived from previous studies. Many elements have yet to be factored in, including the cost of haemovigilance, about which almost nothing is presently known. Adoption of effective strategies to optimize blood usage, reduce variability, and minimize waste would have an enormous impact on lowering overall health-care costs.

SUMMARY

The use of blood and blood products throughout the world's health-care systems contributes substantially to overall health-care costs. Although many prior and worthwhile attempts to estimate the cost of blood have been made, a comprehensive "vein-to-vein" approach that assumes a societal perspective is still needed. Beginning with the costs of donor recruitment, and encompassing all tasks, personnel, and infrastructures associated with blood collection, processing, distribution, pre transfusion preparation, administration, wastage, adverse event handling, and long-term haemovigilance, it is clear that this is an enormous and complex undertaking. Sophisticated knowledge is required about transfusion medicine, clinical outcomes, administrative structures, health-care economics, and blood distribution networks worldwide. The Society for the Advancement of Blood Management has spearheaded an initiative to gather this expertise and to tie all critical cost elements together into one comprehensive and practical model. Once developed, the model will apply to all single-donor blood products, and may be used by academic, private, and multi- or single-center practices to compute costs associated with blood and blood products. The purpose of having such a comprehensive model is severalfold. First, it will serve future research

that seeks to determine the cost-effectiveness of interventions for improving blood safety and optimizing blood utilization. Second, the model will be adaptable to institutions wanting to increase institutional efficiency and reduce costs at each point-of-care. Finally, and perhaps most importantly, it will raise awareness about the economic realities of blood, its impact on individuals, institutions, and society, and encourage practitioners to think more critically about their blood usage patterns.

Practice points

- Blood is a valuable resource and transfusions should be administered only after careful consideration of the risks and benefits
- Monitor and report all transfusion-related adverse events
- Develop and adhere to institutional efforts to conserve blood, eliminate waste, and optimize resources

Research agenda

- Further determinations of the cost of blood products should attempt to utilize an activity-based model to ensure that all relevant cost elements are accounted for
- Analyses of the cost-effectiveness of blood alternatives or interventions aimed at improving blood safety may need to be reperformed once such a model is available
- Haemovigilance systems and their associated costs need to be further explored

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