Cost effectiveness of blood substitution in elective orthopedic operations

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Cost effectiveness was compared between substitution with autologous blood, implying no risk of transmission of diseases, and homologous blood, with a definite risk of transmission. Primary and revision hip arthroplasties were included in this study, as well as scoliosis operations. The risk of contracting chronic non-A, non-B hepatitis (NANBH) was included in the calculations of the long-term economic consequences of a transmittable disease.

Our study showed that predonated blood alone, with a donation of up to four units, was the most suitable and cost-effective method for substitution of blood losses up to about 2.5–3 liters A combination of predonated blood and intraoperative autotransfusion was more suitable and less expensive for substituting blood losses of 2.5 liters or more. Homologous blood was the least cost-effective alternative considering the influence of non-A, non-B hepatitis.

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The risks of homologous blood transfusion (HB) include transmission of non-A, non-B hepatitis (NANBH), AIDS, malaria, cytomegalic virus (Conard 1981, Tabor 1982, Surgenor 1987), and other rare retrovirus infections, such as HTLV 1, causing leukemia and tropical paraparesis (Grillner 1988). The risk of developing NANBH in Sweden is 2.4 percent following orthopedic and surgical operations other than cardiac surgery (Widell et al. 1987). A specific test for hepatitis C, which causes 40–60 percent of the NANBH cases, may be helpful in its prevention (Salo 1988, Mosley et al. 1990). Further concerns are transfusion-related AIDS, which cannot always be revealed by current tests, and also the increased rate of postoperative infections following homologous blood transfusion (Solomon et al. 1988, Tartter 1988, Ward et al. 1988).

The aim of the present study was to analyze the cost effectiveness of autologous and homologous blood substitutions in relation to long-term consequences of transmitted NANBH.

Material and methods

Three alternatives of blood substitution during elective orthopedic operations were analyzed: autologous preoperative blood donation (PBD), intraoperative autotransfusion (IAT) using a blood-cell saver (Electromedics AT-1000, Englewood ,CO, U.S.A.) in combination with PBD, and homologous blood transfusion (HB).

The estimated costs were calculated for three different volumes of total blood loss: approximately equivalent to the blood loss from a primary hip arthroplasty (1.5 L), scoliosis operations (2.5 L), and a revision hip arthroplasty (3.5 L).

Predeposited blood

In this method the patient donates blood prior to the planned operation for his own use during or after the operation. The donation is usually done over a 5–7-day interval. Up to six units can be donated within 6 weeks before the operation. This is limited because the storage period for blood in the liquid state is 42 days. However, if the freezing method is used, blood can be stored for up to 2 years. The cost of one unit (300 mL) of red blood cells (RBC) concentrate was calculated by the Blood Center at Malmö General Hospital as being 600 SEK, which includes the costs of material including testing (320 SEK) and personnel costs (estimated at 280 SEK). For each unit of RBC concentrate in PBD, one unit of plasma was obtained free of charge.

Intraoperative autotransfusion (IAT)

This method involves the use of a special autotransfusion device (the cell saver). Blood lost during the operation is retrieved and washed, ultimately producing a red-cell concentrate. The cost of IAT was estimated by calculating the annual cost of the cell saver, assuming 5 years of economic useful life and a discount rate of 5 percent. The capital cost of 100 operations per year was set at 510 SEK per operation. The cost per operation of disposable material was 1,400 SEK, and the extra time cost for the cell-saver operator was 375 SEK. We assume that the average cost of IAT per operation was independent of the amount of blood lost during the operation, but depended on the number of operations in which the cell saver was used.

Homologous blood (HB)

This is the method now widely used, where blood loss during or after surgery is replaced by banked blood from other donors. The cost of one unit of RBC was set at 460 SEK. The cost of material and testing was 320 SEK. The personnel costs were half that of PBD, i.e., 140 SEK, because organized blood donors take less time at donation.

Albumin was used as a colloid substitution in patients receiving homologous blood. In PBD patients, autologous plasma was used. The cost of one unit (500 mL) of albumin was set at 500 SEK according to the 1990 price index.

In general, a cross-matching fee of 50 SEK was charged for every unit of RBC ordered for an operation. Thromboprophylaxis using dextran was almost equivalent in the three groups, and it is also equivalent when using any type of heparin.

Estimation of blood loss and blood substitution

Data from previous studies at our orthopedic department were used to estimate the blood loss. The average total blood loss in primary hip arthroplasty was 1,600 ± 570 mL (Elawad et al. 1990). The estimated total blood loss of 2,700 ± 750 mL during scoliosis surgery was obtained from another study (Benoni, personal communications). Data from the patients' records at our department were used for calculating the blood loss during revision hip arthroplasty, range 2,500–4,000 mL, with an average of 3,120 ± 720 mL.

The methods of blood substitution were used according to our routine (Table 1).

Risk of obtaining NANBH

The risk was calculated at 2.4 percent by Widell et al. (1987) from a median number of 2.5 transfused units per operation. According to several studies, 50 percent of all the NANBH infections will become a chronic disease (Alter et al. 1981, Tremolada et al. 1982, Olsson et al. 1984, Ito et al. 1986, Mattsson et al. 1989, Lindholm et al. 1990). There was an increased risk of posttransfusion NANBH in younger patients, with 4.5 percent in recipients below aged 40 years, 3.4 per cent in patients below aged 70 years, and 1.2 percent in patients over aged 70 years (Widell et al. 1987). Also, it has been shown that 0.4–2.4 percent of patients receiving a blood transfusion ran the risk of developing chronic NANBH (Alter et al. 1981, Tremolada et al. 1982, Olsson et al. 1984, Ito et al. 1986, Widell et al. 1987, Lindholm et al. 1990). We have assumed a risk of 0.5 percent per unit of HB to obtain chronic NANBH.

Direct costs of NANBH

The costs of treating patients with chronic NANBH were based on a study by Grillner (1988; personal communications). Based on a 10-year follow-up study of 400 patients, the annual number respectively of physician visits and inpatient bed days was estimated at 2 and 1.5 per patient and the cost per physician visit and per bed day at 750 SEK and 2,500 SEK.

The total lifetime costs were estimated by assuming that the annual treatment costs would prevail for all the remaining years of life. All the future costs were discounted at a rate of 5 percent.

Indirect costs of NANBH

The costs are represented by the value of those goods and services that could have been produced if the person had not fallen ill. The valuation of the lost production proceeds from the concept of income. The income is assumed to be equal to the value of marginal productivity, which means that the value of output added by the marginal or last-hired worker equals the cost that a firm is willing to pay as wage plus nonwage cost (Lindgren 1981).

As mentioned above, approximately 50 percent of the infections will develop into chronic NANBH. After a 4-year follow-up, 20 percent of these patients will have received an early retirement pension of about 50 percent (Mattsson 1989). The consequences of early retirement extend for many years into the future, which have been taken into account by estimating the

Table 1. Cost (SEK) of blood substitution per operation at different volumes of blood loss using different strategies (number of units available)

Blood loss Type of operation	1.5 L Primary hip	2.5 L Scoliosis	3.5 L Revision hip
PBD	1,800 (3)	2,400 (4)	3,600 (6)
Plasma	0	0 (4)	0 (6)
Total	1,800	2,400	3,600
PBD	1,800 (3)	1,800 (3)	1,800 (3)
Plasma	0	0 (3)	0 (3)
IAT[a]	0	2,280	2,280
Total	1,800	4,080	4,080
HB	1,380 (3)	1,840 (4)	2,760 (6)
Albumin	0	1,000 (2)	1,500 (3)
Total	1,380	2,840	4,260

[a] Calculation of use based on 100 operations/year.
PBD Autologous preoperative blood donation.
IAT Intraoperative autotransfusion.
HB Homologous blood transfusion.

Table 2. Present value of total lifetime health-care costs and lost production due to chronic non-A, non-B hepatitis per patient at different ages of patients at the time of operation, 10^3 SEK in 1990 prices, discount rate 5 percent

Age at operation years	Total lifetime health-care costs	Total lifetime lost production (half-time pension)	Total
20	103	1,460	1,563
30	95	1,328	1,423
40	85	1,077	1,162
50	77	667	744
60	61	86	147

expected number of years left to retirement age. The value of lost production was calculated by multiplying the number of lost production years with the average wages plus social securities for different ages. Future costs were discounted at a rate of 5 percent.

Table 2 shows the present value of lost production for a chronic NANBH patient from the time of operation, as estimated from a risk of 0.5 percent per unit of transfused HB multiplied by the 20 percent rate of retirement. The present value of expected lost production (PVP) for an individual at a given age of onset of chronic NANBH was calculated according to the following formula:

$$PVPt = \sum_{n=a}^{64} \frac{Pan * Wn}{(1 + r)^{n-t}}$$

where PVPt = present value of lost production related to the time of blood transfusion t · Pan = probability that a person who contracted chronic NANBH at age a will survive until age n · Wn = average earned income (including nonwage labor cost) of a person working full time until the age of n · r = discount rate.

Results

Table 3 illustrates the economic consequences of the three blood substitution strategies as in Table 1 combined with the expected total value of health-care costs and lost production (Table 2).

The risk of contracting NANBH exists only with the HB strategy. Accordingly, HB is shown to be the most expensive blood substitution strategy due to the expected health-care costs and lost production as a result of chronic NANBH.

For young age groups, HB will be more expensive due to the increased total lifetime costs of health care and lost production due to NANBH. In assessing the older age groups, the HB strategy will be less expensive when compared with younger age groups. Nevertheless, it is still more expensive than the PBD strategy.

Discussion

We have tried to present a model for three different but equivalent strategies for substituting the total blood loss and the cost effectiveness of this substitution to the long-term economic consequences of obtaining posttransfusion NANBH. The model is theoretic, but it is based on clinical practice and experience of autologous blood substitution.

Some previous studies comparing autologous and homologous blood transfusion have reported that autotransfusion is cost effective (Glover et al. 1982, Kruger and Colbert 1985, Popovisky et al. 1985, Bovill et al. 1986, Tawes et al. 1986). Solomon et al. (1988) studied the cost effectiveness of IAT and compared it with the use of an equivalent amount of HB for different types of operations, and they concluded that IAT was cost effective in certain situations.

Table 3. Cost (SEK) of blood substitution per operation at different volumes of blood loss using homologous blood transfusion (HB), autologous preoperative blood donation (PBD), or PBD + intraoperative autotransfusion (IAT) considering health-care costs and production loss due to chronic non-A, non-B hepatitis. The risk/transfused unit HB: health-care costs 0.5 percent, production loss cost 0.1 percent

Blood loss (L)	1.5			2.5			3.5		
Age (years)	40	50	60	20	40	50	40	50	60
HB									
RBC	1,380	1,380	1,380	1,840	1,840	1,840	2,760	2,760	2,760
Health care	1,275	1,155	915	2,060	1,700	1,540	2,550	2,310	1,830
Lost production	3,231	2,001	258	5,840	4,308	2,668	6,462	4,002	516
Total expected cost	5,386	4,536	2,553	9,780	7,848	6,048	11,772	9,072	5,106
PBD									
RBC	1,800	1,800	1,800	2,400	2,400	2,400	3,600	3,600	3,600
PBD + IAT									
100 operations/year	2,310	2,310	2,310	4,080	4,080	4,080	4,080	4,080	4,080
20 operations/year	4,310	4,310	4,310	6,080	6,080	6,080	6,080	6,080	6,080

RBC Red blood cell concentrate (mL).

We have, in the present study, calculated with a PBD donation up to six units, which is not possible to obtain in elderly persons. However, according to the recommendation of the American Association of Blood Banks, donations are allowed at weekly intervals or even at 4-day intervals (Council on Scientific Affairs 1986), which may provide about five to six units within the 42 days' storage limit. This may be valid for younger patients.

IAT alone was not considered a realistic alternative for substituting blood loss of more than 2,000 mL, because the cell saver is only used in the operating room and in the recovery room. Blood loss during the first 2 days postoperatively in the ward is usually replaced by autologous or homologous banked blood. However, IAT is a desirable method for securing transfusion blood during surgery in patients unable to undergo a PBD, or in patients who are otherwise not willing to accept a bank blood transfusion for religious or other reasons (Clarke 1982). In young patients the reason for using IAT will always be the reduced risk of contracting a blood-borne infection.

Autologous blood transfusion carries almost no risk of transmitting infections to the recipient, and should therefore be the method of choice, especially in young patients. To study the patients' willingness to pay for blood free of risks, a more extensive study design is required using the willingness-to-pay method (Jones Lee 1989). The improved quality of life due to avoidance of the causative agents, i.e., HB, has also an economic value in terms of "utility." This aspect could be assessed by using quality adjusted life years (QALYS; Williams 1985). This, however, would not change our present conclusions.

The selection of the method for blood substitution achieving cost effectiveness during elective orthopedic operations is multifactorial. However, predonated autologous blood should always be the first-hand alternative.

One advantage of PBD compared with HB is less postoperative and total blood loss, with about 500 mL in a total hip arthroplasty. The reason may be due to the effect of the relative anemia in stimulating the hemopoietic system of the patient and also probable stimulation of the coagulation system due to the presence of fresh active thrombocytes. This will decrease the cost of blood substitution and probably require fewer transfusion units when using PBD (Elawad et al. 1991).

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