

Accurate costs of blood transfusion: a micro-costing of administering blood products in the United Kingdom National Health Service

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Abstract

Background: In an environment of limited healthcare resources, it is crucial for healthcare systems who provide blood transfusion to have accurate and comprehensive information on the costs of transfusion, incorporating not only the costs of blood products, but also their administration. Unfortunately, in many countries accurate costs for administering blood are not available. Our study aimed to generate comprehensive estimates of the costs of administering transfusions for the UK National Health Service.

Study Design and Methods: A detailed micro-costing study was used to cost two key inputs into transfusion: transfusion laboratory and nursing inputs. For each input, data collection forms were developed to capture staff time, equipment and consumables associated with each step in the transfusion process. Costing results were combined with costs of blood product wastage to calculate the cost per unit transfused, separately for different blood products. Data were collected in 2014/15 British pounds, and converted to US dollars.

Results: 438 data collection forms were completed by 74 staff. The cost of administering blood was \$71 (£49) per unit for red blood cells, \$84 (£58) for platelets, \$55 (£38) for fresh frozen plasma and \$72 (£49) for cryoprecipitate.

Conclusions: Blood administration costs add substantially to the costs of the blood products themselves. These are frequently incurred costs; applying estimates to the blood components supplied to UK hospitals in 2015, the annual cost of blood administration, excluding blood products, exceeds \$175 (£120) million. These results provide more accurate estimates of the total costs of transfusion than those previously available.

Key words: Blood transfusion, blood administration, cost

Introduction

Healthcare resources are limited and therefore it is important to understand what resources (and associated costs) are required to provide healthcare services. In the area of blood transfusion, whilst the total costs of actually administering the blood exceed the cost of the blood products themselves,¹⁻³ there is limited international evidence on the magnitude of these administration costs.^{4,5} Furthermore, given the number of steps involved in the transfusion process, there are likely to be differences in practice between countries. It is not clear therefore that estimates based on US practice for example would be relevant to other countries such as the UK, where there may be differences in the type of staff responsible for transfusion processes.

The best estimates of the costs of administering blood in the UK are based on just five observations at each of two hospitals in England in 2004,⁶ combined with more recent expert opinion and updated unit costs.⁷ However, these estimates have a number of limitations. First, such a small sample is unlikely to capture the variation between settings and patients. Second, while some time estimates were updated to reflect changes in practice since 2004, these were not informed by direct measurements. Third, activities undertaken in the transfusion laboratory that do not result in a transfusion episode were not considered. Fourth, the costs associated with blood bank machines and disposables were not updated, and may have changed significantly since that time, not least with increasing automation. Finally, wastage figures were not updated but more recent estimates are available.⁸ In summary, there is significant scope to improve estimates of the costs of administering blood in the UK. It is not possible to determine whether blood components are being used in an efficient manner if it is unclear how much transfusions actually cost.

A secondary aim of the *Patient Blood Management* (PBM) approach to optimise care for patients who might need transfusion, is to reduce healthcare costs,⁹ yet the financial

consequences of recommendations can only be fully assessed if the total costs associated with transfusion are known. Recent evidence suggests that promoting single-unit transfusions has greater success in decreasing red blood cell usage than encouraging restrictive transfusion triggers;^{10,11} the financial impact of a single-unit transfusion policy can only be fully understood if the individual components of the costs of administering blood can be separated out, since this policy will have different effects on different components of costs.

More generally, more reliable estimates of the unit costs of transfusion would be useful inputs for economic evaluations, which compare the costs and effects of different healthcare interventions to determine the most cost-effective option which maximises health gain from available resources. Excluding the costs of administering blood from economic evaluations of blood transfusion strategies or healthcare interventions which include transfusion could introduce bias into results.

The aim of this study is to generate accurate estimates of the costs of administering transfusions of different blood products, through detailed measurement and valuation of resource inputs. This paper describes two detailed micro-costing studies,^{12,13} which estimate the costs of the two main inputs into transfusion: laboratory inputs and nursing inputs.

Methods

Laboratory inputs into transfusion

A micro-costing (or bottom-up costing) approach is a detailed and precise method of collecting cost data, which requires the measurement of all individual components of resource use.¹⁴ The first micro-costing study was undertaken to estimate the laboratory inputs for grouping and issuing blood, in terms of the staff time, consumables and equipment costs associated with these activities at two hospitals (the John Radcliffe Hospital, Oxford

University Hospitals (OUH) NHS Foundation Trust, Oxford and Royal Berkshire Hospital, Royal Berkshire NHS Foundation Trust, Reading, hereafter referred to as Oxford and Reading). Oxford is a large teaching hospital and a major trauma centre, Reading is a district general hospital, both have emergency departments. There were three elements to data collection: quantifying the direct inputs into transfusion related activities, quantifying the indirect staff time associated with transfusion related activities, and capturing the capital equipment and activity of the transfusion laboratories. These data could then be used to estimate the cost per group and screen, the cost per red blood cell (RBC) and non-RBC unit issued and the cost per RBC and non-RBC unit transfused.

In order to quantify the direct inputs into transfusion, data collection forms were developed to capture the staff time and consumables for each of the different laboratory inputs into transfusion shown in Figure 1. For each input, the process was split into a series of individual tasks and staff were asked to record their inputs. Only staff time that was spent directly related to the process was captured, for example the time taken to set the analysers running was captured but not the time taken for them to run, since staff were undertaking other activities during this time.

While non-senior staff spend most of their time on direct bench inputs, senior biomedical scientists (BMS) spend a significant amount of time on non-bench activities such as training, supply and reagent issues and validation of new equipment, which is vital to the running of the transfusion laboratory, and needs to be incorporated into costs. Senior BMS and the transfusion laboratory managers at each hospital were asked to complete an additional data collection form capturing time spent on bench and non-bench activities for a week.

The costing questionnaire completed by the transfusion laboratory managers captured the equipment used by each laboratory, and either the year and cost of purchase and lifespan of items or the annual lease cost, and any maintenance costs. In terms of annual activity, the

number of group and screens and electronic and non-electronic cross-matches were captured, as well as the number of units of blood products managed by the laboratory.

Data collection was undertaken between February and July 2013 at Oxford, and between May and December 2013 at Reading. This study was reviewed and approved by the University of Oxford Central University Research Ethics Committee.

For each of the direct inputs into transfusion, the mean staff time per task was calculated and costed at a Band 6 (Agenda for Change salary scales for England), and mean consumable costs were calculated. The Agenda for Change system assigns all National Health Service posts to one of nine pay bands, (nine being the highest); the mid-point salary of a Band 6 was \$43,833 (£30,157) in 2014/15. In the absence of any variables anticipated to be good predictors of missing data, mean imputation was used to handle any missing values of staff time, by replacing them with the mean of the observed data.¹⁵ From the forms completed by senior staff on indirect time, the percentage of time spent on non-bench activities by senior BMS and the laboratory managers was calculated, and costed at Bands 7 and 8a respectively. The annual cost of this time was then apportioned uniformly across the total activity of the transfusion laboratory (defined as the sum of the total number of groups and screens and units of blood issued). For each item of equipment, the equivalent annual cost was calculated, and apportioned over the total number of uses of the equipment per year. Information technology (IT) equipment (computers and printers) was apportioned across the total activity of the transfusion laboratory. Analyses were conducted in Microsoft Excel 2013.

Staff time was costed using mid-points of salary ranges for each Band,¹⁶ inflated by 20% to incorporate National Insurance and Superannuation. Consumable costs and the costs of capital equipment were obtained from the transfusion laboratories, and where necessary were inflated to 2014/15 prices using the Hospital and Community Health Services inflation

index.¹⁷ Value added tax at 20% was included in all cost estimates. Overheads were also included, calculated at 20% of the cost per activity. Costs are presented in 2014/15 prices.

Estimates of the cost per group and screen, and the costs per RBC and non-RBC unit issued and transfused were each generated separately for Oxford and Reading and then an unweighted average of the two costs calculated. Further details on the calculation of each of these costs is described in the online supplementary material (section 1). To ensure our costing was comprehensive and that all the costs of the transfusion laboratory were incorporated into the costs associated with transfusion, the costs of group and screens and units issued that did not result in transfusion were incorporated into the costs per unit transfused.

Nursing inputs into transfusion

This second micro-costing study was undertaken as part of the 'Trial of prophylactic versus no prophylactic platelet transfusions' (TOPPS) trial,¹⁸ and was therefore conducted at two hospitals participating in this trial. The study was carried out on the haematology day units at OUH NHS Foundation Trust, Oxford, and at Guy's and St Thomas' NHS Foundation Trust, London (hereafter referred to as Oxford and London).

On a ward or day unit, nurses perform two key inputs into transfusion: taking blood samples and placing requests for blood, and administering transfusions of blood products. Building on previous work on the steps involved in administering blood products,¹⁹ two data collection forms were developed to capture the direct staff time and consumables associated with these two nursing inputs into transfusion. Each input was split into a series of tasks, and each form captured the time associated with each task, and the consumables associated with the process as a whole. Forms were used to capture the inputs into transfusions of RBCs or platelets, and were completed by nursing staff on the haematology day units prospectively, as they undertook each task in the process for a patient.

Ethical approval for this work was granted by Oxfordshire Research Ethics Committee C as a substantial amendment to the approval for the TOPPS trial. Data collection was undertaken between October 2011 and March 2012 in Oxford, and between November 2011 and September 2012 in London.

Data were entered in to Microsoft Excel 2013 and analyses were conducted in Stata 14. The mean nursing staff time per task was calculated (mean imputation was used to handle any missing data) and costed at the mid-point of a Band 5, Agenda for Change salary scales for England,¹⁶ inflated by 20% to incorporate National Insurance and Superannuation. Mean consumable costs for each input were calculated, consumable costs were taken from the NHS Supply Chain National Catalogue 2011 or provided by the hospitals.²⁰ Costs are presented in 2014/15 prices, any unit costs in earlier prices were inflated (as described previously). Overheads have not been included in cost estimates; it was assumed these would be incorporated into the 'hotel' costs associated with the location in which the transfusion related activities took place, which were assumed to be added separately.

The information was used to calculate the total staff time and consumables required, and associated costs, for taking a blood sample and placing a request for blood, and for administering a transfusion, separately for first and subsequent units (within the same transfusion episode). For blood administration, the cost of all consumables used was attributed to the first unit transfused, consumable costs were zero for subsequent units. Unit cost estimates were generated separately for Oxford and London and then an unweighted average of the two costs calculated.

Generalisability of nursing inputs into transfusion on a day unit with other settings

The second micro-costing study estimated the nursing inputs to transfusions given on a haematology day unit; while the inputs and associated costs of transfusions given on a ward

are likely to be similar, the costs in other hospital settings such as the emergency department (ED) and theatre may be different. To explore the generalisability of the findings on the haematology day units with alternative settings, four semi-structured interviews were conducted in December 2015 with nurses working in ED and theatre. Based on the two data collection forms in the micro-costing study, nurses were asked whether each of the steps in the process on the haematology day unit would be done in their setting or how the process varied, and how long this might take.

Wastage of blood products

According to the UK Blood Stocks Management Scheme 2012-2014 Report, 2.4% of RBCs and 3.8% of platelets issued to transfusion laboratories in England and North Wales were wasted.⁸ The most common reason for RBC wastage was time-expiry, and for platelets it was being clinically ordered but not used. These percentages and the number of units of RBCs and platelets delivered to the transfusion laboratories at Oxford and Reading, were used to calculate the number of units of RBCs and platelets wasted at each hospital in 2014/15. The cost of this wastage was calculated based on the NHS Blood and Transplant 2014/15 price list,²¹ and apportioned across the number of RBC/ platelets units transfused at each hospital in 2014/15. The cost of wastage of each type of blood product was averaged (unweighted) across the two hospitals. Estimates of wastage are not available for frozen products, further details on the calculation of wastage costs for these products are described in the online supplementary material (section 2).

Total costs of administering a transfusion

The three elements of the costs of administration (laboratory and nursing inputs, and wastage) can be summed to calculate the total cost of administering blood, separately for each blood product. While the costs associated with laboratory inputs and wastage are constant per unit, the costs of nursing inputs are higher for a first unit within a transfusion episode, compared to subsequent units. Frequently in an economic evaluation, the

transfusion related resource use data collected would be the number of units of each blood product given to patients during their admission (for example, four units of RBCs and one unit of platelets), and therefore the number of transfusion episodes and units transfused within each episode are unknown. We therefore need to be able to apportion the costs of administration evenly across units; further details on these calculations are provided in the online supplementary material (section 3).

Throughout the results, British pounds have been converted to US dollars using purchasing power parities; these are rates of currency conversion which eliminate price differences between countries, so a sum of money will have the same buying power in each country.²²

Results

Laboratory inputs into transfusion

A total of 210 data collection forms of direct inputs into transfusion practice were completed (148 in Oxford, 62 in Reading) and 20 forms capturing Senior BMS time on bench and non-bench related activity (11 in Oxford, 9 in Reading). These 232 forms were completed by 28 staff members at Oxford and 16 staff members at Reading. There was some missing data on the direct inputs into transfusion forms, which is described in the online supplementary material (section 4).

Figure 1 summarises the staff time and associated costs from the data collection forms of direct inputs into transfusion practice (averaged across the two hospitals). Average staff time (and standard deviations) for each of the direct inputs for each laboratory are provided in the supplementary material (section 5). It usually only takes a few minutes to book in and process a group and screen on the analyser, but when antibody investigations are required (on average for 6% of patients), this adds significantly to the time taken to complete a group and screen. Issuing blood products electronically involves less staff time than serological

cross-matching (the vast majority of RBC cross-matches were performed electronically, on average 93%).

Analysis of the 20 daily records of time spent on bench and non-bench activities by senior staff showed that on average the laboratory managers and senior BMS spent 99% and 40% of their time on non-bench work respectively. Apportioning the proportions of salary costs of laboratory managers and senior BMS spent on non-bench work across the total activity of each transfusion laboratory, added on average \$1.72 (£1.18) to the cost of each activity.

Table 1 summarises the costs of transfusion laboratory inputs (averaged across the two laboratories), costs for each laboratory are provided in the supplementary material (section 5). For every unit of blood transfused, on average 2.3 group and screens are performed, and for every unit of RBCs transfused on average 1.4 cross-matches are conducted. These are factored into the cost per RBC unit transfused. For every unit of non-RBCs transfused, on average 1.2 units are issued. Further details on the breakdown of costs per RBC and non-RBC unit transfused by equipment, consumables and staff components, for each hospital are also provided in the supplementary material (section 5).

Nursing inputs into transfusion

A total of 58 forms capturing the inputs for blood sample collection (28 from Oxford, 30 from London), and 148 forms capturing the inputs into blood administration (87 from Oxford, 61 from London) were returned. Forms were completed by 12 nurses in Oxford, and 18 nurses in London. Staff time on four of the Form 2s were not completed (two at each site). Of the remaining Forms 1 and 2, 16% and 5% of the times were missing at Oxford and London respectively, and needed to be imputed.

Table 2 summarises the staff time and costs of nursing inputs to transfusion; staff time (and variation) and costs at each hospital are provided in the supplementary material (section 6).

The nursing costs associated with subsequent units within a transfusion episode are much lower than for the first unit. Consideration was given as to whether findings differed depending on the type of blood product or the mode of administration, however nursing staff time and the cost of consumables was similar for RBCs and platelets, and whether administered via a cannula or a central line.

Generalisability of nursing inputs into transfusion on a day unit with other settings

Findings from the interviews suggested that the costs of staff inputs to take a blood sample for a group and screen in theatre or ED are likely to be similar to those reported on the haematology day unit. The time taken to administer blood in these settings is less than on the day unit. Given that theatre and resuscitation in ED are higher cost settings than a ward or day unit, and staff and equipment are available for potentially emergency situations, it is perhaps intuitive to think that activities in these environments are done more quickly. Consumable costs are similar, except where large volumes are transfused and blood warming sets are used.

Total costs of administering a transfusion

The three elements of the costs of blood administration (laboratory and nursing inputs, and wastage) are summarised in Table 3 for first and subsequent units transfused. Since national estimates of the average number of blood products administered per transfusion episode are not available in the UK,^{23,24} local data were sought from Oxford and Reading. The best estimates available of the mean number of units of each blood product per transfusion episode are shown in Table 4 (further details are provided in the supplementary material, section 7). These estimates were used to calculate the mean costs of administering blood per unit transfused (also in Table 4) which can be used to cost blood administration using resource use data which are frequently captured in economic evaluations (the number of each type of blood product transfused). If a patient has several transfusion episodes (of the same or different blood products), it is possible that a group and

screen could be valid for more than one transfusion episode; adjusting costs to reflect this is described in the supplementary material (section 8).

Discussion

The full indirect costs of processing and administering blood add substantially to the direct costs of the blood components; we estimate administration costs are \$55-\$84 (£38-£58) per unit transfused. For RBCs, costs are 40% (\$71, £49) higher when the costs of administration are added to the cost of the RBCs. The cost of administering fresh frozen plasma exceeds the cost of the blood product itself. Applying these estimates to the blood products supplied to UK hospitals in 2015,²⁵ the annual cost of blood administration, excluding the direct costs of the blood products themselves, is in excess of \$175 (£120) million.

The estimates generated here add significantly to the limited existing literature on the costs of administering blood in the UK;^{3,6,7} they are based on substantially more primary data than the previous best estimates from a UK perspective and address the limitations of these estimates.⁷ Those previous estimates reported in the NICE guidelines on blood transfusion of \$104 (£72) for a first unit, and \$67 (£46) for subsequent units in 2014/15 prices (available for RBCs only), are higher than the \$83 (£57) for a first unit, and \$53 (£36) for subsequent units reported here.^{7,17} For the costs per first unit, the higher costs in the NICE evidence were largely due to higher costs of nursing inputs, driven by a higher unit cost being used. For the cost per subsequent unit, costs associated with nursing inputs were again higher in the NICE estimates, not only due to higher unit costs but also due to much higher estimates of associated nursing time (based on expert opinion). However, the higher nursing costs for subsequent units were more than outweighed by the lower costs associated with transfusion laboratory inputs for subsequent units in the NICE estimates, largely because the activity of

the transfusion laboratory that does not result in transfusion was not incorporated into the costs of transfusion. Both NICE estimates include 15 minutes of a porter's time to transport blood samples and blood products, an input that was beyond the scope of our study, but this only accounts for \$9 (£6) of the additional cost. Neither our estimates nor the NICE estimates included costs associated with physician inputs.

In the US and elsewhere in Europe, activity-based costing (ABC) has been used to generate estimates of the costs of administering blood.^{4,5} The ABC models were used to map every process relating to blood administration and to identify the detailed resources required for each process, this information was then combined with frequencies of each process to calculate the costs per blood product transfused. While this is a very detailed method, it is difficult to compare resource use from ABC studies to those reported here, since staff time is only presented broken down into a great number of very detailed steps. In contrast, we collected primary data on many steps in each process, but aggregated resource use for each process, for example the nursing time associated with administering a single-unit transfusion is provided, and those using our cost estimates can consider whether that time estimate is relevant to their setting. Since we present staff time separately to costs, the reader can identify the labour intensive tasks within the transfusion process, and can also apply their own unit costs to our time estimates for use in their setting.

Sharing more reliable estimates of the costs of transfusion with the clinical community will help to promote more appropriate use of blood; more effort is likely to be made to conserve resources if their true costs are not underestimated. Furthermore, accurate and transparent cost estimates such as those generated here, which report costs separately for laboratory and nursing inputs, for first and subsequent units, and for wastage, enable the financial impact of transfusion policies which might have different effects on different components of costs to be assessed. In addition, it is important that the costs of administering blood as well as the costs of the blood products themselves are taken into account in economic

evaluations. If two alternative blood transfusion strategies are being compared, a failure to fully account for the costs of transfusion would bias the cost results in favour of the transfusion strategy with the greater blood use (by making that strategy appear less costly than it really is), and might result in misleading recommendations on cost-effectiveness grounds being made. The cost estimates summarised in Table 4 (or Table 3) could be used in future economic evaluations. These estimates can reasonably be applied to blood products administered on a ward, it is less certain how accurate they are for other settings, but they are the best estimates available.

The two micro-costing studies were each conducted at two hospitals. While we can be confident in the findings from each hospital, since a significant amount of primary data was collected, we would have more confidence in the generalisability of the findings if they had been conducted at several more hospitals. The unweighted average cost estimates calculated do not reflect the different levels of activity at each hospital, but with only two sites and two costs to weight, it is not clear that this would have produced costs that are more reflective of the national picture. In the study of laboratory inputs, a key driver of costs was the number of group and screens and units issued, for every unit transfused. It would be useful to obtain this information from a greater number of transfusion laboratories to enhance the generalisability of the findings.

The total cost to healthcare providers of blood administration is likely to increase in the future, since the demand for blood is expected to rise in the next five to ten years due to an increasingly aging population (who have higher transfusion rates, and require more complex surgery than younger patients).²⁶ Comprehensive estimates of the costs of administering blood will be vital to determining whether blood products, a scarce resource, are being used efficiently, and to promote more appropriate use of transfusions, and to assess the financial consequences of the PBM approach.

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Table 1: Summary of the costs of transfusion laboratory inputs

Activity	Average cost across hospitals	
	(£)	(\$)
Group and screen	8.40	12.21
RBC cross-match and issue	8.07	11.73
Non-RBC issue	8.26	12.01
RBC unit transfused	28.56	41.51
Non-RBC unit transfused	27.28	39.65
RBC, Red blood cell		

Table 2: Nursing inputs into transfusion and associated costs

Activity	n	Mean time (minutes)	Cost of staff time (£)	Cost of Consumables* (£)	Total cost (£) (\$)	
Blood sample and request blood	58	17.8	5.57	2.44	8.01	11.64
Administer first unit	144	39.2	12.25	5.38	17.63	25.63
Administer subsequent units	108	14.7	4.58	0	4.58	6.66

*Cost of consumables is based on 136 forms

Table 3: Mean costs associated with administering a transfusion on a day unit

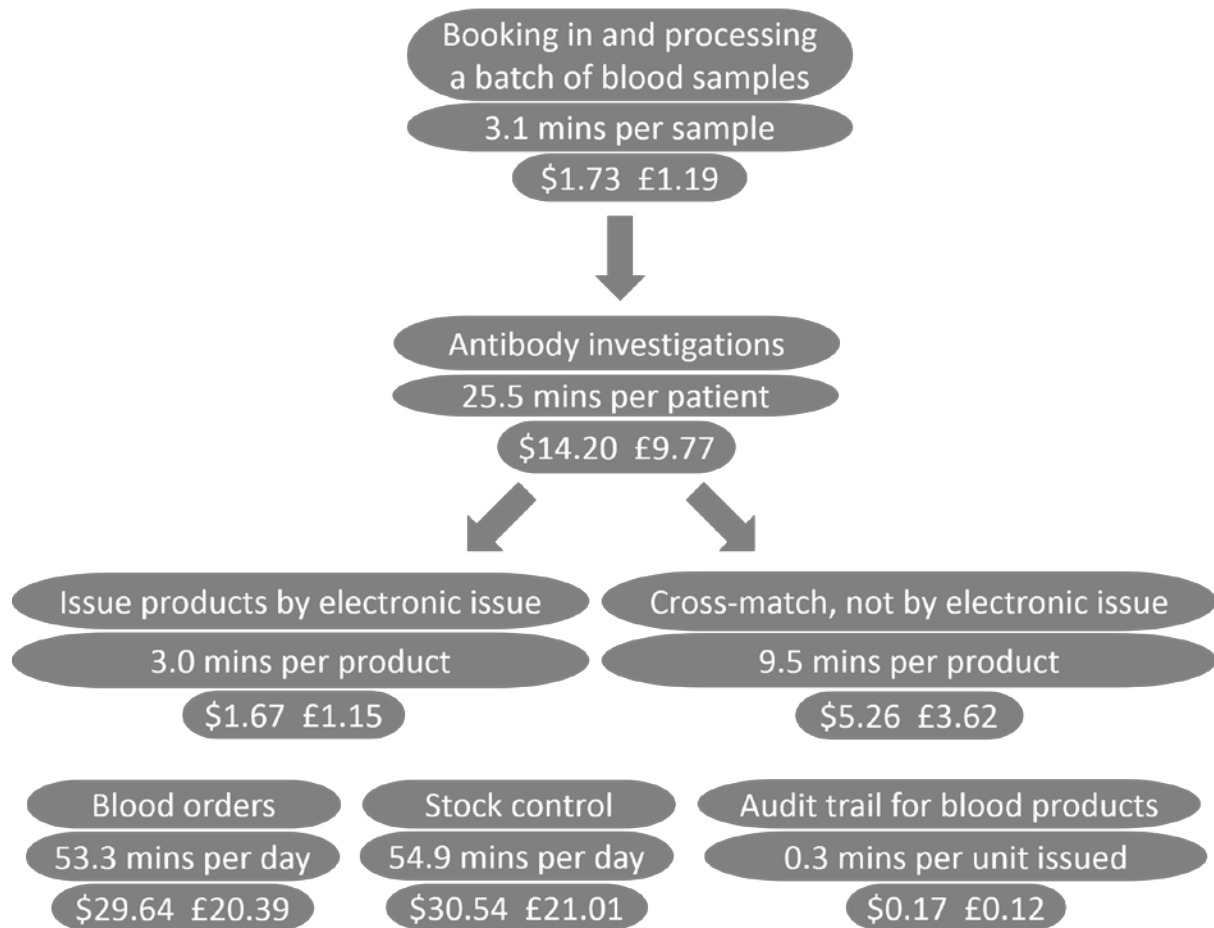
	RBCs		Platelets		Fresh frozen plasma		Cryoprecipitate	
	First unit	Subs. units	First unit	Subs. units	First unit	Subs. units	First unit	Subs. units
Laboratory inputs (£)	28.56	28.56	27.28	27.28	27.28	27.28	27.28	27.28
Nursing inputs (£)	25.64	4.58	25.64	4.58	25.64	4.58	25.64	4.58
Wastage (£)	2.99	2.99	8.45	8.45	1.34	1.34	6.86	6.86
Total (£)	57.19	36.13	61.37	40.31	54.26	33.20	59.78	38.72
Total (\$)	83.13	52.51	89.20	58.59	78.87	48.26	86.69	56.28

RBC, Red blood cell; Subs., Subsequent

Table 4: Mean costs of administering blood per unit transfused

	Red blood cells	Platelets	Fresh frozen plasma	Cryoprecipitate
Mean units per episode	1.7	1.2	4.4	2.0
Mean cost per episode (£)	82.48	69.43	167.14	98.50
Mean cost per unit (£)	48.52	57.86	37.99	49.25
Mean cost per unit (\$)	70.52	84.10	55.22	71.58

Figure 1: Direct laboratory inputs into transfusion, and associated mean staff time and mean staff costs



Supplementary Material

Section 1: Calculating the cost per group and screen, and the costs per RBC and non-RBC unit issued and transfused

The cost per group and screen incorporated the costs of the direct inputs of staff time, consumables and equipment, the indirect inputs of senior staff time and IT equipment, and overheads. The costs per unit issued were calculated in the same way but included the additional costs of maintaining a supply of blood products (ordering, managing the stock) apportioned across all blood products issued, and the capital costs associated with storing blood, apportioned across all RBCs (or non-RBC units) issued.

The costs per unit transfused incorporated the costs of group and screens and issuing products. For every unit of blood transfused, on average more than one group and screen has been performed and more than one unit of blood has been issued, since for some patients a group and screen is performed but blood is never requested, and for others blood is requested but is returned unused to the transfusion laboratory. Clearly group and screens and issues that do not result in transfusion still incur costs to the transfusion laboratory. To ensure our costs associated with transfusion accounted for all transfusion laboratory inputs, the average number of group and screens and units issued per unit transfused were calculated for Oxford and Reading, and incorporated into the cost per unit transfused. This was done separately for RBCs and non-RBCs.

Section 2: Calculation of wastage costs for frozen products

Estimates of wastage are not available for fresh frozen plasma (FFP) and cryoprecipitate, but given that once these products have been thawed they have to be used quickly, the higher wastage rate of 3.8% for platelets was applied. While the number of units of frozen products delivered to the transfusion laboratories were available, these numbers were not available separately for FFP and cryoprecipitate. As the vast majority of frozen products

transfused are FFP rather than cryoprecipitate, wastage costs for FFP were calculated in the same way as for RBCs, assuming that all frozen products delivered were FFP. In the absence of any other data, the cost of wastage for cryoprecipitate was estimated to be 3.8% of the unit cost of cryoprecipitate in 2014/15 prices.¹

Section 3: Apportioning the costs of administration evenly across units

In order to be able to do this, estimates of the mean number of units of blood product given per transfusion episode were sought. The mean administration cost per transfusion episode was calculated by adding the cost per first unit transfused to $(n-1)$ times the cost per subsequent unit transfused, where n was the average number of units given in a transfusion episode. The mean cost per unit was then calculated by dividing the total cost per episode by the mean units per episode.

Section 4: Missing data in the micro-costing study of laboratory inputs to transfusion

There was no missing data on the forms completed by Senior BMS, and no missing data on the form collecting information on the audit trail of blood products. Of the other direct inputs into transfusion forms, the staff time on four forms at Oxford were unusable (times not meaningfully completed), and 13% of the times on the remaining forms were missing and needed to be imputed. At Reading, all forms were usable, and overall 18% of times were missing and needed to be imputed.

Section 5: Further information on the costs of transfusion laboratory inputs

Tables S1 and S2 report the staff time (and variation), and the costs of staff time and consumables associated with direct laboratory inputs into transfusion at each hospital, results are broadly similar. Table S3 summarises the costs of transfusion laboratory inputs at each hospital. For every unit of blood transfused, on average 1.4 and 3.1 group and screens are performed, and for every unit of RBCs transfused on average 1.4 and 1.3 cross-matches are conducted at Oxford and Reading respectively. For every unit of non-RBCs

transfused, on average 1.2 and 1.1 units are issued at Oxford and Reading respectively. For the costs per unit transfused, it is the higher costs associated with a greater number of group and screens that makes Reading more expensive than Oxford. For the costs per RBC and non-RBC unit transfused, the breakdown of cost estimates by equipment, consumables and staff components, for each hospital is provided in Tables S4 and S5 respectively.

Table S1: Staff time and the costs of staff time and consumables associated with direct laboratory inputs into transfusion, Oxford

Form		Number of forms completed	Mean (standard deviation) staff time (minutes)	Cost of staff time (£)	Cost of consumables (£)
1	Booking in a batch of blood samples	20	Per sample 1.7 (0.5)	0.65	0
2	Processing a batch of group and screens	25	Per patient 1.9 (0.7)	0.73	2.37
3	Antibody investigations	24	Per patient 32.0 (18.3)	12.25	12.23
4	Issue products by electronic issue	25	Per product issued 3.2 (1.6)	1.23	0
5	Cross-match, not by electronic issue	26	Per product issued 9.6 (6.3)	3.68	0.47
6	Stock control	23	Per day 52 (19.4)	19.91	0
7	Audit trail for blood products	5	Per unit issued 0.21 (0.10)	0.08	0

Table S2: Staff time and the costs of staff time and consumables associated with direct laboratory inputs into transfusion, Reading

Form		Number of forms completed	Mean (standard deviation) staff time (minutes)	Cost of staff time (£)	Cost of consumables (£)
1	Booking in a batch of blood samples and processing the group and screens	20	Per sample 2.6 (1.1)	1.00	2.24
2	Antibody investigations	11	Per patient 19.0 (12.9)	7.28	11.30
3	Issue products by electronic issue	18	Per product issued 2.8 (0.7)	1.07	0
4	Automated cross-match	2	Per product issued 9.3 (0.4)	3.56	1.80
5	Manual cross-match	1	Per product issued 15.0*	5.74	2.67
6	Stock control	3	Per day 57.7 (16.0)	22.10	0
7	Blood orders	2	Per day 40.5 (4.9)	15.51	0
8	Audit trail for blood products	5	Per day 9.4 (3.4)	3.60	0

* No standard deviation reported since only one form completed.

Table S3: Summary of the costs of transfusion laboratory inputs, by transfusion laboratory

Activity	Oxford	Reading	Average across hospitals	
	(£)	(£)	(£)	(\$)
Group and screen	9.94	6.86	8.40	12.21
RBC cross-match and issue	8.69	7.45	8.07	11.73
Non-RBC issue	7.95	8.56	8.26	12.01
RBC unit transfused	26.22	30.90	28.56	41.51
Non-RBC unit transfused	23.51	31.04	27.28	39.65

RBC, Red blood cell

Table S4: Cost per RBC unit transfused at each transfusion laboratory

Inputs		Cost category			Total	
		Equipment	Consumables	Staff		
Oxford	Group and screen	£1.46	£4.69	£3.30	£9.45	\$13.74
	Cross-match	£0.11	£0.05	£1.99	£2.16	\$3.14
	Indirect inputs*	£5.99	£0.00	£4.26	£10.25	\$14.90
	Total (before overheads)	£7.56	£4.74	£9.55	£21.85	\$31.76
	TOTAL (including overheads)^	-	-	-	£26.22	\$38.11
Reading	Group and screen	£1.42	£8.35	£3.99	£13.76	\$20.00
	Cross-match	£0.03	£0.14	£1.59	£1.76	\$2.56
	Indirect inputs*	£3.93	£0.00	£6.30	£10.23	\$14.87
	Total (before overheads)	£5.38	£8.49	£11.88	£25.75	\$37.43
	TOTAL (including overheads)^	-	-	-	£30.90	\$44.91
Average	TOTAL (including overheads)^	£7.76	£7.94	£12.86	£28.56	\$41.51

* Indirect inputs include senior staff time, IT equipment and maintaining a supply of blood products.

^ Overheads were calculated as 20% of the cost per activity.

Table S5: Cost per non-RBC unit transfused at each transfusion laboratory

Inputs		Cost category			Total	
		Equipment	Consumables	Staff		
Oxford	Group and screen	£1.46	£4.69	£3.30	£9.45	\$13.74
	Electronic issue	£0.53	£0.00	£1.47	£2.00	\$2.91
	Indirect inputs*	£4.14	£0.00	£4.00	£8.14	\$11.83
	Total (before overheads)	£6.13	£4.69	£8.77	£19.59	\$28.47
	TOTAL (including overheads)^	-	-	-	£23.51	\$34.17
Reading	Group and screen	£1.42	£8.35	£3.99	£13.76	\$20.00
	Electronic issue	£0.31	£0.00	£1.18	£1.49	\$2.17
	Indirect inputs*	£4.53	£0.00	£6.09	£10.63	\$15.45
	Total (before overheads)	£6.26	£8.35	£11.26	£25.87	\$37.60
	TOTAL (including overheads)^	-	-	-	£31.04	\$45.12
Average	TOTAL (including overheads)^	£7.43	£7.82	£12.02	£27.28	\$39.65

* Indirect inputs include senior staff time, IT equipment and maintaining a supply of blood products.

^ Overheads were calculated as 20% of the cost per activity.

Section 6: Further information on the costs of nursing inputs

Table S6 shows the costs of nursing inputs to transfusion, separately for each hospital.

Table S6: Nursing inputs into transfusion and associated costs

Activity	Hospital	n	Mean (SD) time (minutes)	Cost of mean time (£)	Cost of consumables (£)	Total cost	
						(£)	(\$)
Blood sample and request blood	Oxford	28	17.0 (6.1)	5.32	0.97	6.29	9.14
	London	30	18.6 (14.5)	5.82	3.90	9.72	14.13
Administer first unit	Oxford	85	37.2 (9.5)	11.64	5.28*	16.92	24.59
	London	59	41.1 (22.1)	12.86	5.47*	18.33	26.64
Administer subsequent units	Oxford	79	11.2 (4.0)	3.50	0	3.50	5.09
	London	29	18.1 (5.8)	5.66	0	5.66	8.23

SD, Standard deviation

* Cost of consumables is based on 77 forms from Oxford, and 59 forms from London.

Section 7: Mean number of units of blood product per transfusion episode

At both Oxford and Reading, the mean number of units transfused per request for RBCs in 2015 was 1.3. This is the mean number of units transfused across all RBC requests, regardless of whether the requests resulted in any RBCs being transfused. Oxford were able to supply greater detail around these figures: the total number of RBCs transfused in 2015, the number of requests for RBCs made, and the number of requests made where no RBCs were given. It was therefore possible to calculate the mean number of RBC units transfused per request where blood products were actually given, this was 1.7. This is the best estimate available of the number of units of RBCs per transfusion episode. Similar data for 2015 were available from Oxford for platelets and FFP, a mean of 1.2 units of platelets and 4.4 units of FFP were transfused per request where blood was actually given. (Data were not available from Reading on non-RBCs). Similar data were not available for cryoprecipitate, the mean units per episode was assumed to be two (personal communication with the Oxford transfusion laboratory manager, October 2016; this is also the dose recommended in the NICE guidelines).²

While these are the best estimates available, it is important to recognise that they may underestimate the true mean number of units per episode. For example, if a patient's haemoglobin is retested after a single-unit transfusion, and a second unit is ordered and transfused via the cannula or central line through which the first unit was given, this is really part of the first transfusion episode (for nursing inputs), but in these figures would be classed as a separate episode. With the introduction of the single-unit transfusion policy, this may have become more of an issue in recent years, but equally because of this shift in practice, recent data were sought to reflect these changes.

Section 8: Adjusting costs to reflect multiple transfusion episodes or multiple types of blood products

In the figures presented in Tables 3 and 4, every transfusion episode included the nursing costs of taking a blood sample for a group and screen (\$11.64 / £8.01). For the first transfusion episode, this will clearly be necessary, but there will be some variability about whether a second transfusion episode would require another group and screen. For RBCs, the British Committee for Standards in Haematology guidelines recommend that cross-matching (including electronic issue) is performed on samples that are taken no more than three days in advance of the transfusion (when the patient has been transfused RBCs or pregnant within the preceding three months).³ Therefore if a blood sample is taken on day one, and a RBC transfusion is administered that day, then any RBC transfusions on days two or three can be matched for the patient using the blood sample taken on day one; from day four onwards a new sample would be required. For non-RBCs only one group and screen is required, blood products are issued based on a patient's blood group and a valid recent sample is not required. If the dates of transfusion episodes are recorded, then the exact number of group and screens conducted can be estimated. If this is not the case, and the time period over which transfusions occur is recorded, then a maximum number of group and screens required can be calculated and compared to the number of group and screens included in the costs of administration; costs associated with nursing inputs to group and screens can be capped if necessary.

References

1. NHS Blood and Transplant. NHS Blood and Transplant Price List 2014-2015, 2014.
2. National Institute for Health and Care Excellence (2015) Blood transfusion. (NICE guideline 24). <https://www.nice.org.uk/guidance/ng24>.
3. British Committee for Standards in Haematology, Milkins C, Berryman J, Cantwell C, Elliott C, Haggas R, et al. Guidelines for pre-transfusion compatibility procedures in blood transfusion laboratories. *Transfus Med* 2013;23(1):3-35.