Improving transfusion appropriateness through an online educational module: a controlled before-after quality improvement study

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Complete List of Authors:	Lee, Todd; Royal Victoria Hospital, Internal Medicine and Infectious Diseases Murray, Jennifer McDonald, Emily; McGill University, Internal Medicine
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Abstract:	Background: Many studies have failed to show clinical benefits from liberal transfusion of packed red blood cells. Professional societies have made value-based statements aimed at reducing inappropriate transfusions; however, translating these statements into changes in clinical practice is challenging. We sought to determine if mandatory completion of an accredited free online training course would improve transfusion knowledge amongst medical residents and increase transfusion appropriateness. Methods: We describe a controlled before-after evaluation of two medical clinical teaching units (47 and 45 beds respectively) at a university hospital centre in Montréal, Canada. Fifty-five resident physician pre and post-test scores were compared and the impact on transfusion appropriateness was evaluated by comparing the proportion occurring below a hemoglobin of 80g/L. Results: Of 55 resident physicians, 53 completed the training (96.4%). The median pre-test score was 50% (IQR 40%-60%), post-test one 90% (IQR 80%-90%) and post-test two 80% (IQR 80%-90%), p<0.0001. With training, the proportion of transfusions below 80g/L increased from 80.1% to 86.9% (p=0.038) on the intervention unit; on the control unit it decreased from 75.6% to 71.1% (p=0.37). The proportion of transfusions occurring below 80g/L prior to the intervention did not differ significantly between groups (intervention 80.1% vs. control 75.6%, p=0.07); following the intervention, a significant

	difference was observed (86.9% vs. 71.1%, p=0.002) in favor of the intervention unit. Interpretation: Mandatory training in transfusion appropriateness using an online educational module resulted in significant improvements in transfusion knowledge amongst resident physicians and is a low-cost educational initiative for improving transfusion appropriateness.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	a) 1 b) 2/3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	5
b)Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	8

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Improving transfusion appropriateness through an online educational module: a controlled before-after quality improvement study

Todd C. Lee MD MPH[1,2], Jennifer Murray MScPH[1], Emily G. McDonald MD MSc[1,2]

[1]Clinical Practice Assessment Unit, Department of Medicine, McGill University Health Centre, Montréal, Canada

[2]Division of General internal medicine, Department of Medicine, McGill University Health Centre, Montréal, Canada

Correspondence and Reprint Requests to:
Emily G. McDonald
Royal Victoria Hospital
1001 Decarie Boulevard Room D5.5843
Montréal, QC Canada H4A 3J1
Tel: (514) 934-1934, local 34673
Fax: (514) 843-1676
Email: emily.mcdonald@mcgill.ca

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Abstract:

Background: Many studies have failed to show clinical benefits from liberal transfusion of packed red blood cells. Professional societies have made value-based statements aimed at reducing inappropriate transfusions; however, translating these statements into changes in clinical practice is challenging. We sought to determine if mandatory completion of an accredited free online training course would improve transfusion knowledge amongst medical residents and increase transfusion appropriateness.

Methods: We describe a controlled before-after evaluation of two medical clinical teaching units (47 and 45 beds respectively) at a university hospital centre in Montréal, Canada. Fifty-five resident physician pre and post-test scores were compared and the impact on transfusion appropriateness was evaluated by comparing the proportion occurring below a hemoglobin of 80g/L.

Results: Of 55 resident physicians, 53 completed the training (96.4%). The median pre-test score was 50% (IQR 40%-60%), post-test one 90% (IQR 80%-90%) and post-test two 80% (IQR 80%-90%), $p<0.0001$. With training, the proportion of transfusions below 80g/L increased from 80.1% to 86.9% ($p=0.038$) on the intervention unit; on the control unit it decreased from 75.6% to 71.1% ($p=0.37$). The proportion of transfusions occurring below 80g/L prior to the intervention did not differ significantly between groups (intervention 80.1% vs. control 75.6%, $p=0.07$); following the intervention, a significant difference was observed (86.9% vs. 71.1%, $p=0.002$) in favor of the intervention unit.

Interpretation: Mandatory training in transfusion appropriateness using an online educational module resulted in significant improvements in transfusion knowledge amongst resident physicians and is a low-cost educational initiative for improving transfusion appropriateness.

Introduction

The Choosing Wisely campaign contains more than seventy lists of common tests and procedures that specialty societies have created to improve healthcare through the avoidance of low-value practices(1). The campaign has evolved in order to place a stronger emphasis on implementation and the evaluation of clinically meaningful interventions(2). In order to effect change, it is generally accepted that the movement must go beyond statements of avoidance; toolkits outlining practical implementation strategies may be one means of accomplishing this(3). One important recommendation that would benefit from this approach, and is shared by a number of professional societies, recommends the avoidance of transfusions in stable patients for arbitrary hemoglobin values. Patient care can benefit in a multitude of ways from restrictive transfusion strategies. In most circumstances, restrictive transfusion practices have been shown to be as safe, or safer than, liberal transfusions (4-7). In addition, the frequency of adverse events related to blood products is likely underreported (8), packed red cells indirectly cost approximately $1200 (CAD) per unit transfused (9), blood products can be a limited resource in smaller centres and packed red cells are often overused (10-13).

As one low-cost initial strategy for improving transfusion appropriateness, we sought to determine if the universal, mandatory completion of a freely-available, accredited, online educational module *Bloody Easy Lite for Physicians* (14) could lead to improvements in transfusion appropriateness in a pragmatic before-and-after study design.

Methods

Study Sites

This study was performed on the medical clinical teaching units (CTU) of the Royal Victoria Hospital (47 beds). As a comparator, we used a 45 bed CTU at the Montreal General Hospital as a contemporary control. These two hospitals belong to the McGill University Health Centre, which is an 832-bed tertiary care center in Montréal, Canada. Both medical CTUs predominantly admit acutely ill patients via the emergency department who do not require surgery, acute chemotherapy, critical care, or specialized cardiac care. Each CTU cares for a similar proportion of patients with coronary artery disease, congestive heart failure, and gastrointestinal hemorrhage.

Intervention

At baseline, all resident physicians in the first three years of the internal medicine core residency program receive a one-hour session, given every two years, on the management of transfusion reactions, but there is little focus placed on transfusion appropriateness. Beginning July 1, 2015, in addition to the standard one-hour session, resident physicians working on the intervention unit were required to complete a free online module called *Bloody Easy Lite for Physicians* (available from the Ontario Regional Blood Coordinating Network website at http://belite.transfusionontario.org/). This Royal College of Physicians and Surgeons of Canada accredited online learning program provides education about transfusion medicine including: pre-transfusion testing, indications for transfusion, transfusion appropriateness (e.g. thresholds for transfusion), and the diagnosis and management of adverse transfusion reactions. It features a pre-test and two post-test evaluations of performance for the individual learner to gauge their own performance. Completion was required before the end of the first week of their first CTU rotation.

On the intervention unit medical students were encouraged to take the module but were not required to do so as they cannot order transfusions. Faculty members attending on the intervention CTU were also invited to take the module at their own discretion.

Data sources

Transfusion data was obtained from the blood bank through the Canadian Blood Services system *TRACE LINE*, which is an FDA licensed software designed for large scale hospital transfusion services and used in over 80 hospitals in Québec. Individual transfusions were manually cross-referenced with corresponding pre-transfusion hemoglobin values using the laboratory information system, OACIS. The earliest data available were from April 1, 2013. The most recent hemoglobin value up to 48 hours before transfusion was extracted and used in the adjudication of the primary outcome. In the rare cases where there was no hemoglobin measured between two or more transfused units, we inferred the subsequent pre-transfusion hemoglobin by adding 10g/L to the initial pre-transfusion value for each unit transfused. Two patients who received 4 or more units of packed red blood cells within a single day for significant bleeding were excluded from the analysis.

Outcomes

Based on high quality evidence, the Clinical Practice Guideline on red blood cell transfusion from the American Association of Blood Banks strongly recommends (4) “adhering to a restrictive transfusion strategy (70 to 80 g/L) in hospitalized, stable patients.” In conjunction with Choosing Wisely Canada (15) and the Ontario Regional Blood Coordinating Network, we

decided on a value of 80g/L as being a reasonable indicator of potentially inappropriate transfusions. Thus, while 80 g/L does not imply a clinical threshold for transfusion, we used this value for detecting potentially inappropriate transfusions. Secondary outcomes were the rates of transfusions standardized per 100 admissions and per 1,000 patient days.

To evaluate how well the primary outcome served as a surrogate for potentially inappropriate transfusions, two authors (TCL and EGM, both staff general internists) blinded to transfusion date and location, reviewed a convenience sample of 75 charts of patients who were transfused with hemoglobin values above 80g/L. Transfusions above 80g/L were judged as inappropriate in non-bleeding, hemodynamically stable patients, and in the absence of active cardiac ischemia documented in the medical record. Consensus was reached through discussion in cases of disagreement.

Statistical Analysis

Based on a previous audit, about 70-75% of transfusions on medicine were occurring at a threshold of less than 80 g/L (local unpublished data). Whereas a comparable tertiary care hospital in Ontario has been able to achieve 80% of transfusions below a threshold of 80 g/L based on a 2014 audit of pRBC transfusions from the Ontario Regional Blood Coordinating Network. In order to have 80% power to demonstrate an absolute difference of 8% in the proportion of transfusions occurring below 80g/L, we calculated that we would need approximately 125 transfusions. Given an average of 25 transfusions per month, we estimated this would take six months and allowed an extra month in case of lower than expected rates. We therefore compared the time period before (April 1, 2013 – June 30, 2015) and after (July 1,

2015 – January 31, 2016) within the intervention site, as well as a comparison to the control site. Comparisons of proportions were made using Chi-Square. Comparisons of transfusion rates were made using a Z-test of the summary rate difference using inverse variance weights. Comparisons between anonymized trainee pre-test and post-test performances were performed using a Wilcoxon rank sum on the paired data.

Ethics

This study was approved by the McGill University Health Centre Research Ethics Board.

Results

Of 55 resident physicians who worked on the intervention units, 53 successfully completed the training (96.4%) along with four of the fifteen faculty (27%). No faculty or senior residents from the control group received the training; however, thirteen first-year residents from the control hospital did one-month rotations at the intervention site at various times. The median pre-test score was 50% (interquartile range 40%-60%), post-test one 90% (interquartile range 80%-90%) and post-test two 80% (interquartile range 80%-90% ($p<0.0001$ for both comparisons).

A total of 1,410 units of blood were transfused over the entire period. The pre and post-intervention data for both units is shown in Table 1. Following the educational intervention, on the intervention unit the proportion of transfusions occurring with a hemoglobin below 80g/L (appropriate) increased from 80.1% to 86.9% ($p=0.038$) whereas on the control unit it decreased from 75.6% to 71.1% after ($p=0.37$). Prior to the intervention, the proportion of transfusions

occurring with a hemoglobin below 80g/L (appropriate) was no different between the intervention site and the control site (80.1% vs. 75.6% respectively, p=0.07); following the intervention, there was a significant difference between the intervention and control sites (86.9% vs. 71.1% respectively, p=0.002) in favor of the intervention site. This corresponded to an absolute improvement of 6.8% and a relative improvement of 34% in the proportion of transfusions occurring below a hemoglobin of 80 g/L.

Based on a convenience sample of 75 blinded chart reviews, the proportion of inappropriate transfusions occurring above 80g/L was 78.7% (kappa 0.80 for inter-observer agreement), indicating that the majority of transfusions that occurred above this threshold might have been unnecessary and could have been avoided.

In contrast to the above findings, both population-based rates were actually significantly lower at all times in the control unit and the number of transfusions per 100 admissions or per 1,000 patient days significantly decreased on the control unit but not on the intervention unit (Table 1).

Interpretation

In this pragmatic before-after study conducted on our medical CTUs, the mandated completion of *Bloody Easy Lite for Physicians* by all resident physicians was associated with an absolute 6.8% and relative 34% improvement in the proportion of transfusions at a hemoglobin below 80g/L, with no significant change seen on the contemporary control unit. Uptake of the training module was nearly complete (96%) and transfusion knowledge, as evidenced by standardized post-test performance, was greatly improved compared to baseline. Importantly, the only

institutional cost associated with this intervention was approximately 60 minutes of resident physician time.

On the intervention unit, metrics of transfusions per 100 admissions or per 1,000 patient days did not capture a demonstrable difference in transfusion appropriateness between sites, with a concomitant decrease in both rates seen on the control unit. This highlights the limitations of these and similar metrics for both intra and inter-site comparisons and is important to keep in mind for designing future quality improvement initiatives. These metrics are a measure of rates of transfusion but do not necessarily reflect transfusion appropriateness. A comparison of the pros and cons of different transfusion metrics is available in the supplementary appendix. In our study, on the control unit the number of hematologic and solid organ cancer patients who were admitted decreased around the time of the intervention. This population requires a large number of transfusions, but appropriately-so. Transfusions for 100 admissions may be highest for these patients but also completely appropriate (making the proportion of transfusions below 80g/L a much better metric for appropriateness). Changes in patient acuity and complexity can explain why per-admission/patient day rates decreased on the control unit in the absence of a specific intervention. In further support of this, the proportion of transfusions under 80g/L did not improve on the control unit, because there was no specific change in transfusion behavior, merely fewer overall scenarios potentially requiring transfusion.

There have been several publications involving traditional educational interventions to improve transfusion appropriateness ranging from frequent verbal presentations to more formal behavioral interventions, which have had mixed results depending on the training personnel,

clinical champions, and specific curriculum used (16-19). A recent meta-analysis of behavior modification interventions (including protocols, education, electronic medical record alerts, audit and feedback, and policy interventions) to optimize red blood cell transfusion practices found that use of an intervention decreased the pooled odds of inappropriate transfusion (pooled OR 0.46 (95% CI 0.36 to 0.59)(20). The authors noted that no study to date had examined the cost-effectiveness of such interventions.

There are key advantages to the success of the online intervention used in our study: Bloody Easy Lite for Physicians is standardized and accredited; it is self-directed and the trainee can complete it on their own time, including from home; it can easily be used at non-academic institutions; improvement in knowledge can be measured objectively through the scored pre-test and post-test components; and the intervention doesn't require an individual with specialized knowledge to champion the intervention, teach ongoing sessions, or rely on voluntary attendance at rounds. Moreover, if implemented at a more central level, this type of online learning module could be applied systematically across a training program or even an institution or university, promoting change and reaching a larger and broader audience than might be achieved with grand rounds, monthly unit-based teaching sessions, or even specific educational campaigns.

Limitations:

It is worth noting that in many studies, multi-modal interventions, especially the subsequent addition of computerized decision support at the time of ordering a transfusion led to even further reductions suggesting this pairing is more effective than educational efforts alone (16-18,

21). At our institution we currently have no means of implementing such computerized decision support; however, some degree of decision support can even be introduced into paper-based systems with standardized transfusion order forms (22). We tested this intervention on a medical unit where most patients are acutely ill, have a variety of diagnoses and comorbidities, and often require transfusions. If potentially inappropriate transfusions can be limited in this environment, training may prove effective in other inpatient settings as well. Although many previous educational interventions have been described, the use of an online training module that can be accessed from home is relatively novel. The cost of the intervention was negligible given the online training was freely available and each transfusion prevented would have saved on average $1200. Nonetheless, this was a non-randomized study that was conducted at a single academic health center on a medical teaching unit and the external validity needs to be considered. It is unproven if such an approach would work in centers with more extensive pre-existing transfusion education, on surgical or critical care units, or in non-teaching centers. Also, before-and-after studies have methodological limitations which can raise concerns for internal validity. The use of a contemporary control unit does help strengthen our conclusions and our primary outcome metric is easily obtained and relatively independent of patient volume or case mix. Finally, it should be cautioned that the metric of transfusions below 80g/L is a proxy for appropriateness. Improvements here may not necessarily translate into reductions in harder outcomes such as transfusion-associated adverse events which are too rare for a study of this size to detect.

Conclusion

When it comes to the transfusion of packed red cells, interventions to improve appropriateness

are necessary and can have an important impact if deployed broadly and early on in a physician's training. An online training module that is widely available, accredited, and inexpensive presents a very promising option. Subsequent studies are needed to evaluate this educational initiative in a broader context. Given the promising findings of the present study, our institution will mandate *Bloody Easy Lite* training for all residents in post-graduate medical education starting June 2019. This pragmatic intervention provides promise for directed learning as a means of turning value-based avoidance statements into meaningful advances in high value healthcare.

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We would like to acknowledge the Canadian Society of Internal Medicine's Choosing Wisely Workgroup for their participation in the genesis of this project. We would like to thank the Ontario Regional Blood Coordinating Network for the use of their online education module. We would like to thank Dr. Patricia Pelletier and Ann Wilson from our Blood Bank and Alain Biron from our Department of Performance, Safety and Quality for their assistance in study design, expert hematology review, and with obtaining the relevant data.

Role of the Funding source

Funding was provided by the Royal Victoria Hospital 9C Clinical Teaching Unit Quality Improvement Fund and from the McGill University Health Center Association of Physicians.

The funders had no role in the design, conduct or reporting.

Table 1 – Comparison of proportion of transfusions below 80g/L on the intervention and control units before and after intervention

	MGH			RVH		
	Before	After	p-value	Before	After	p-value
Total Transfusions	455	90		689	176	
Proportion Below 80g/L	75.6	71.1	0.37	80.1	86.9*	0.04
Patient Days	36678	10774		40454	11149	
Admissions	2873	851		3829	1101	
Per 1000 Patient Days	12.4	9.3	<0.001	17.0*	17.8*	0.36
Per 100 Admissions	15.8	11.9	<0.001	18.0**	16.0*	0.16

* p-value <0.005 for comparison to MGH during same time period. ** p=0.03 for comparison to MGH during same time period. Any comparison of proportions used Chi-Square and any comparison of rates used a Z-test of the rate difference using inverse variance weights.

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Supplemental appendix 1 – Pros and Cons of Various Measures of Blood Transfusion Utilization

Measure	Pros	Cons
Overall number of units	• Easiest to obtain	• Sensitive to the population being measured • Not comparable between institutions with different populations • Does not assess appropriateness of the transfusion
Transfusions per 1000 patient days	• Allows standardization and comparison within a unit or institution	• Sensitive to the population being measured • Not comparable between institutions with different populations • Does not assess appropriateness of the transfusion • May underestimate overuse in units with low acuity patients and long lengths of stay
Transfusions per 100 admissions	• Allows standardization • For many services, newly admitted patients are, in general, much more likely to be transfused than long-term patients	• Sensitive to the population being measured • Not comparable between institutions with different populations • Does not assess appropriateness of the transfusion
Number of single unit transfusions	• Addresses appropriateness and supports campaigns such as Choosing Wisely Canada's "why use two when one will do?" • Eliminating routine orders to transfuse two units will reduce overuse	• Does not address the appropriateness of the first transfusion given or of single unit transfusions • Not always straightforward to electronically collect this type of data particularly when the transfused units occur on two calendar days (i.e. pre/post-midnight)
Proportion of transfusions with hemoglobin below 80g/L (or other value)	• Allows for internal and external comparisons which are independent of case mix • Addresses appropriateness and can be used in goal setting for an institution e.g. "80% below 80" • Sensitivity and specificity of potential overuse can be adjusted by changing the hemoglobin cut-off	• More difficult to obtain in some centers because it requires both transfusion and laboratory data • Can be confused with stating that 80g/L is the clinical threshold for transfusions
Proportion of appropriate transfusions	• Allows for internal and external comparisons which are independent of case mix • Addresses appropriateness	• Requires expert adjudication • Time consuming and impossible to automate • Comparisons highly dependent on inter-observer reliability