Evaluation of immunohematology knowledge in hematology trainees

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BACKGROUND: Canadian hematology trainees are expected to attain clinical knowledge in the subject of red blood cell and platelet antigen systems and the principles of transfusion medicine. However, the relative degree of expertise required in blood bank serology is not well defined.

STUDY DESIGN AND METHODS: A modified Delphi approach involving 10 Canadian hematology program directors was utilized to identify 12 relevant topics in immunohematology. A multiple-choice exam was developed and validated among hematology trainees from 13 hematology training programs across Canada. A Rasch analysis was used to determine fit of the examination before deploying the exam the following year to ascertain the level of knowledge in hematology trainees.

RESULTS: The exam was piloted with 62 hematology trainees. The reliability of the exam was 0.93 with a mean item fit score of 1.01. The exam was able to discriminate between training years and self-rated expertise with better performance attained by more advanced trainees ($p < 0.01$). No differences were seen between geographic regions. A modified version of the exam was deployed the following year to 85 trainees, with a mean score of 58.9% $\pm$ 15.3%. Trainees scored poorest on topics concerning antibody investigations and D variants.

CONCLUSION: A standardized exam for assessing hematology trainees on their expected expertise in transfusion immunohematology has been developed and can be used to assess the efficacy of educational resources provided in the subject. Trainees had a low overall mean score indicating additional educational initiatives are warranted.

In Canada, postgraduate specialty training in clinical hematology must meet the educational objectives of the Royal College of Physicians and Surgeons of Canada (RCPSC), with one key competency being an understanding of the principles of blood transfusion.[1] Recognizing that clinical hematologists may be expected to provide directorship of a hospital blood bank as part of their work portfolio, competency in transfusion medicine involves not only activities surrounding the administration of blood products (e.g., obtaining informed consent, administering products appropriately, and managing adverse reactions), but also a basic understanding of immunohematology. In fact, depending on the location of practice, a hematologist may be viewed as the local expert on transfusion medicine within his or her institution.[2] Therefore, ensuring adequate exposure to the foundations of serologic investigations and more nuanced details of transfusion medicine is of critical educational value to trainees. However, RCPSC expectations regarding the breadth and depth of expertise in transfusion serology are not well defined, with only two specific objectives listed: "Describe the red blood cell and platelet antigen systems and the principles of transfusion medicine (2.1.10)" and "Describe the principles of laboratory testing (2.1.16)."[1] As a result, the duration and specific content delivered during a transfusion rotation varies between academic institutions across the country.[3]

Several tools have been validated for the assessment of clinical transfusion knowledge in internal medicine and

ABBREVIATION: RCPSC = Royal College of Physicians and Surgeons of Canada.

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obstetrics trainees.[4,5] Most recently, the assessment tool developed by the Biomedical Excellence for Safer Transfusion (BEST) Collaborative was deployed to evaluate clinical transfusion knowledge in hematology trainees across 17 international sites.[3] This evaluation tool focused on basic concepts of transfusion consent, indications, and reaction management. Not surprisingly, hematology trainees scored higher than their internal medicine counterparts. However, the mean scores achieved were lower than expected for hematology trainees with formal transfusion education. While the BEST tool assessed basic concepts of clinical transfusion, it is unknown how hematology trainees would fare with more advanced transfusion concepts, such as immunohematology. In an attempt to objectively measure the performance of trainees in immunohematology and identify opportunities for educational initiatives, a 12-question exam was created and distributed to hematology trainees in Canada.

MATERIALS AND METHODS

Knowledge topics for inclusion in the immunohematology assessment tool were identified using a modified Delphi technique.[6] The panel of experts consisted of a diverse group of hematology program directors from 12 Canadian academic institutions (Table 1). Hematology program directors were selected to participate in the panel as they were believed to be best positioned to understand the curricular needs of their trainees and programs as well as the clinical practice of a hematologist. A survey was sent to the panel with the question "What knowledge or skills related to blood bank serology are absolutely essential for clinical hematologists (not transfusion medicine specialists) practicing in the Canadian health-care system?" Respondents were asked to provide their answers as free text and to be as specific as possible, avoiding broad responses such as "compatibility testing." Responses were then collected, grouped into 22 categories with duplicates removed, and then returned for rating by the program directors on a Likert scale from 1 to 6 for relevance (1 = not relevant to 6 = very relevant). Items that scored 4 or higher by at least 80% of respondents were retained as key topics to include in the assessment tool and residency training curriculum. Program directors were also asked to briefly describe the duration and method by which teaching in transfusion medicine serology was provided.

TABLE 1. Demographics of hematology program directors included in the modified Delphi panel*

Characteristic	
Respondents	12
Degrees	
MD	7 (58)
MD/MSc or PhD	2 (17)
MD/Master of Education	3 (25)
Specialty	
Bone marrow transplantation	1 (8)
General hematology	2 (17)
Malignant hematology	4 (33)
Thrombosis	3 (25)
Transfusion medicine	2 (17)
Work setting	
Academic hospital	12 (100)
Experience (years)	11.6 (6-29)

* Data are reported as number (%) or mean (range).

As a means of determining the efficacy of current Canadian hematology programs in teaching these identified knowledge topics, a 12-question multiple-choice question exam was developed based on best practices as defined by the Medical Council of Canada and the AABB.[7,8] Although the hematology program directors identified knowledge topics, the content of the exam was created by a transfusion medicine specialist and reviewed by eight other transfusion medicine specialists for validation. A digital copy of the examination can be obtained by contacting the corresponding author.

The examination was piloted by administration to Postgraduate Year (PGY)-4, -5, and -6 hematology trainees across Canada in July 2017. As Canadian hematology trainees complete 3 years of internal medicine residency before commencement of 2 years hematology training, at the time of exam administration PGY-4s were at the start of their hematology training, PGY-5s were at mid-point, and PGY-6s had completed their training and were awaiting final RCPSC certification. In addition to demographic information on training year and location, trainees were also asked to self-rate their competency in transfusion medicine by choosing between the options of "no knowledge," "beginner," "intermediate," or "advanced."

The examination was completed in person during a national hematology trainee retreat attended by trainees from 13 academic institutions across Canada. Trainees completed the exam independently from one another, without access to reference material, and were not advised in advance regarding exam content. The exam was administered in English only (all trainees from French-language training programs were fluently bilingual). To preserve validity of the examination for future sittings, trainees were not permitted to keep copies of exam questions or told the correct answers.

A Rasch analysis was performed using computer software (Rasch measurement software, Winsteps) to determine the overall fit of the examination based on responses from the pilot. In brief, the Rasch analysis provides a psychometric evaluation of assessment tools to ensure their predictability and reliability in measuring performance.[9] Overall exam fit was determined based on the alignment between student ability and the difficulty of a question. Student ability is in turn calculated by utilizing the natural logarithm of the percentage of correct items divided by the percentage of incorrect items selected by that individual, whereas item difficulty is obtained by using the natural logarithm of the percentage of the exam cohort's correct responses divided by the percentage of overall wrong responses for the exam

item.[9] An ideal assessment tool would display concordance between student ability and item difficulty, meaning that high-performing students should have the best probability of answering a difficult question correctly. Questions with poor fit, on the other hand, are those where students with low overall ability perform as well or better than those with overall higher ability. Poor fit might arise if a question is either too easy or too difficult. A mean square value of 0.7 to 1.3 and standardized value of −2.0 to 2.0 is indicative of an acceptable fit for the Rasch analysis.[9] A one-way analysis of variance (ANOVA) was calculated to determine if the exam was able to discriminate between different levels of training, self-assessed competency, and geographic location of training (defined as Ontario, Quebec, Western provinces, and Eastern provinces).

After the initial piloting of the exam, questions with poor fit were identified and modified to improve performance of the exam. The updated examination was then administered 1 year later in July 2018, using an Internet-based tool (SurveyMonkey) to hematology trainees across Canada, with local invigilation provided by program directors to ensure the same test-taking conditions were in place as with the previous year's examination. No specific educational interventions were introduced between the first and second versions of the exam aside from usual progression through each trainee's respective residency program during the intervening 12 months.

RESULTS

Hematology program survey

Responses were received from 12 hematology program directors. The most common method of teaching transfusion medicine reported was didactic lectures (92%), followed by journal clubs or trainee presentations (75%) and independent study (75%). A smaller proportion reported direct performance of serologic procedures (58%), transfusion medicine workshops (58%), and on-call coverage for the hospital blood bank (17%). Eleven program directors reported a median of 2 months (interquartile range, 1.25-2 months) of transfusion medicine training during the trainees' 2-year hematology program.

Responses were received from 10 hematology program directors regarding essential subject matter education in transfusion medicine, from which 12 key topics were selected (Table 2). Recognizing that competency in interpretation of an antibody investigation panel might not be optimally evaluated through a multiple-choice question, a specific educational assessment tool for this topic was developed and will be reported on in a separate publication.

Assessment tool: results of pilot

A total of 62 trainees from 12 hematology programs completed the pilot examination. There was near-even distribution of trainees for each training year and most trainees (90%) evaluated their own transfusion medicine expertise as being in the beginner to intermediate range of knowledge (Table 3). Twenty-six respondents (42%) were completing their training at Ontario universities, approximating the proportion of the Canadian population living in that province.

A Rasch analysis demonstrated overall high exam reliability at 0.93, a mean item fit of 1.01, and mean trainee fit of 0.99. A range of student ability and item difficulty was observed in the pilot examination (Fig. 1). ANOVA determined that the examination significantly discriminated between training level and perceived knowledge level, with better performances noted in advanced trainees (Table 3). There were no differences in performance noted when trainees were grouped by geographic location of their residency programs (there were too few trainees at each individual program to

TABLE 2. Topics covered by each examination question and the corresponding percentage of correct responses from all trainees

	Mean percentage of correct items	
Question topic	2017	2018
1. ABO grouping: understand forward and reverse ABO grouping.	72.6	82.4
2. Antibody screen: interpret the meaning of a negative antibody screen.	95.2	97.6
3. Panagglutination: appreciate causes of a pan-reactive panel.	56.5	60.0
4. Blood group antigens: identify clinically significant blood group antigen.	69.4	62.4
5. Cold agglutinins: understand factors in determining the clinical significance of a cold agglutinin.	80.7	72.9
6. Crossmatch: appreciate the different types of RBC crossmatches.	40.3	51.8
7. DAT interpretation: interpret a DAT result.	46.8	48.2
8. Panel interpretation: appreciate the steps in an antibody investigation.	40.3	36.4
9. RBC antigen–antibody reactions: understand the differences observed in antigen–antibody reactions (e.g., IgG vs. IgM).	19.4	48.2
10. Transfusion support for special populations: understand the transfusion workup in warm autoimmune hemolytic anemia.	41.9	41.1
11. Transfusion reactions: identify the types of transfusion reactions that require further workup by the laboratory.	77.4	76.5
12. Variants of D: appreciate the difference of weak D in blood donors versus recipients.	41.9	29.4
Total % correct for all items (±SD)	56.9 (±19.8)	58.9 (±15.3)

TABLE 3. Breakdown of correct responses by trainee year and self-assessed competency

	2017 pilot exam		2018 finalized exam	
	Number	Mean % correct (±SD)	Number	Mean % correct (±SD)
Training level				
PGY-4	19	46.5 (±16.0)	28	50.9 (±11.9)
PGY-5	20	55.4 (±20.1)	29	60.6 (±15.4)
PGY-6	23	66.7 (±18.1)	28	65.1 (±15.6)
		p = 0.003		p = 0.001
Self-assessed competency level				
No knowledge	6	37.5 (±15.6)	9	47.2 (±4.1)
Beginner	28	52.4 (±19.9)	41	54.7 (±14.0)
Intermediate	28	65.5 (±16.2)	31	66.1 (±15.7)
Advanced	0		4	72.9 (±10.5)
		p = 0.001		p = 0.0001

allow institution-to-institution comparisons). Questions 1 and 9 (involving ABO typing and antigen–antibody reactions, respectively) were identified as having a fit value slightly outside of the predefined acceptable ranges, in both cases because respondents earlier in training scored higher than more advanced trainees. Further analysis revealed that the poor fit was due to alternative responses functioning as excessively strong distractors; these distractors were removed and replaced in the updated exam.

Assessment tool: results with final version

A total of 85 trainees completed the updated examination in 2018. This included 36 trainees who participated in both 2017 and 2018. Again, there was a near-even distribution of PGY-4, -5, and -6 trainees with most trainees (85%) at a beginner or intermediate knowledge level (Table 3). Forty trainees (47%) attended an Ontario-based postgraduate training program followed by 24 trainees (28%) from Quebec and 21 trainees (25%) from the remaining provinces. A Rasch analysis was repeated on the updated 2018 examination demonstrating ongoing high reliability at 0.93, mean item fit of 1.00, and a mean trainee fit of 1.00. All items on the exam were now within the acceptable fit values.

The results of the examination stratified by question topic are presented in Table 2. The mean score was 58.9% ± 15.3% with scores ranging from 33% to 100%. Only one trainee (PGY-6) attained a perfect score, while nine trainees (five PGY-4s, three PGY-5s, and two PGY-6 s) attained the lowest score of 33%. Less than 50% of trainees recorded the correct answer for Questions 7, 8, 9, 10 and 12. Trainees scored the poorest on Questions 8 and 12, which required appreciating the process of an antibody investigation and understanding indications for weak D testing. Trainees in higher years and trainees with more advanced self-rated expertise scored higher than their counterparts. The difference in scores between these groups was significant (Table 3). The location of training was again not found to affect the scores of the trainees.

Although 36 returning trainees (42%) completed the exam in 2017 and 2018, there was no significant difference in mean total scores for all trainees between both years the exam was written (57% vs 59%; Table 2). In the 10 questions that remained unchanged (i.e., excluding Questions 1 and 9), the mean scores improved by more than five percentage points for Question 6, but decreased by the similar amounts for Questions 4, 5, and 10. However, none of these differences in scores between 2017 and 2018 were significant.

DISCUSSION

A validated assessment tool for the evaluation of relevant immunohematology knowledge in hematology trainees has been developed. The study also highlighted a lower than expected level of transfusion knowledge, with respondents on average able to answer only two-thirds of exam questions correctly by the end of their hematology training programs. While these results were superior to those observed in trainees just commencing their hematology program (who answered approximately half the exam questions correctly), the difference represents only two additional questions answered correctly and overall suggests that there is still room for improvement in teaching this subject matter. In addition, there was significant variation in the performance among the most senior PGY-6 trainees: one trainee attained a perfect score, while two trainees attained the lowest score of 33%. All three were based out of different training locations, which likely speaks to the variation in transfusion education provided in hematology training programs across the country. Having validated tools for assessment available are likely to prove useful as medical education shifts toward competency-based learning where trainees need to demonstrate mastery of prespecified milestones throughout their training.[10]

The assessment tool revealed several areas where additional educational focus might be of benefit, most notably on the topics of antibody investigation and D variants. While expertise on these topics is arguably a more appropriate expectation of a hematopathologist or transfusion medicine specialist, the specific applications of these concepts in the exam were within the scope of practice of a consulting hematologist. For example, the question on antibody investigation

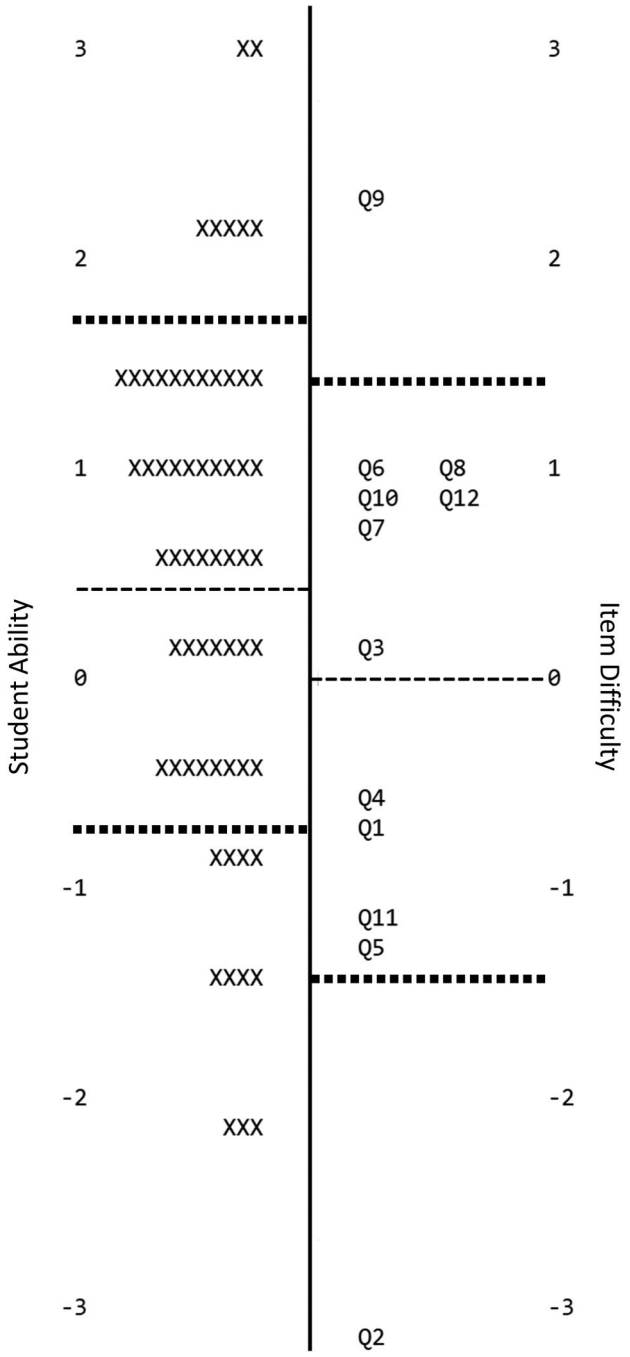

Fig. 1. Wright map displaying the distribution of student ability (left side of the figure) and item difficulty (right side of the figure) as calculated from the 2017 pilot examination. Individual students (X) and questions (Q#) near the top of the map have higher ability and difficulty respectively compared to items near the bottom of the figure. --- = mean; ■■■ = one standard deviation.

required only that respondents understand the principle of rule-outs using nonreactive panel cells, while the question on D variants required understanding of the different significance of a weak D in blood donors versus transfusion recipients. These concepts are also frequently assessed during the certification examinations in clinical hematology administered by the RCPSC.

While greater emphasis on these subjects may be of benefit in Canadian hematology training programs, it may also be worth reevaluating the processes by which education in blood bank serology is currently being provided. Most program directors reported that coverage of transfusion serology is typically provided in 2-month focused blocks, primarily via didactic lectures and self-directed learning. Shifting toward a more longitudinal approach, in which subject matter is covered progressively throughout the training program and with greater emphasis on interactive learning, may be worth exploring. An analogy may be made to the experience of Lin and colleagues[11] in creating a longitudinal curriculum in clinical transfusion practice for nonhematology residents, using both didactic lectures and collaborative small-group learning exercises. Learners were exposed to five full-day sessions throughout the academic year totaling 18 hours of lectures and 11 hours of group work. With this pedagogical approach, average scores on the BEST-TEST assessment tool increased from 50% to 76%.[11] Champion and coworkers[12] demonstrated similar improvements with evidence of retention in surgical residents utilizing elements of a flipped classroom with assigned prereadings followed by a didactic session and case-based discussions. The use of flipped classroom methods, which emphasize active learning strategies such as team-based learning over traditional lectures, have grown in popularity in medical education.[13]

Others have incorporated the use of simulation in transfusion education as an additional method of active learning. Simulation allows learners to experience highly interactive transfusion scenarios in a mock environment with the opportunity for immediate feedback after the activity. Konia and colleagues[14] analyzed the use of high-fidelity simulation delivered in-person or online or using a hybrid of both methods. Medical students in all three arms had improvements in their posttest scores compared to pretest values. However, the largest improvement was seen in the in-person group (47% pre to 85% post). In-person simulation also attained the highest satisfaction scores, with students specifically lauding the debriefing sessions that followed each activity. Other studies have also reported on the benefits of simulation in the delivery of transfusion education to medical learners.[15,16]

Limitations of this study include the use of hematology program directors as the main experts in the modified Delphi process. Hematology program directors are positioned to understand the needs of trainees and their curriculum but are unlikely to be subject matter experts in transfusion medicine. Although transfusion medicine experts did review the content of the exam, the lack of additional transfusion medicine physicians in the modified Delphi panel may have resulted in the absence of other relevant transfusion topics. Another limitation is the inclusion of 36 trainees in both the

pilot and the final versions of the examination. Repeat trainees were included due to the limited number of hematology trainees across Canada and the slight differences in the examinations with changes in Questions 1 and 9 following initial Rasch analysis. The main risk to this approach is that trainees may have remembered the examination questions from the initial pilot, allowing them to attain a higher score and skew the results. However, care was taken to not allow trainees to retain copies of the exam after sitting it or to receive feedback on whether they answered specific questions correctly or not. This approach appeared to be successful, as there were no significant differences observed in the mean scores for all trainees between 2017 and 2018 suggesting limited impact from repeat examinees. Finally, the generalizability of these findings for hematology trainees outside of Canada is unclear. Its applicability may vary by region depending on the structure of hematology training and differences in exposure to transfusion medicine.

In summary, we have developed a validated assessment tool for transfusion immunohematology knowledge in hematology trainees. The tool was able to discriminate between training year and self-rated knowledge and identified specific gaps in transfusion knowledge. More importantly, the use of a standardized assessment tool allows for benchmarking against which novel educational initiatives may be evaluated and compared.

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