

Original article

The development of computerized program-based diagnosis for the common adverse events of blood transfusion

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Abstract:

Introduction: Blood transfusion is essential in medical practice but carries a risk of adverse events. The complexity of diagnostic criteria and the shortage of medical personnel with expertise in transfusion medicine often result in the underreporting of these incidents. Improving the reporting system's efficiency is imperative. **Objective:** To develop a web application for diagnosing transfusion reactions using patient symptom data and automated database recording. **Materials and Methods:** We developed a web-based application to facilitate the diagnosis of acute transfusion reactions based on Centers for Disease Control and Prevention (CDC) case definitions. Each diagnostic step was validated by specialists. The application's efficacy was evaluated through a blind test, comparing diagnoses made by the application with those made by specialists. Statistical analysis included calculating agreement using Cohen's Kappa coefficients. **Results:** Tests were conducted on 256 cases reported from King Chulalongkorn Memorial Hospital (KCMH) from January 2022 to April 2024. Specialists' diagnoses included febrile non-hemolytic transfusion reaction (FNHTR) (49.6%), allergic reaction (30.8%), and others (19.6%). The application demonstrated a Kappa coefficient of 0.982 (95%CI: 0.959-1.000). **Conclusion:** The diagnostic results showed a high level of agreement between the application and specialists' diagnoses, demonstrating the application's potential for implementation in the hospital settings. With patients' data management and review features, the application offers broad benefits for the healthcare system, contributing to the development of the hemovigilance system.

Keywords : ● Transfusion reaction ● Hemovigilance ● Diagnosis application

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นิพนธ์ต้นฉบับ

การพัฒนาโปรแกรมวินิจฉัยและบันทึกภาวะแทรกซ้อนของการรับโลหิต

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¹ฝ่ายเวชศาสตร์ชั้นสูงตร โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย ²ภาควิชาเวชศาสตร์ชั้นสูงตร คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

บทคัดย่อ

บทนำ การให้โลหิตและส่วนประกอบของโลหิตมีความสำคัญในเวชปฏิบัติ ในขณะเดียวกันเป็นการเพิ่มความเสี่ยงต่อการเกิดเหตุการณ์ไม่พึงประสงค์ แต่ด้วยเกณฑ์การวินิจฉัยที่ซับซ้อน ประกอบกับการขาดแคลนแพทย์ด้านเวชศาสตร์บริการโลหิต ส่งผลให้การวินิจฉัยและการรายงานต่ำกว่าที่คาดการณ์ไว้ การพัฒนาระบบเพื่อช่วยวินิจฉัย จึงมีความสำคัญในการพัฒนางานด้านธนาคารเลือด **วัตถุประสงค์** พัฒนาแอปพลิเคชันเพื่อการวินิจฉัยเหตุการณ์ไม่พึงประสงค์จากการรับโลหิตโดยอาศัยข้อมูลอาการและการแสดงของผู้ป่วยและบันทึกในฐานข้อมูลแบบอัตโนมัติ **วัสดุและวิธีการ** สร้างและออกแบบเว็บแอปพลิเคชัน โดยยึดหลักเกณฑ์การวินิจฉัยตามมาตรฐานสากลขององค์การควบคุมโรคติดต่อสหรัฐอเมริกา (CDC) โดยอัลกอริทึมของโปรแกรมผ่านการรับรองโดยแพทย์ผู้เชี่ยวชาญเวชศาสตร์บริการโลหิต ผู้วิจัยได้ทำการทดสอบจากข้อมูลผู้ป่วยจริงโดยให้แพทย์ทั่วไปใช้แอปพลิเคชัน เปรียบเทียบผลการวินิจฉัยกับแพทย์ผู้เชี่ยวชาญ และประมวลผลทางสถิติโดย Cohen's Kappa coefficient **ผลการศึกษา** ผู้วิจัยรวบรวมข้อมูลผู้ป่วยที่มีรายงานเหตุการณ์ไม่พึงประสงค์ในโรงพยาบาลจุฬาลงกรณ์ 256 ราย ระหว่างเดือนมกราคม พ.ศ. 2565 ถึงเดือนเมษายน พ.ศ. 2567 โรคที่วินิจฉัยโดยแพทย์ผู้เชี่ยวชาญ ได้แก่ febrile non-hemolytic transfusion reaction (FNHTR) 49.6%, allergic reaction 30.8% และโรคอื่นๆ 19.6% ผลการเปรียบเทียบการวินิจฉัยมีค่า Kappa coefficient ที่ 0.982 (95%CI: 0.959-1.000) **สรุป** แอปพลิเคชันสามารถให้การวินิจฉัยที่แม่นยำเทียบกับแพทย์ผู้เชี่ยวชาญ และมีศักยภาพที่จะใช้งานในโรงพยาบาลทั่วไป ประกอบกับความสามารถในการบันทึกและแก้ไขข้อมูล จึงมีประโยชน์สำหรับระบบสาธารณสุขในวงกว้างในการพัฒนาความปลอดภัยในการให้โลหิตและส่วนประกอบของโลหิตต่อไป

คำสำคัญ : ● ภาวะไม่พึงประสงค์จากการรับส่วนประกอบโลหิต ● ระบบเฝ้าระวังอาการไม่พึงประสงค์จากการรับโลหิต

● แอปพลิเคชันเพื่อการวินิจฉัย

วารสารโลหิตวิทยาและเวชศาสตร์บริการโลหิต. 2567;34:237-45.

Introduction

Blood transfusion plays a crucial role in medical practice, yet it is not without risks of adverse events¹⁻⁵. To improve the quality and safety of blood transfusion services, a system of surveillance procedures known as hemovigilance has been developed. Hemovigilance covers the entire transfusion chain and enables hospital personnel to report transfusion reactions to centralized databases for analysis, helping to identify trends and shape policies for prevention. The incidence rate of transfusion reactions varies widely, ranging from 120.5 to 413 per 100,000 units transfused⁶⁻¹⁰. However, the complexity of diagnostic criteria and the shortage of medical personnel with expertise in transfusion medicine often result in the underreporting of these incidents.

Yeh, et al., demonstrated that reliance on clinical judgment from nurses and time-consuming paperwork led to underreporting of transfusion reactions in their institute. The implementation of an online transfusion reaction reporting system for nurses significantly increased the documented incidence of these reactions, highlighting the benefits of integrating such tools into the patient care system. However, their system lacked a diagnostic algorithm, and they did not assess the accuracy of the reported reactions against the final diagnosis, limiting the system's effectiveness in ensuring accurate reporting¹¹.

A study conducted by Jhaveri P, et al., revealed significant discrepancies in the diagnosis of transfusion-related adverse reactions between electronic health records and blood bank databases, attributed to various factors such as differing diagnostic criteria, communication gaps between clinical teams and blood banks, and variability in clinician knowledge regarding transfusion reactions¹². This inconsistency underscores the need for effective diagnostic tools.

Our study aims to address this gap by developing a web application that utilizes patient symptom data and automated database recording for the accurate and timely diagnosis of transfusion reactions.

Materials and Methods

We constructed a diagnostic model based on the case definition provided by the Centers for Disease Control and Prevention (CDC) in the United States¹³. We categorize acute transfusion reaction in 5 main categories: 1) pulmonary complications: consisting of transfusion-associated circulatory overload (TACO) and transfusion-related acute lung injury (TRALI), 2) infection: transfusion-transmitted infection (TTI), 3) hemolytic reaction: acute hemolytic transfusion reaction (AHTR), 4) allergic complications: including mild allergic reaction and severe allergic reaction (anaphylaxis) and 5) others: comprising febrile non-hemolytic transfusion reaction (FNHTR), transfusion-associated dyspnea (TAD) and unclassified.

Our diagnostic algorithm operates on a sequential basis, resembling a structured 'Sequence' of diagnostic steps. The first component, the 'Approach Algorithm', determines the initial starting point based on the presented symptoms and patient information, allowing flexibility to start at different points within the sequence. Each step in the sequence is a 'Diagnosed Algorithm' node, which compares the patients' features, including signs, symptoms, and laboratory data, against the standard diagnostic criteria outlined by the CDC.

If the symptoms meet the criteria, a diagnosis is made at that node. If the criteria are not met, the Diagnosed Algorithm proceeds to the next node in the sequence. The application can differentiate between multiple main symptoms and continues if there are unexplained symptoms, generating a comment alongside the diagnosis. The sequence progresses forward only, potentially skipping nodes based on the presented signs and symptoms (Figure 1).

To ensure the validity of each step in the diagnostic model, a content validity assessment was conducted by three specialists within our department. Subsequently, the refined model was transformed into a web-based application incorporated with a software engineer. The effectiveness of the application was assessed through

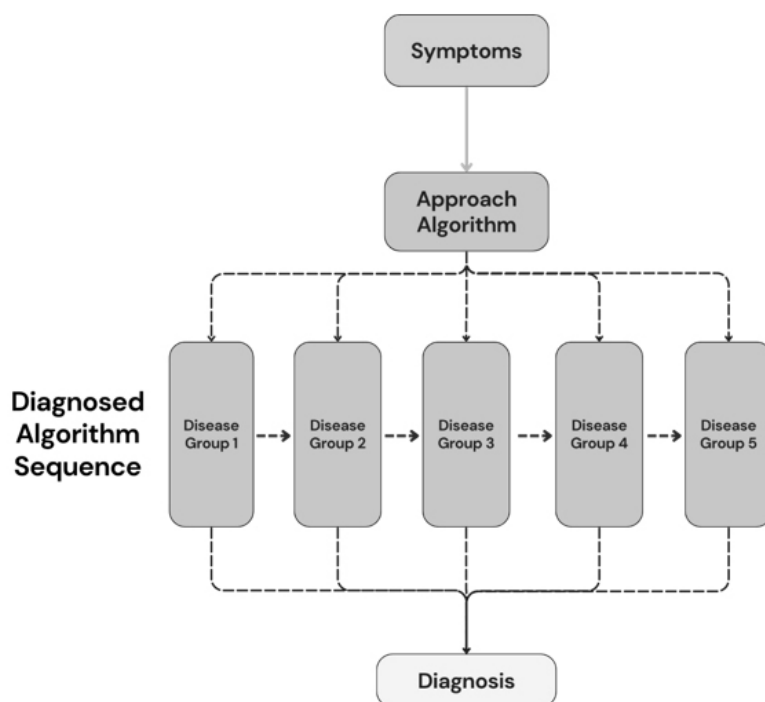


Figure 1 Diagnosis model of the application. The diagnosis begins with the patient's symptoms. The 'Approach Algorithm' determines the initial starting point within the 'Diagnosed Algorithm' nodes. These nodes compare the patient's features, including signs, symptoms, and laboratory data, against the standard diagnostic criteria outlined by the CDC. The sequence continues until a diagnosis is made.

a blind test involving both specialists and general physicians. This evaluation comprised two components: a retrospective test to validate the algorithm's accuracy and a prospective test to determine its real-life efficacy. In the retrospective analysis, specialists and general physicians utilized information from electronic medical records. In the prospective analysis, general physicians participated in transfusion reaction consultations within our department and employed the application to assist in diagnosis. Diagnoses made by specialists and general physicians were compared immediately after diagnosis, and all relevant information was collected.

The sample size was calculated using the sample size calculator for the Kappa statistic¹³. We set the expected kappa to 0.9, with a precision of 0.1 and a 95% confidence interval. The proportion was calculated based on incidence rates of transfusion reactions at King Chulalongkorn Memorial Hospital. The transfusion reaction diagnosis was compared with that from specialist, and agreement was calculated with Cohen's

Kappa coefficients. Sensitivity and specificity were not calculated for each specific diagnosis, as the study's primary focus was on overall agreement. The data was analyzed with SPSS version 27, p -value < 0.05 is considered statistically significant.

Results

The application features an interactive form on its first page, where patients' main signs and symptoms, such as dyspnea, fever/chill, hypotension, and skin/mucosal symptoms are recorded. Each diagnostic algorithm has its own dedicated page with a corresponding question list based on its diagnostic criteria. Once a diagnosis is made, the result page is displayed, accompanied by a submit button to save all patient data along with the diagnosis (Figure 2). Furthermore, the application includes a patient data management system, allowing viewing and editing of individual patient records (Figure 3). Users are categorized as administrators, doctors, or nurses, with varying levels of data access. Admini-

☰

Patient Data

First Name (Patient)

Last Name (Patient)

Ward / Department *

Unit Number *

Sex *

Choose ▾

Age *

Blood Group *

Select ▾

Blood Component *

Select ▾

Rh Blood Group *

Choose ▾

Patient Diagnosis

Patient's prior transfusion reaction

Patient's prior transfusion reaction

☐ Allergic

☐ HTR

☐ PTP

☐ AHTR

☐ TTI

☐ DHTR

☐ TACO

☐ DSTR

☐ TRALI

☐ FNHTR

☐ TAD

Pulmonary Complication *

Physical Exam

☐ Wheezing/Stridor/Bronchospasm

☒ Creptitation/Crackles

☐ Clear breath sound/Not sure

Additional Information

☐ O2 saturation ≤ 90%

☒ Positive Fluid Balance ≥ 1000 ml in 24 hr

☐ Cardiovascular change

Elevated CVP, Widened pulse pressure, Jugular venous distension, Peripheral edema (Not explain by U/D)

☒ X-ray shows increased bilateral infiltrates

☒ X-ray shows increased cardiomegaly

☐ Elevate NT-proBNP ≥ 1,000 pg/ml

☐ None of Above

Severity & Imputability *

Severity

☐ Recover by Medication only

☐ Not Recover by Medication, hospitalization, prolong hospitalization

☒ Life Threatening AND Need Intervention: ETT, Vasopressor

☐ Death

Imputability

☒ There are no explanation for overload

☐ Patient recieve other fluid OR has hx cardiac insuff but not explained

☐ Patient has hx cardiac insuff that likely explain

Diagnosis Result

Most Likely Diagnosis

Transfusion-associated circulatory overload (TACO)

Imputability

Definite

Severity

Life-Threatening

Comments

During Transfusion

Symptoms *

Patient Symptoms

☐ Fever/Chills
Body temperature ≥ 38C or increase ≥ 1C from baseline

☒ Dyspnea
New onset or significant worsening of shortness of breath / chest discomfort / increase in respiratory rate

☐ Skin & Mucosal
Symptoms involve skin & mucosa: Rash, Itching, Angioedema

☐ Hypotension
Adult: SBP drop ≥ 30 mmHg and SBP ≤ 80 mmHg
Infants, children, adolescents: SBP drop ≥ 25% Baseline

☐ Other
Other symptoms that not met definition above

Vital Signs *

BT(Celsius), BP(mmHg), HR(/min), RR(/min), Sat(%)

[Before] Body Temperature (°C) 36	[After] Body Temperature (°C) 36.9
[Before] Blood Pressure (mmHg) 100 62	[After] Blood Pressure (mmHg) 144 84
[Before] Heart Rate (Beats / Minute) 100	[After] Heart Rate (Beats / Minute) 100

Figure 2 Interface of application. (A), (B) The first page for inputting general information, vitals, and main symptoms of the patient. (C) The diagnostic page for entering detailed responses to questions. (D) The result page shows the most likely diagnosis along with imputability, severity, and comments in case a secondary diagnosis is made.

Full Name		Department	Approval Status			
		Type to search	SEARCH	Show All	DIAGNOSE +	
No.	Name	Resident	Doctor	Department	Most Likely Diagnosis	Created at
1	Patient Name	Resident Name 09:50	-	Ward	Allergic reaction	23/05/2024 09:50
2	Patient Name	Resident Name	-	Ward		21/05/2024 10:06
3	Patient Name	Resident Name 20/05/2024 10:57	-	Ward	Allergic reaction	20/05/2024 10:57
4	Patient Name	Resident Name 10:53	-	Ward	Allergic reaction	20/05/2024 10:53
5	Patient Name	Resident Name 11:38	-	Ward	Transfusion-associated circulatory overload (TACO)	08/05/2024 11:38

Figure 3 Patient management system of the application. The ‘Resident’ column lists the general or resident physicians who registered each case, while the ‘Doctor’ column shows the transfusion medicine attending staff who approved the diagnosis. The ‘Most Likely Diagnosis’ column displays the diagnosis made by the application. Attending staff can review and edit all information for each case; any changes in the diagnosis are updated on this page.

strators have the authority to approve cases recorded by doctors and nurses. A case management system ensures specialist evaluation of every diagnosis before export to the database.

The refined model of the application diagnosed acute transfusion reaction cases at King Chulalongkorn Memorial Hospital from January 2022 to April 2024. The diagnoses were compared with those made by our transfusion medicine specialists for a total of 256 cases. The results were categorized into two subgroups: the retrospective group with 194 patients and the prospective group with 62 patients. The most common diagnosis was febrile non-hemolytic transfusion reaction (FNHTR) with 127 cases (49.6%), followed by allergic reaction with 79 cases (30.8%) and others (19.6%) (Table 1). The total Cohen’s Kappa result was 0.982 (95%CI: 0.959-1.000). Subgroup analysis showed a Kappa of 0.992 (95%CI: 0.975-1.000) in the retrospective group and 0.956 (95%CI: 0.889-1.000) in the prospective group (Table 2).

Discussion

The application designed for diagnosing adverse events in blood transfusions demonstrated a high level of diagnostic accuracy, as indicated by the Cohen’s Kappa result of 0.982 (95%CI: 0.959-1.000). This suggests a near-perfect agreement between the application and the diagnoses made by transfusion medicine specialists¹¹. Such high concordance underscores the potential of the application to be integrated into hospital settings for routine use, improving the efficiency and accuracy of transfusion reaction diagnoses.

In a previous study by Jhaveri P, et al., a significant discrepancy was observed between electronic medical records and the blood bank database, even for common diagnoses. For instance, in the case of febrile non-hemolytic transfusion reactions (FNHTR), 119 cases were recorded in the medical records and 146 in the blood bank database, with only 31 cases overlapping between the two systems¹². In contrast, our study identified a

Table 1 Diagnosis results from application and transfusion medicine specialists

Diagnosis	Retrospective (N = 194)		Prospective (N = 62)		Total* (N = 256)
	Application	Specialist	Application	Specialist	N (%)
Febrile non-hemolytic transfusion reaction (FNHTR)	99	99	26	28	127 (49.6)
Allergic reaction	64	65	15	15	79 (31.2)
Transfusion-associated dyspnea (TAD)	11	11	6	4	15 (5.9)
Transfusion-associated circulatory overload (TACO)	4	3	5	5	8 (3.1)
Anaphylaxis	7	7	5	5	12 (4.7)
Transfusion-transmitted infection (TTI)	1	1	2	2	3 (1.2)
Transfusion-related acute lung injury (TRALI)	1	2	0	0	2 (0.8)
Hypotensive transfusion reaction (HTR)	6	6	1	1	7 (2.7)
Acute hemolytic transfusion reaction (AHTR)	0	0	2	2	2 (0.8)
Unclassified	1	0	0	0	0

*Total number demonstrate diagnoses from specialists

Table 2 Cohen's Kappa statistic

	Patients (N)	Cohen Kappa (95%CI)
Retrospective	194	0.983 (0.956-1.000)
Prospective	62	0.956 (0.887-1.000)
Total	256	0.976 (0.948-1.000)

total of 127 febrile non-hemolytic transfusion reactions (FNHTR) cases, of which 125 were accurately diagnosed using the application. This demonstrates that the diagnostic algorithm significantly improves consistency of diagnosis and potentially reducing discrepancies seen in previous studies.

However, the variability in user inputs presents a limitation. Different users, based on their experience and perspective, may interpret symptoms differently, potentially leading to inconsistent diagnostic outcomes. For instance, in two of the 127 febrile non-hemolytic transfusion reactions (FNHTR) cases diagnosed by specialists, discrepancies arose due to differences in the interpretation of chest discomfort by general physicians, resulting in a diagnosis of transfusion-associated dyspnea (TAD) instead. To address this, the application's review feature allows senior physicians or specialists to validate and refine the initial diagnoses, ensuring a higher level of consistency and reliability. Despite these challenges, the application's user-friendly inter-

face and structured diagnostic algorithms provide a robust tool for medical personnel, including those with less expertise in transfusion medicine. The ability to switch languages further enhances its accessibility for a diverse user base.

The study has another limitation. The primary objective was to develop an application for diagnosing transfusion reactions, with the main outcome being the agreement between the application and specialist diagnoses. Given the nature of our case collection, we did not calculate sensitivity, specificity, or other performance metrics for each specific diagnosis, as we only collected data from patients with confirmed transfusion reactions, not include patients without a diagnosis. This approach did not provide the necessary true negative or false positive cases required for such calculations. However, in the future, if sufficient cases for specific diagnoses are collected, sensitivity and specificity calculations could be performed to further validate the application's diagnostic accuracy in comparison to specialists.

The implementation of this application in clinical practice could significantly enhance the reporting and management of transfusion reactions, contributing to better patient outcomes and more efficient use of health-care resources². Future improvements could focus on enhancing the algorithm's ability to handle a broader range of symptoms and integrating more advanced data analytics to support continuous improvement in diagnostic accuracy¹⁵.

To our knowledge, there has been no previous development of a transfusion reaction diagnostic tool integrated with a reporting system like the one presented in this study. This innovative approach not only streamlines the diagnostic process but also facilitates accurate reporting and data collection for hemovigilance purposes. This opens new possibilities for future developments in transfusion medicine, such as expanding the system to diagnose delayed transfusion reactions and improving its integration with hospital workflows to further enhance patient safety.

Conclusion

Overall, the computer-based diagnostic application provides a reliable and user-friendly tool for diagnosing transfusion reactions, with the potential to enhance clinical practice and patient outcomes. The data collected from each case aligns with the National Hemovigilance format, making validation and reporting straightforward. The subjective nature of symptom interpretation underscores the importance of the review process to ensure high diagnostic accuracy and consistency. In conclusion, the application offers broad benefits for the healthcare system, contributing significantly to the development and efficiency of the hemovigilance system.

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References

1. Delaney M, Wendel S, Bercovitz RS, Cid J, Cohn C, Dunbar NM, et al. Transfusion reactions: prevention, diagnosis, and treatment. *The Lancet*. 2016;388:2825-36.
2. Ackfeld T, Schmutz T, Guechi Y, Le Terrier C. Blood transfusion reactions-a comprehensive review of the literature including a Swiss perspective. *J Clin Med*. 2022;11:2859. doi: 10.3390/jcm11102859.
3. Acharya D, Gaussen A, Poder TG, Lambert G, Renaud C, Nawej K, et al. Associated criteria used in investigating suspected septic transfusion reactions: a scoping review. *Vox Sang*. 2023;118:1029-37.
4. Gehrie EA, Roubinian NH, Chowdhury D, Brambilla DJ, Murphy EL, Gottschall JL, et al. A multicentre study investigating vital sign changes occurring in complicated and uncomplicated transfusions. *Vox Sang*. 2018;113:160-9.
5. Vassallo RR. Review: IgA anaphylactic transfusion reactions. Part I. laboratory diagnosis, incidence, and supply of IgA-deficient products. *Immunohematology*. 2004;20:226-33.
6. Guo K, Wang X, Zhang H, Wang M, Song S, Ma S. Transfusion reactions in pediatric patients: an analysis of 5 years of hemovigilance data from a National Center for Children's Health in China. *Front Pediatr*. 2021;9:660297. doi: 10.3389/fped.2021.660297.
7. Saha S, Krishna D, Prasath R, Sachan D. Incidence and analysis of 7 years adverse transfusion reaction: a retrospective analysis. *Indian J Hematol Blood Transfus*. 2020;36:149-55.
8. Bahrami M, Felekhari F, Darvish-Khezri M, Kheirandish A, Mollaie A, Ahmadi M, et al. Prevalence of adverse transfusion reactions in hospitalized patients in Tertiary Heart Center of Sari, Iran in 2014-2020. *Tabari Biomed Stu Res J*. 2022;4:17-22.
9. Savinkina AA, Haass KA, Sapiano MRP, Henry RA, Berger JJ, Basavaraju SV, et al. Transfusion-associated adverse events and implementation of blood safety measures - findings from the 2017 National Blood Collection and Utilization Survey. *Transfusion*. 2020;60(Suppl 2):S10-6.
10. Karafin MS, Bruhn R, Westlake M, Sullivan MT, Bialkowski W, Edgren G, et al. Demographic and epidemiologic characterization of transfusion recipients from four US regions: evidence from the REDS-III recipient database. *Transfusion*. 2017;57:2903-13.
11. Yeh SP, Chang CW, Chen JC, Yeh WC, Chen PC, Chuang SJ, et al. A well-designed online transfusion reaction reporting system improves the estimation of transfusion reaction incidence and quality of care in transfusion practice. *Am J Clin Pathol*. 2011;136:842-7.

12. Jhaveri P, Bozkurt S, Moyal A, Belov A, Anderson S, Shan H, et al. Analyzing real world data of blood transfusion adverse events: opportunities and challenges. *Transfusion*. 2022;62:1019-26.
13. U.S. Centers for Disease Control and Prevention. The National Healthcare Safety Network (NHSN) Manual: Biovigilance Component v2.5. Atlanta, GA: Division of Healthcare Quality Promotion, National Center for Emerging and Zoonotic Infectious Diseases. Available at: <http://www.cdc.gov/nhsn/PDFs/Biovigilance/BV-HV-protocol-current.pdf>. Accessed [2023 Feb 7].
14. Arifin WN. Sample size calculator [Internet]. [cited 2023 Apr 15]. Available from: <http://wnarifin.github.io>
15. Bright RA, Bright-Ponte SJ, Palmer LAM, Rankin SK, Blok SV. Use of diagnosis codes to find blood transfusion adverse events in electronic health records. *J Patient Saf*. 2022;18:e823-66. doi: 10.1097/PTS.0000000000000946.
16. Torres R, Kenney B, Tormey CA. Diagnosis, treatment, and reporting of adverse effects of transfusion. *Laboratory Medicine*. 2012;43:217-31.

