

การพัฒนาเว็บแอปพลิเคชันเพื่อใช้ในกระบวนการควบคุมคุณภาพ การตรวจปริมาตรเม็ดเลือดแดงอัดแน่น ณ จุดดูแลผู้ป่วย ของโรงพยาบาลภูเขียวเฉลิมพระเกียรติ จังหวัดชัยภูมิ

สมพร ทาบัว^{1,2} มยุรี ชนะสกุลนิยม² ณิชภัทร อนุวงศ์เจริญ² และ สุมนา ดาเก็ง^{2*}

¹กลุ่มงานเทคนิคการแพทย์และพยาธิวิทยาคลินิก โรงพยาบาลภูเขียวเฉลิมพระเกียรติ จังหวัดชัยภูมิ

²คณะเทคนิคการแพทย์ มหาวิทยาลัยมหิดล จังหวัดนครปฐม

บทคัดย่อ

การตรวจปริมาตรเม็ดเลือดแดงอัดแน่นเป็นการตรวจทางห้องปฏิบัติการเพื่อประเมินภาวะเลือดจางหรือภาวะเลือดข้น ที่ทำได้ง่าย สะดวก และรวดเร็ว การตรวจนี้จึงใช้เป็นรายการทดสอบ ณ จุดดูแลผู้ป่วย ซึ่งต้องการความรวดเร็วและความถูกต้อง โดยเฉพาะผู้ป่วยที่อยู่ในชั้นวิกฤตที่กระบวนการดูแลผู้ป่วยต้องแข่งขันกับเวลา การตรวจปริมาตรเม็ดเลือดแดงอัดแน่น ณ จุดดูแลผู้ป่วยที่ไม่มีระบบการจัดการควบคุมคุณภาพที่ดีอาจส่งผลกระทบต่อความปลอดภัยในการดูแลผู้ป่วยได้ ดังนั้นเพื่อการพัฒนาการดำเนินการให้มีประสิทธิภาพและสะดวก ผู้ศึกษาจึงพัฒนาเว็บแอปพลิเคชันสำหรับใช้ในกระบวนการควบคุมคุณภาพ โดยมีวัตถุประสงค์ คือ 1) เพื่อพัฒนาเว็บแอปพลิเคชันสำหรับใช้ในกระบวนการควบคุมคุณภาพ การตรวจปริมาตรเม็ดเลือดแดงอัดแน่น ณ จุดดูแลผู้ป่วย และ 2) เพื่อพัฒนาระบบบริหารคุณภาพการตรวจ ปริมาตรเม็ดเลือดแดงอัดแน่น ณ จุดดูแลผู้ป่วย วิธีการศึกษาเป็นการพัฒนาและประเมินประสิทธิภาพ การทำงานของเว็บแอปพลิเคชันที่ใช้ในการควบคุมคุณภาพการตรวจปริมาตรเม็ดเลือดแดงอัดแน่น โดยแบ่งออกเป็น 3 ระยะ ได้แก่ ระยะที่ 1 ก่อนการใช้เว็บแอปพลิเคชัน ระยะที่ 2 หลังใช้ เว็บแอปพลิเคชัน เวอร์ชัน 1 และระยะที่ 3 หลังใช้เว็บแอปพลิเคชัน เวอร์ชัน 2 การประเมินผล ทำโดยใช้ข้อมูลด้านคุณภาพและประสิทธิภาพการทดสอบ รวมถึงแบบสอบถามความพึงพอใจและ แบบสัมภาษณ์ผู้บริหาร พยาบาล นักเทคนิคการแพทย์และเจ้าหน้าที่ห้องปฏิบัติการ ผลการศึกษาพบว่า การพัฒนาปรับปรุงเว็บแอปพลิเคชันส่งผลให้ระดับความพึงพอใจทางการควบคุมคุณภาพ การตรวจปริมาตรเม็ดเลือดแดงอัดแน่นและด้านการใช้งานเว็บแอปพลิเคชันมีระดับเพิ่มสูงขึ้น ค่าสัมประสิทธิ์ความแปรผัน (%CV) อยู่ในเกณฑ์ที่กำหนด (%CV Limit < 4%) และระยะเวลา ส่งผลกลับมีแนวโน้มดีขึ้น ผู้บริหารมีความคิดเห็นสอดคล้องกันว่าสามารถลดระยะเวลา ลดภาระงาน

*ผู้รับผิดชอบบทความ E-mail address: sumana.dak@mahidol.ac.th

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ช่วยลดค่าใช้จ่าย และเป็นประโยชน์ต่อองค์กร สรุปผลการศึกษาแสดงว่าการนำเทคโนโลยีสารสนเทศที่พัฒนาขึ้นเองมาใช้ในระบบการจัดการควบคุมคุณภาพการตรวจปริมาณเม็ดเลือดแดงอัตโนมัติ จุดดูแลผู้ป่วย ของโรงพยาบาลภูเขียวเฉลิมพระเกียรติ จังหวัดชัยภูมิ ส่งผลให้มีประสิทธิภาพ ตอบสนองต่อความต้องการของผู้ใช้งาน และประหยัดค่าใช้จ่าย

คำสำคัญ: เว็บแอปพลิเคชัน การตรวจปริมาณเม็ดเลือดแดงอัตโนมัติ จุดดูแลผู้ป่วย กระบวนการควบคุมคุณภาพ

Development of a Web Application for Use in the Quality Control Process of POC Hematocrit Testing at Phukhieo Chalermprakiat Hospital, Chaiyaphum Province

Somporn Thabua^{1,2}, Mayuree Chanasakulniyom²,
Nuttapat Anuwongcharoen² and Sumana Dakeng^{2*}

¹*Department of Medical Technology and Clinical Pathology,
Phukhieo Chalermprakiat Hospital, Chaiyaphum Province, Thailand*

²*Faculty of Medical Technology, Mahidol University, Nakhon Pathom Province, Thailand*

Abstract

Hematocrit testing is a laboratory test used to assess anemia or polycythemia. It is simple, convenient, and rapid. Therefore, it is used as a point-of-care test for patients which requires speed and accuracy, especially patients in critical stages, where patient care must compete against time. Point-of-care hematocrit testing without a good quality control management system can affect patient care safety. To create convenient and efficient operation, a web application was developed for use in the quality control process. The objectives were 1) to develop a web application for use in the quality control process of point-of-care hematocrit testing and 2) to develop a quality management system for point-of-care hematocrit testing. The study method was to create and evaluate the performance of a web application used to control the quality of hematocrit testing, which is divided into 3 phases: 1) before using web application; 2) after using the web application version 1.0; and 3) after using the web application version 2.0. The study was assessed by using quality control and test efficiency data as well as satisfaction questionnaires. Additionally, hospital executives, nurses, medical technologists, and laboratory staff were interviewed. The results of web application development showed that the satisfaction levels, regarding the quality control of hematocrit measurement and the use of the web application, increased. Coefficient of variation (%CV) of hematocrit testing within the specified criteria (%CV Limit < 4%) and the period for returning results tended to improve. Hospital executives and all QC personnel agreed that using web applications could save time, reduce workload, decrease cost, and benefit the organization.

*Corresponding author E-mail address: sumana.dak@mahidol.ac.th

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In conclusion, the developed web application could be used as in-house information technology in the quality control management system for point-of-care hematocrit testing at Phukhieo Chalermprakiat Hospital, Chaiyaphum province, and ensure effectiveness, cost savings, and satisfaction of the user needs.

Keywords: Web application, Point-of-care hematocrit testing, Quality control process

Introduction

Point-of-care testing (POCT) is laboratory testing conducted outside of the traditional lab environment, providing convenience to physicians and patients for efficient medical care. The accuracy of these tests depends on the technicians' skills and the precision of the equipment used.^(1,2) The microcentrifuge method for measuring hematocrit (Hct) is a blood test parameter that determines the proportion (%) of red blood cells in the blood. It is the key parameter used to identify anemia. This basic laboratory test assists physicians in the preliminary diagnosis, treatment progress monitoring, and assessment of patient conditions in various settings, including inpatient wards, emergency rooms, and critical care units.⁽³⁻⁵⁾

At Phukhiew Chalermphrakiat hospital in Chaiphum province, discrepancies were found between the Hct results from POCT at various wards and those from the central laboratory. Additionally, the blood volume collected for these tests was often inadequate, leading to sample rejections and the need for repeated blood draws. Hct was done by non-laboratory technicians, such as nurses and nurse assistants. Hct measurement using the standard centrifugation method is recommended to include internal quality control (IQC), which is routinely performed by laboratory staff. Additionally, centrifuge performance is monitored through IQC blood

samples and periodic calibration twice per year.⁽⁶⁾ In contrast, Hct measurement by POCT methods is based on distinct principles, such as portable handheld devices enabling rapid analysis without the need for centrifugation.^(7,8) IQC of POCT using the centrifugation method varies, depending on the non-laboratory staff performing the procedure and the type of microcentrifuge used.^(1,4) This issue underscores the need for a review and improvement of the quality control (QC) processes for POCT. To address the need for quality control of Hct testing, the researchers developed a web application to facilitate the recording, monitoring, and evaluation of quality control measures. This application aimed to minimize factors affecting test accuracy at the point-of-care.

Blood is a fluid that circulates within the blood vessels and constitutes about 7-8% of a normal human's body weight. There are three types of blood cells: red blood cells (RBCs), white blood cells (WBCs) and platelet (PLT).^(9,10) Hct levels can be determined using three main laboratory methods. 1) Microcentrifuge method, 2) Automated hematocrit analysis, and 3) Portable handheld devices.⁽¹¹⁻¹³⁾ The World Health Organization (WHO) has established criteria for POCT devices, summarized by the acronym ASSURED: Affordable (low-cost), Sensitive (low false-negative rate), Specific (low false-positive rate), User-friendly (simple procedures), Rapid & Robust (quick results

and no need for refrigeration), Equipment-free (no complex equipment required), and Delivered to end-users (results accessible to users).⁽¹⁴⁻¹⁶⁾ The web-based platform, developed using Python for database management, is proved for the effective implementation in collecting QC data, evaluating results, and visually presenting QC graphs and parameters to users. In addition, web applications are designed to facilitate data collection and interpretation, ensuring ease of use for non-laboratory staff. Consequently, POCT operators can input IQC data directly from their respective locations, enabling real-time identification of abnormalities in Hct measurements and facilitating timely corrective actions. Furthermore, the centralized aggregation of POCT IQC data allows the laboratory's QC manager to systematically assess the accuracy and precision of POCT-based Hct measurements across the hospital, thereby enhancing overall quality assurance.⁽¹⁶⁾ Therefore, this study aimed to develop a web application for use in the quality control process of point-of-care hematocrit testing and to develop a quality management system for point-of-care hematocrit testing in Phukhieo Chalermprakiat Hospital, Chaiyaphum Province.

Materials and Methods

1. Scope of study

This study used research and development (R&D) design across three phases: (1) before using the web application,

(2) after using the web application version 1.0, and (3) after using the web application version 2.0. The scope of the study includes: developing the web application using Python, conducting two surveys to gather opinions and satisfaction levels on the QC in Hct testing and the performance of the web application among 16 laboratory staffs and 24 nurses, evaluating the web application's efficiency by calculating the percentage coefficient of variation (%CV) of Hct values and turnaround time for returning QC values to the laboratory, and interviewing nurses, medical technologists (MTs), and five hospital executives with subsequent analysis of the interview scripts.

2. Tools and equipment

The tools and equipment used in this study included centrifuge equipment (Boeco H-240, Germany) for Hct testing, the QC materials from Horiba Thailand are classified into three levels: low, ranges from 16% to 19%; normal, ranges from 38% to 42%; and high, ranges from 47% to 53%, the developed web application, survey questionnaires (Table 2 and 3) and interview guides, derived from the study by Phumeechanya and Teamsriratchaneekorn, 2021,⁽¹⁷⁾ for collecting feedback from web application users and hospital executives. The questionnaire was then reviewed for accuracy and appropriateness by three experts, yielding an IOC (Index of item objective congruence) value ranging from 0.83 to 1.00.

3. Procedure

The study procedure involved conducting a meeting to explain the study and request coordination. The test materials were distributed to each POCT site once per month. The QC materials, consisting of three levels, were tested once per sample, and the point-of-care staff were responsible for conducting the tests, performing Hct tests according to standard procedures (microcentrifuge method),⁽¹¹⁾ recording results using the web application, and analyzing the collected data.

Phase 1: Before using the web application. Prior to system implementation, laboratory processes were entirely manual. Staff conducted all tests independently and recorded data on paper worksheets. The absence of digital tools resulted in time-consuming operations, slow information flow, and frequent inconveniences. (January 2021 - March 2023)

Phase 2: After using web application version 1.0. During this phase, laboratory staff and nurses conducted IQC testing by using a web application to record test results and perform data processing. The goal was

to improve operational efficiency and reduce manual workload. Although the system provided basic functions for data entry and analysis, it lacked automated alert systems and data security features. As a result, users had to manually monitor QC and ensure data accuracy without support from notification mechanisms or protective features. (April 2023 - December 2023)

Phase 3: After using web application version 2.0. In this phase, laboratory staff and nurses utilized the upgraded web application version 2.0 to support IQC processes. Testing was conducted by staff at POCT sites to evaluate the application's real-time performance and usability. The updated version introduced an instant notification feature that alerts users when values fall outside the acceptable range, significantly enhancing responsiveness and data accuracy. System security was also improved with user authentication through individual usernames and passwords, ensuring access control to the system. (January 2024 - April 2024)

Table 1 Comparison of quality recording for POC hematocrit measurement; phase1 - phase 3.

List	Phase 1 Before using web application	Phase 2 After using web application version 1.0	Phase 3 After using web application version 2.0
Responsibility	laboratory staff	laboratory staff/nurse	laboratory staff/nurse
Record form	work sheet	web application	web application
Process	laboratory staff conduct all tests	the staff at the patient care point are the testers	the staff at the patient care point are the testers
Notification	none	none	instant notification when values go outside the range
Access to usage	everyone	everyone	username & password
Duration	long time	low	very low
Ease of use	inconvenient	convenient	convenient
Data safety	low with the risk of loss	low	high
Data storage	paper	stored on the web host	own storage database server
Cost	none	If the data exceeds 100 MB, the server fee will be 300 THB per month.	The server service fee and quality control substances are free of charge.

4. Data collection

Data collection consisted of gathering records of internal quality control for Hct testing using a centrifuge at Phukhiew Chalermprakiat hospital in Chaiyaphum province from 2020-2024, obtaining IQC records of POCT online. Interviews with hospital executives, nurses, medical technologists, and laboratory

staff, and feedback collection through user surveys were conducted after ethics committee approval. In Phase 1, laboratory staff and nurses evaluated the QC testing process for Hct. The questionnaire for opinions and satisfaction assessment of quality control of hematocrit testing (Table 2). In Phases 2 and 3, laboratory staff and nurses evaluated

both the QC testing process for Hct and the web application, while hospital executives provided their opinions through interviews. The questionnaire for opinions and satisfaction

assessment was based on Quality Control of Hematocrit Testing (Table 2) and Web Application Usability (Table 3).

Table 2 Questionnaire on opinions and satisfaction of service Users: Quality Control of Hematocrit Testing.

No.	Evaluation Topic	Rating
1	Convenience of accessing test samples	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
2	Clear and simple sample packaging format	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
3	User manual and test guidelines	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
4	safety and security of quality control sample	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
5	Testing guidance	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
6	Sample transportation to test points	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
7	Clarity in test result interpretation	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor

Table 3 Questionnaire on opinions and satisfaction of service users: web application usability.

No.	Evaluation Topic	Rating
1	Ease of using the system	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
2	System suitability and meeting user needs	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
3	Responsiveness of the system	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
4	System functionality and accuracy	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
5	System security	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
6	Benefits of data storage within the system	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
7	System design	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
8	Presence of user guides and instructions	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor
9	System compatibility with all devices and ability to display results accurately	<input type="checkbox"/> Excellent <input type="checkbox"/> Good <input type="checkbox"/> Average <input type="checkbox"/> Poor <input type="checkbox"/> Very Poor

5. Development of a web-based quality control application for point-of-care Hct testing

The web application developed for QC in point-of-care Hct testing version 1.0 and 2.0 was structured following the Model-View-Controller (MVC) architecture⁽¹⁷⁾ (Fig. 1). Development comprised two main

components: client-side and server-side. Web application version 1.0 was initially implemented in 2023, followed by version 2.0, which has provided improved efficiency from 2024 to the present. A comparison of the efficiency between the two versions is presented in Fig.1.

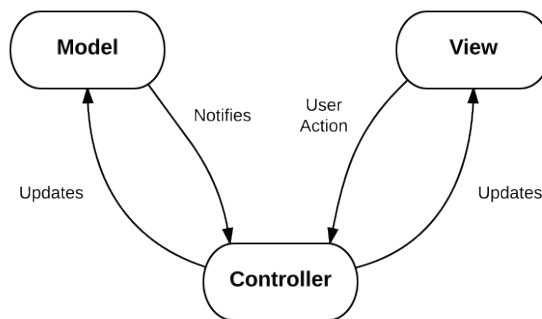


Fig. 1 The MVC (Model-View-Controller) architecture.

5.1 Client-side Components

The client-side component facilitated user interactions through a web browser supplemented by necessary plugins. Key functionalities developed included secure user authentication through username and password systems, a homepage dashboard designed to

present quality control metrics via a graphical “Monthly Summary,” which displayed mean, standard deviation (SD), and coefficient of variation (%CV) values monthly, and an integrated notification system utilizing “Line Notify” (Fig. 2 and Fig. 3).

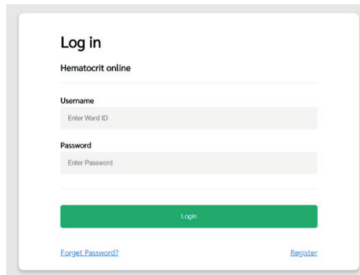


Fig. 2 Log in page for accessing the web application.

Dashboard Monthly Summary (1)

Section on inspection and usage methods, various manuals. (2)

QR code to Line (3)

Section for data entry and result recording (4)

Section for menu linking to other pages (5)

Table displaying the results of the login points (6)

Ward ID	Month	Control Lot	Expire Date	Level1	Level2	Level3	ผู้ตรวจ	ปี
HCTM001	1	PH440	05-03-2024	17	40	49	วิมลรัตน์	2024
HCTM002	2	PH440	05-03-2024	18	40	49	วิมลรัตน์	2024
HCTM003	3	PH440	05-03-2024	18	39	50	วิมลรัตน์	2024

Fig. 3 Overview of the web-based IQC platform for POCT hematocrit monitoring. Key sections include: (1) Dashboard & Monthly Summary, (2) Inspection & Usage Guide, (3) QR Code for Line Access, (4) Data Entry & Results, (5) Navigation Menu, and (6) Results Table for QC performance tracking.

5.2 Server-side Components

The server-side component encompassed the web application itself, programmed in Python using the PyCharm Integrated Development Environment (IDE). The XAMPP version 3.3.0 served as the web server environment, while Ngrok was employed to expose the local host to the public internet. The server operations were executed on hardware equipped with the Microsoft SQL operating system, featuring a 3.00 GHz ARM-based processor, 8.00 GB of RAM, and a 64-bit operating system.

6. Statistical analysis

The statistical methods used in this study included: (1) Hct value analysis using mean, standard deviation (SD), coefficient of variation (%CV), %CV limits, and percentage calculations; and (2) satisfaction evaluation using a 5-level rating scale: 4.51-5.00 (very high), 3.51-4.50 (high), 2.51-3.50 (moderate), 1.51-2.50 (low), and 1.00-1.50 (very low).

Results

1. Users' feedback and satisfaction regarding the developed web application in quality controlling of POC Hct testing

The evaluation was conducted across three phases:

1.1 Before using web application

Before implementing the web application, laboratory staff and nurses who

observed and monitored the process of POC Hct control showed the highest satisfaction with the convenience of result reporting, with a mean score of 3.63. The lowest satisfaction scores were for the safety of sample materials and convenience of usage instructions, with average scores of 3.19 and 3.20, respectively. Additionally, laboratory staff and nurses expressed the need for quicker, more user-friendly testing procedures to save time and reduce redundant data entry.

1.2 After using web application version 1.0

While laboratory staff reported the highest satisfaction with the design of the application (mean score of 3.50), nurses were satisfied most with the easiness of system usage (mean score of 3.50). Both groups reported the lowest satisfaction with system security, with an average score of 3.00 from laboratory staff and 3.04 from nurses. Additional feedback from both groups indicated that data processing was inconvenient, as it required re-entering data into Excel and lacked a notification system

1.3 After using web application version 2.0

The web application version 1.0 revealed security issues, as data was not secure, allowing everyone to input results for one another. Additionally, the system lacked notification features. Therefore, further development was carried out, leading to the phase of using web application version 2.0. The highest satisfaction among laboratory

staff was noted with system security, benefits of data retention, and usability across devices, all scoring as 4.69. Nurses rated the highest satisfaction with usability across devices, scoring as 4.75. Regarding the QC in Hct testing, the laboratory staff reported the highest satisfaction with the convenience of recording test results, with an average score of 4.69. Among nurses, the highest satisfaction was with the process of sending samples to the testing site, with an average score of 4.71. Most items were rated at high to very high levels of

satisfaction.

For additional feedback, the users indicated that the web application was well developed, modern, and easy to use. The application effectively incorporated technology into the work process, with a clear and well-designed format. Instructions were also clearly explained. AN suggestion was to display the application on the hospital’s website for more convenient use (Fig. 4 and Fig. 5)

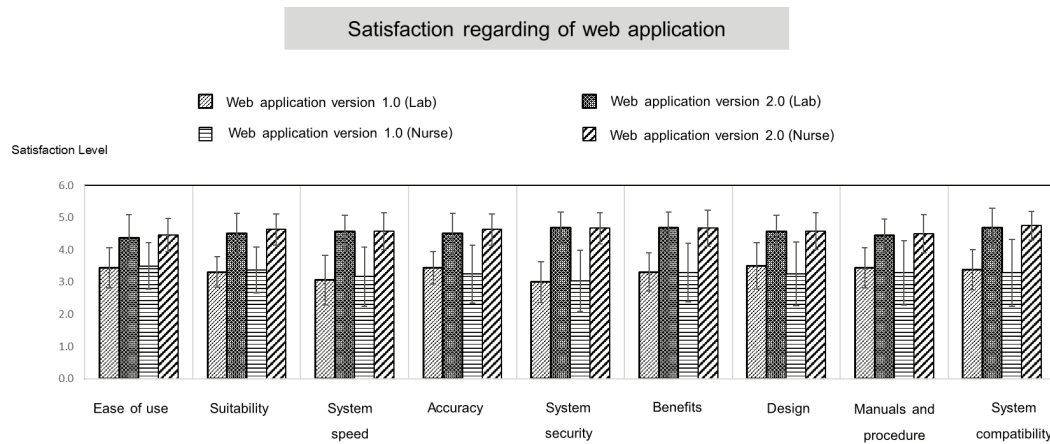


Fig. 4 Satisfaction levels regarding of web application.

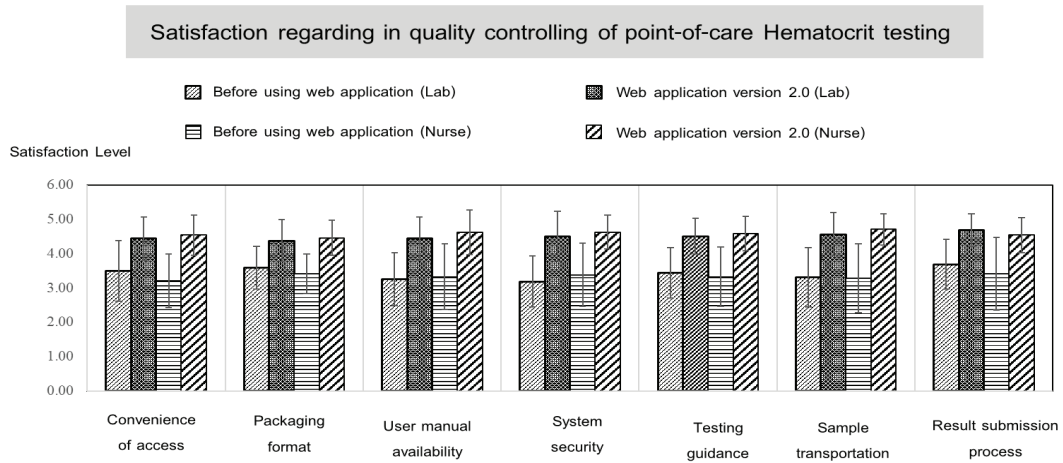


Fig. 5 Satisfaction levels regarding in quality controlling of point-of-care hematocrit testing.

2. Evaluation of effectiveness in quality management of POC Hct Testing

Evaluation was based on the %CV (with a 4% acceptance limit defined by CLIA 2019⁽¹⁸⁾ and the Thailand Medical Technology Council⁽⁶⁾) and turnaround times across three phases:

2.1 Before using web application

Medical technologists were responsible for conducting QC for Hct testing in the patient wards. The results showed that %CV values of QC material at normal levels met the standards, except for September 2020 (Fig. 6). The %CV values for low and high Hct measurements were outside the acceptable range, with %CVs of 5.6 and 4.1, respectively. Turnaround time data was not available for this phase.

2.2 After using web application version 1.0

The nurses in the patient wards conducted the QC tests for Hct and entered the results through web application version 1.0. The %CV values did not meet the standards more frequently, with a non-compliance rate of 33.3%. Turnaround time exceeded expectations by 12.5%.

2.3 After using web application version 2.0

The nurses in the patient wards conducted the QC tests for Hct and entered the results through web application version 2.0. The %CV values showed significant improvement with a compliance rate of 91.7%. Turnaround time exceeded expectations by 6.8%. Due to the improvements in web application version 2.0,

a notification system through Line application was added. The official Line account was set to send notifications for sample submissions and expiration dates. The web application allowed results to be entered by scanning QR

code and sent to the server. The information was up-to-date and secure, making the process more convenient. The system automatically calculated the %CV and provided notifications through Line notify. (Fig. 6)

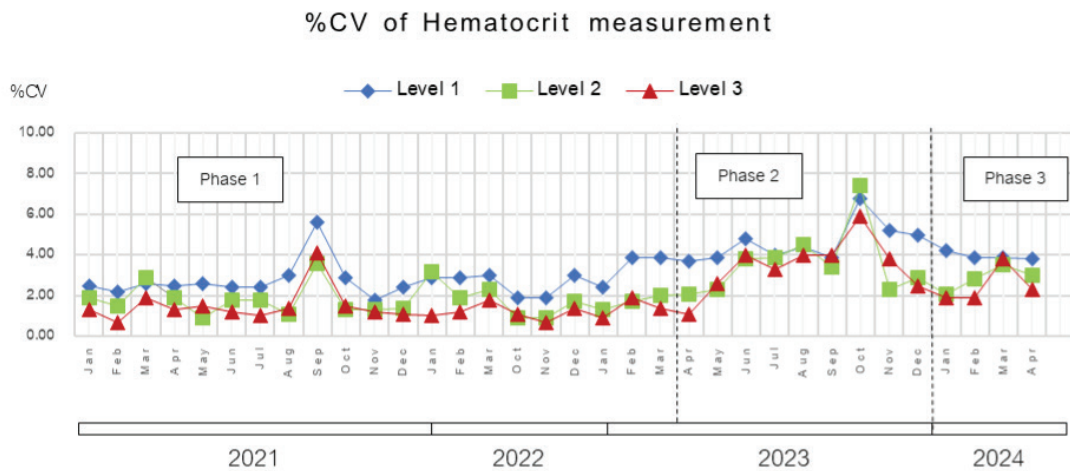


Fig. 6 Monthly %CV of hematocrit QC at three levels across 3 phases.

3. Analysis of management interviews

The hospital executive and all QC personnel interviews, conducted with a group of five executives including two doctors, one medical technologist, one professional nurse, and one computer scientist, revealed key insights. The interviews focused on six main questions: 1) The process of managing development and QC, 2) The benefits of developing the web application and the QC process, 3) The reduction in turnaround time before and after the development of the web application, 4) The reduction in workload before and after the development of the web application, 5) The reduction in costs, and

6) Suggestions for improvement.

The results showed positive outcomes in system development, continuous problem solving, and operational recommendations. The web application significantly improved convenience for laboratory staff in testing areas. Laboratory staff were not needed to go to the wards for QC because results could be easily entered and immediately accessed. The speed of processing was enhanced, as results can be entered online in real-time, ensuring that data remained up-to-date. Moreover, the web application reduced workload by eliminating the needs for manual record keeping in notebooks or Excel sheets.

In terms of cost savings, the web application was developed in-house; therefore, it helped reduce expenses. Additionally, it cuts costs by utilizing QC substances left over from daily inspections. Despite the project having a limited budget, the outcomes were beneficial for the organization. This discovery underscored the positive impact of the web application on improving both efficiency and QC in POCT, as reflected by user feedback and insights from management.

Discussion

Web application version 2.0 was developed using the MVC architecture, which ensured a clear separation of responsibilities and facilitates efficient system management and maintenance. It featured an authentication system, real-time responsiveness with alerts when values are out of range, and automatic monthly data processing. Additionally, the application was available for free.⁽¹⁷⁾ These tools were consistent with the educational approaches by Panwisut, 2019⁽¹⁹⁾ and Prasomsab and Suwantheeraangkoon, 2020.⁽²⁰⁾

Many hospitals conduct IQC for Hct testing by having laboratory personnel performing the tests at the point-of-care. However, some hospitals do not implement any IQC procedures. These QC tests are often performed by non-laboratory personnel, such as nurses or nursing assistants, who might have limited skills and knowledge in laboratory analysis. Therefore, a strict QC

management system is essential to ensure the accuracy of test results.^(1,2,4) According to POCT guidelines, ward staff are responsible for performing the tests.⁽¹⁵⁾ Medical laboratory standards recommended that the laboratory shall provide IQC materials to the POC units for testing.⁽⁶⁾ Additionally, ISO 15189:2022 guidelines suggested that the laboratory should oversee and support POCT conducted by various departments within the organization.⁽¹⁶⁾ Previous studies have shown that the use of web applications or related computer-based technologies can enhance efficiency and improve user satisfaction.⁽¹⁹⁻²¹⁾

Before using the web application, satisfaction levels among laboratory staff and nurses were moderate across all evaluation criteria. However, these satisfactory levels were significantly increased to the high and highest levels during the web application version 2.0 and subsequent improvements. Examples of improvements made during this phase included adding a notification for out-of-range results, visualizing data in graph format, analyzing data, and sending test result notifications via the Line application. The increase in satisfaction found in this study aligns with the study by Naknarin, *et al.*⁽²¹⁾ investigating the development of web applications to enhance marketing potentials of Tak beef cattle in Tak Province. They found high levels of satisfaction regarding the design of the web application and media.

Prior to the implementation of the web application, %CV values were low, ranging from 1-3%, probably because the tests were conducted by experienced laboratory staff. During the web application version 1.0 phase, the number of out-of-range significantly increased to 33.3%. This could be due to nurses, who were in charge of QC testing, possibly lacking experience. However, after web application version 2.0 was developed, and the QC results showed positive improvement and were within acceptable limits. This improvement was attributed to enhancements in the web application, including result management controls, notifications for out-of-range results, and the availability of a Line official for problem inquiries and coordination. The range of each level was the overall average, and with the development of the web application version 2.0 and systematic QC training and follow-up, improvements were observed, and %CV values were within the specified criteria.⁽¹⁸⁾ (Fig. 6)

In Phase 1, the delay in result returns occurred because laboratory staff conducted tests in patient wards, which consumed significant time, required one staff member solely for QC, and did not allow for assessing the skills of POCT personnel. In Phase 2, web application version 1.0 was introduced for recording and tracking QC results; however, it lacked a notification system for deadlines, leading to testers being unaware of result

submission timelines. In phase 2, the delayed return of results was 12.5%, due to the absence of a notification system and unclear documentation. In Phase 3, web application version 2.0 was implemented, incorporating deadline notifications via Line notify and Line official, which informed staff about QC sample submission schedules, increasing awareness and improving on-time result submissions. In phase 3, the results showed a positive trend in which the delayed return of results improved to 6.8%. This improvement was attributed to notifications being sent through the Line official to the responsible personnels and the availability of clear documentation guidelines. (Table 1)

Analysis of interviews with hospital executives revealed that all six aspects were positively aligned. These included having a good format, appropriateness, continuous development, convenience, efficiency, reduction in workflow steps, reduced time, reduced workload, and reduced costs.

This study demonstrates that the application of self-developed information technology in the management system of POC Hematocrit testing control at Phukhieo Chalermphrakiat hospital, Chaiyaphum province, was proved to be effective and satisfy user needs. This encompasses QC in POC Hematocrit testing and usability of the web application, resulting in cost savings.

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