AITCS

Hemodialysis Patient Management System Using Mobile Application

Muhamad Nazhim Ahmad Tohid, Noraini Ibrahim*

[1]Software Engineering Research Group (SERG), Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, MALAYSIA

Abstract: The Darul Ta'zim Hemodialysis Centre is one of the dialysis clinics located in Paritt Raja, Batu Pahat. This center has been in operation for a long time and provides hemodialysis treatment to the surrounding community. However, nurses manually manage clinics for all treatment and appointment information. All patient information has to be documented and more space is required to store all files. Unfortunately, such documentation is less effective because there is no systematic way to access all records more easily. This can cause data loss, redundant documentation and takes a long time to monitor and update information. Therefore, a hemodialysis patient management system using mobile application is developed to assist the dialysis centre to have better information management of their patients, and history treatment recorded in the system. Additionally, the patient can access the scheduled appointment via the system, and the center can easily change and update it within the system. The project involved three users such as administration, health care worker and dialysis patients. The project is then carried out using an object-oriented approach and the Ionic framework for developing mobile applications. It is expected that the system will improve the management of hemodialysis patient information. In conclusion, a hemodialysis patient management system using the mobile app could help nurses and doctors in their day-to-day business processes as well as patients.

Keywords: Dialysis, Appointment, Healthcare

1. Introduction

There are approximately 1.8 million people with end-stage kidney disease worldwide [1]. Kidney failure happens when your kidney loses the ability to filter waste from your blood. These can cause kidney health problems such as exposure to toxic, acute and chronic diseases, severe dehydration and renal trauma. Our kidneys cannot do their daily work when our bodies are overburdened with toxins. These may lead to life in danger if it doesn't treat well. Transplantation is the preferred treatment option for end-stage kidney disease because it provides a life-sustaining benefits over dialysis for the majority of patients [2]. Unfortunately, the increasing number of patients suffering from end-stage kidney disease exceeds the number of organ donor supplies. Due to this cause, dialysis replaces kidney function through the removal of accumulated metabolic waste products, by a process of diffusion, as well as the

removal of excess fluids from the body, by a process of ultrafiltration to some patient [3]. Hemodialysis is one of the most important forms of kidney replacement therapy [4]. Therefore, a hemodialysis process performed on a dialysis patient takes 4-5 hours 3 times a week at the hospital or community services need full monitoring of the patient's progress. The problem occurs when a dialysis patient is not monitored and managed after the hemodialysis process.

Therefore, the hemodialysis patient management (PMH) application is designed to provide some benefit in more systematic and efficient patient management. It provides an easy and flexible interface for storing patient data and facilitating patient information management. Therefore, nurses and doctors can treat and manage the patient effectively. Darul Ta'zim Hemodialysis Center located at Parit Raja, Batu Pahat was selected as the case study. Based on the observation made at the center, the operating process is currently using a manual process. The center is hand-administered by nurses for all therapy records and appointments. All patient details are documented and more space is needed to store all paper-based files. Unfortunately, this type of paper work is less efficient because there is no systematic way to access all documents in a timely manner. This can lead to data loss, redundant documentation and requires a great deal of time to check and update the information. Issues also arise when there is mismanagement of forms and paper documents. Each treatment the patient receives from the centre must be recorded and documented in each paper-based patient's file. There are a lot of paper-based forms, including patient information, history of the treatment cycle, medical records, therapy appointments, sponsorship records and treatment bills.

The process results in poor management of patient information because everything is on the paper-based form. In addition, there are always weaknesses in arranging appointments between the doctor and the patient. Some patient therapy cases require severe supervision from the hemodialysis center to plan treatment, depending on their health status. Right now, the appointment schedule changes over the phone. It will take a period of time to verify the availability of the requested modified slot. This may lead to overlapping appointments between patients. Consequently, the current process applied by the Darul Ta'zim Hemodialysis Center does not make the daily business process of their organization efficient and effective. Therefore, Hemodialysis patient management (HPM) application designed to provide some advantage of managing patient more systematically and efficiently. It provides an easy and flexible interface to record data of the patient and helping management information of the patient. Therefore, nurses and doctor can treat and manage the patient effectively.

2.   Related Work

2.1   Study on Business Process in Darul Ta'zim Hemodialysis Center

Patients who require dialysis treatment at this center should first register with the management office. If the patient does not have a record at the dialysis centre, the patient will need to provide the health information provided and personal details at the time of registration. If the patient has registered for treatment at the Darul Ta'zim Hemodialysis Centre, the administrator will search the patient's medical record.

Prior to the start of the treatment session, the health worker will record the patient's weight, blood pressure, heart rate and body temperature in the patient's treatment booklet. Next, during the treatment process of four hours per session treatment, the health care officer will record the reading of blood flow rate (QB ml / HR), ultrafiltration (UF (L)), Heparin (ml / h), venous line (VP (mm Hg)), Embryonic pressure (TMP (mm Hg)), and conductivity (ms / cm) hourly. Orientation notes will be taken at the end of the session to be used as references for the next course of action.

Furthermore, the treatment schedule is determined based on patient availability. The Darul Ta'zim Hemodialysis Centre offers two-shift treatment on Sunday, Tuesday and Thursday and Monday, Wednesday and Friday. For each of the shift treatment there are three-time slots with a morning session (5.30 am to 9.30 am), afternoon session (9.30 am to 1.30 pm) and evening session (1.30 pm to 5.30

pm). The patient may change the schedule if they are unable to attend treatment. The Health Care Office will reschedule the patient schedule based on the availability of each slot. Figure 1 illustrates the workflow of the hemodialysis patient management system at the Darul Ta'zim Hemodialysis Center.

2.2   Existing System Comparison

Three existing mobile applications are being investigated to support the development of the hemodialysis patient management system through a mobile application. They are Dialysis Monthly Visit Tracker Apps [5], D-Track (Dialysis Tracker Apps) [6], and CKD Care Apps [7] as shown in Table 1.
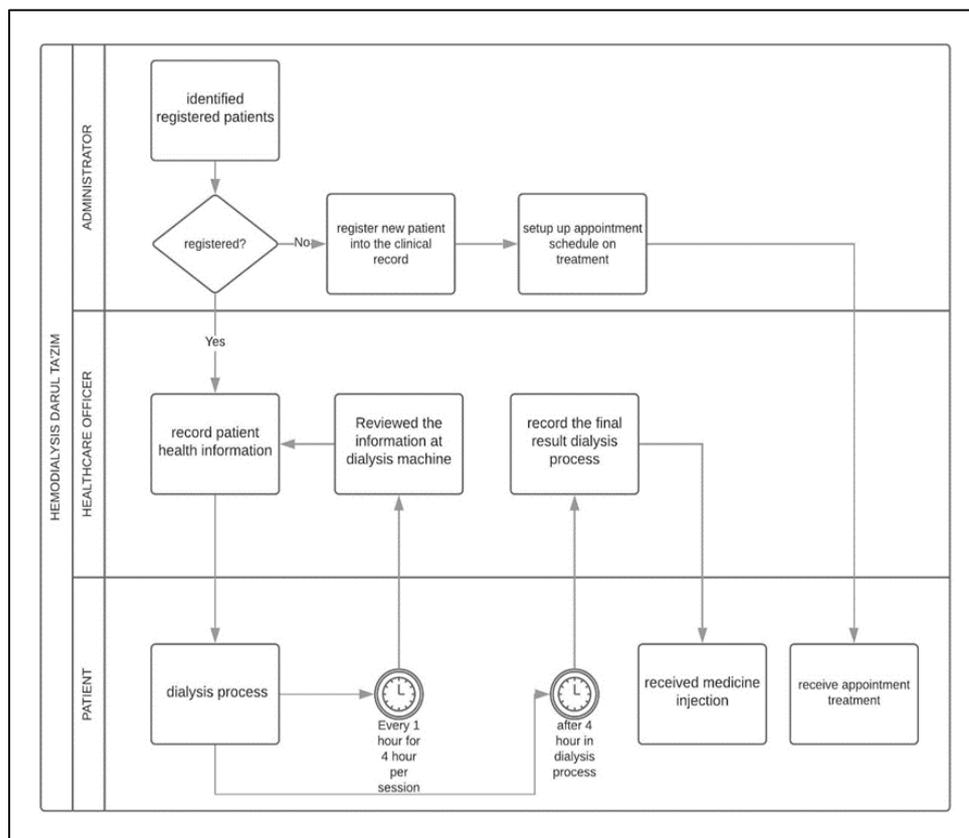

Figure 1: As-Is Model for Darul Ta'zim Hemodialysis Center

**Table 1: Comparison between review exiting application and proposed system**

Criteria / System	Dialysis Monthly Visit Tracker Apps	D-Track (Dialysis Tracker Apps)	CKD Care Apps	Hemodialysis Patient Management System using Mobile Application
Type of User	Healthcare Officer	Patient	Patient	Admin, Healthcare Officer, Patient
System Type	Mobile Application	Mobile Application	Mobile Application	Mobile Application
Login	Yes	No	No	Yes
Registration User	Yes	No	No	Yes
Patient Information Management	Yes	No	Yes	Yes

Table 1: (cont.)

Criteria	System	Dialysis Monthly Visit Tracker Apps	D-Track (Dialysis Tracker Apps)	CKD Care Apps	Hemodialysis Patient Management System using Mobile Application
Treatment Information Management		No	Yes	No	Yes
Schedule Management		No	No	No	Yes
Hemodialysis Report		Yes	Yes	Yes	Yes

Table 1 summarizes the features offered by the similar existing systems and the system that has been developed. All three benchmarks are based on mobile applications. Unfortunately, based on the comparative systems, they do not have schedule management and treatment functionalities.

3. Methodology

The hemodialysis patient management system using the mobile app is developed using the prototyping model. Phases are indicated as blue boxes in Figure 2. Three prototypes have been designed to improve system characteristics. Each version of the prototype requires stakeholder involvement to avoid some of its requirements being overlooked and to prevent system failure at the end of development. Some tools and methods are used at each stage of development to assist in the successful completion of the project.
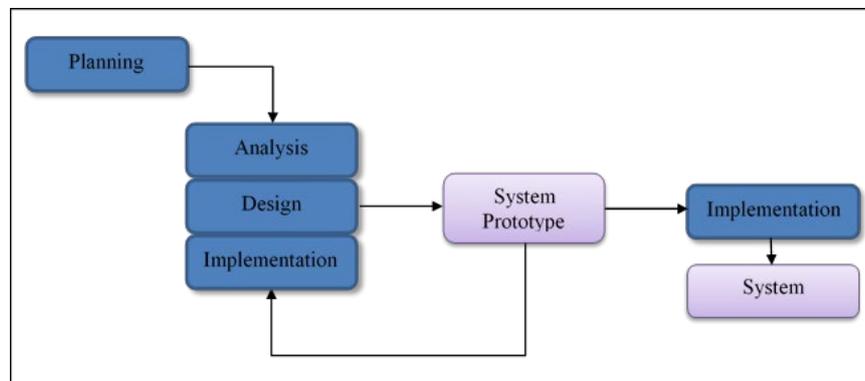
Figure 2: Prototyping Model [8]

Activities in each of the phases are shown in Table 2.

Table 2: Hemodialysis Patient Management System Development Phases

Phase	Activity	Deliverable
Planning Phase	Identify the problem to be solved based on the existing system at the Darul Ta'zim Hemodialysis Centre and create the project plan that is required in the development process.	The proposal of Hemodialysis Patient Management System using Mobile Application that contains the following: 1. Introduction 2. Problem statement

Table 2: (cont.)

Phase	Activity	Deliverables
		3. Objective 4. Scope 5. Methodology 6. Expected Result 7. Project Planning 8. Reference 9. Appendix
Analysis Phase	Identify and analyse the requirements resulting from the interview, observation and revision of the existing system and then construct UML diagrams.	1. Requirement Specification 2. UML Diagram (Use Case Diagram, Sequence Diagram and Class Diagram) Hardware and Software Specification.
Design Phase	Design how the system will store data within the database and how each process interacts with each other on the interface system.	1. System Interface Database Schema
Prototyping Phase	Obtain stakeholder feedback on the current version that was developed for use in the next iteration of prototype development.	First Version, Second Version and Third Version of prototype
Implement and Testing Phase	The prototype converts to the real system, and the tests are performed by the developer with the stakeholder.	1. Developed System 2. Test Case

3.1   Analysis and Design

This section explained about process involve in the analysis and design of the Hemodialysis Patient Management System using Mobile Application based on object-oriented approach.

3.1.1   Analysis

Systems analysis involves methods that allow you to understand the problems that a system must resolve. When developing the Hemodialysis Patient Management system using the mobile app, a UML model is used to model the result of the analysis activity. The output of the analysis is shown in Use Case Diagram and Class Diagram.

A. Use Case Diagram

There were three actors in Hemodialysis Patient Management System using a Mobile Application. They are an Administrator, Healthcare Officer and Patient that interact with the features of the system as shown in Figure 3. Meanwhile, there are six main features for the system which are Login, Registration User, Patient Information Management, Schedule Management, Hemodialysis Report and Treatment Information Management. Each of the actors is interacting with the use case to show the connection and limitation towards the system features.
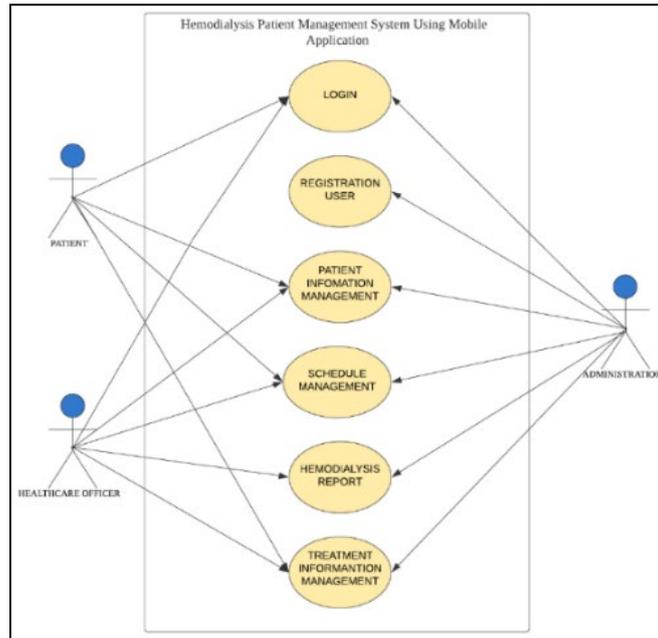
Figure 3: Use case diagram

B. Class Diagram

There are thirteen classes class in the Hemodialysis Patient Management System using a mobile application as shown in Figure 4.
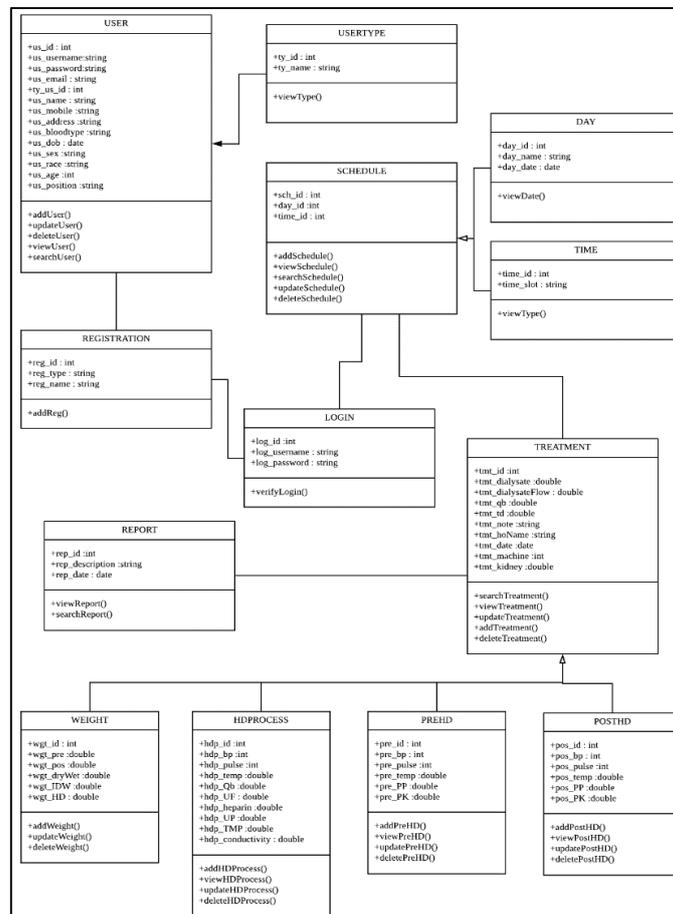

Figure 4: Class Diagram for Hemodialysis Patient Management System

The requirements of hemodialysis patient management system using mobile application are listed in Table 3.

Table 3: System Requirement Definition

Requirement	Software Requirement Specification	Description
Login SRS_REQ_100	SRS_REQ_101	User need to enter the username and password
	SRS_REQ_102	System redirect user to homepage after verification
	SRS_REQ_103	Click "submit" to update the new password.
	SRS_REQ_104	"Successfully updated" pop up message display if the email are valid and "Email invalid" pop up message if the email are invalid.
Register User SRS_REQ_200	SRS_REQ_201	Administrator choose the option between healthcare officer and patient that need to registered
	SRS_REQ_202	Administrator need to fill in the user details in the registration form.
	SRS_REQ_203	Click "Submit" to store the data in the database
	SRS_REQ_204	Confirmation pop-up that administrator to confirm the registration user
Manage Patient Information SRS_REQ_300	SRS_REQ_301	Administrator and healthcare need to insert patient name and select "search" button to perform the searching function.
	SRS_REQ_302	All list patient name is being display in the view patient info before it's been search
	SRS_REQ_303	Patient information will be display after searching are successful be search in the database
	SRS_REQ_304	Administrator and healthcare are able to update any of the patient info.
	SRS_REQ_305	Any empty fill of the patient info that been updated will alert the user to fill it before click" update" button.
	SRS_REQ_306	Administrator able to delete the patient information from the database.
	SRS_REQ_307	System will pop up "Confirmation Delete" before it proceeds delete the data in database.
	SRS_REQ_308	The system will inform the user that patient name incorrect or does not exist in database.
Manage Patient Schedule SRS_REQ_400	SRS_REQ_401	Administrator and healthcare need to insert patient name and select "search" button to perform the searching function to display patient schedule
	SRS_REQ_402	Administrator and healthcare officer able to add schedule by click on button "add appointment".
	SRS_REQ_403	Administrator and healthcare officer need to choose date and time session for the patient treatment.
	SRS_REQ_404	After the schedule been click "submit" the pop up message on confirmation been display before the schedule been store in database.
	SRS_REQ_405	System must display the patient schedule after the searching in the database been performed

Table 3: (cont.)

Requirement	Software Requirement Specification	Description
	SRS_REQ_406	Administrator and healthcare are able to update any of the patient schedule
	SRS_REQ_407	Any empty fill of the patient schedule that been updated will alert the user to fill it before click "update" button.
	SRS_REQ_408	Administrator able to delete the patient schedule info from the database.
	SRS_REQ_409	System will pop up "Confirmation Delete" before it proceed delete the data in database.
	SRS_REQ_410	The system will inform the user that patient name incorrect or does not exist in database.
Manage Patient Treatment SRS_REQ_500	SRS_REQ_501	Administrator and healthcare need to insert patient name and select "search" button to perform the searching function to display patient treatment info.
	SRS_REQ_502	Administrator and healthcare officer able to add treatment record by click on button "add treatment".
	SRS_REQ_503	Administrator and healthcare officer need to fulfil the treatment detail.
	SRS_REQ_504	After the treatment are fully inserted and been click "submit" button the pop up message on confirmation been display before the schedule been store in database.
	SRS_REQ_505	System must display the patient treatment info after the searching in the database been performed.
	SRS_REQ_506	Administrator and healthcare are able to update any of the patient treatment especially every one hour for the four-hour treatment process
	SRS_REQ_507	Any empty fill of the patient treatment info that been updated will alert the user to fill it before click "update" button.
	SRS_REQ_508	Administrator able to delete the patient treament info from the database.
	SRS_REQ_509	System will pop up "Confirmation Delete" before it proceed delete the data in database.
	SRS_REQ_510	The system will inform the user that patient name incorrect or does not exist in database.
Generate Report SRS_REQ_600	SRS_REQ_601	Administrator and healthcare need to insert patient name and select "search" button to perform the searching function to generate patient report.
	SRS_REQ_602	System must display the patient report in term of graphical view searching in the database been performed.
	SRS_REQ_603	The system will inform the user that patient name incorrect or does not exist in database.

3.1.2 Design

The Hemodialysis Patient Management System using Mobile Application consist of thirteen tables in database which are *USER, USERTYPE, REGISTRATION, LOGIN, SCHEDULE, TIME, DAY, TREATMENT, WEIGHT, HDPROCESS, PREHD, POSTHD* AND.*REPORT*.

USER table consist of attributes such as *us_id, us_username, us_password, us_email, us_name, us_mobile, us_address, us_bloodtype, us_dob, us_sex, us_race, us_age, us_position* and, *ty_us_id*. The *us_id* is primary key and *ty_us_id* is foreign key. *USERTYPE* table consist of attributes such *ty_id* and, *ty_name*. The *ty_id* is a primary key. *LOGIN* table consist of attributes such as *log_id, log_username* and, *log _password*. The *log_id* is a primary key. *SCHEDULE* table consist of attributes such as *sch_id, day_id* and, *time_id*. The *sch_id* is a primary key and *day_id* with *time_id* is a foreign key. *DAY* table consist of attributes such as *day_id, day_name* and, *day_date*. The *day_id* is a primary key. *TIME* table consist of attribute such as *time_id* and, *time_slot*. The *time_id* is a primary key. *TREATMENT* table consist of attributes susch as *tmt_id, tmt_dialysate, tmt_dialysateflow, tmt_qb, tmt_td, tmt_note, tmt_honame, tmt_date, tmt_machine* and, *tmt_kidney*. The *tmt_id* is a primary key. *WEIGHT* table consist of attributes such as *wgt_id, wgt_pre, wgt_pos, wgt_dryweight, wgt_IDW* and, *wgt_HD*. The *wgt_id* is a primary key. *HDPROCESS* table consist of attributes such *as hdp_id, hdp_bp, hdp_pulse, hdp_temp, hdp_Qb, hdp_UF, hdp_heparin, hdp_VP, hdp_TMP* and, *hdp_conductivity*. The *hdp_id* is a primary key. *PREHP* table consist of attributes such as *pre_id, pre_bp, pre_pulse, pre_temp, pre_PP* and, *pre_PK*. The *pre_is* is a primary key. *POSTHP* table consist of attributes such as *pos_id, pos_bp, pos _pulse, pos _temp, pos _PP* and, *pos _PK*. The *pos _is* is a primary key. *REPORT* table that consist of attributes such as *rep_id, rep_description* and, *rep_date*. The *rep_id* is a primary key.

3.2 Implementation

The hemodialysis patient management system using the mobile app is developed using Visual Studio software. There are 6 main module interfaces were included. They are Login module, Register module, Manage Patient Information module, Manage Patient Schedule module, Manage Patient Treatment module and Generate Reports Module. In addition, the code segmentation for each module is described.

The interface of the hemodialysis patient management system using mobile application modules shown in Figure 5 to Figure 17. Figure 5 shows the login interface where Administrator and Healthcare Officer need to input username and password for verification. Figure 6 shows the registration form that only administrator can perform registration for healthcare officer and patient.
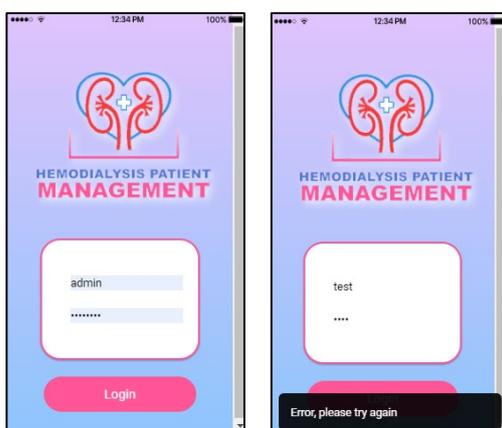

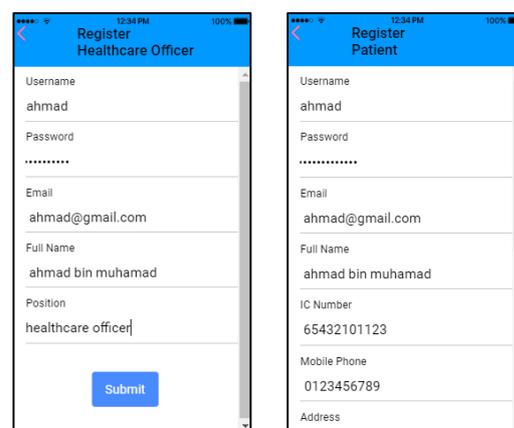**Figure 5: Login Module Interface**   **Figure 6: Register User Module**

The administrator and healthcare officer are allowed to manage patient information. They can view, update and delete the patient info as shown in Figure 7 to Figure 9.
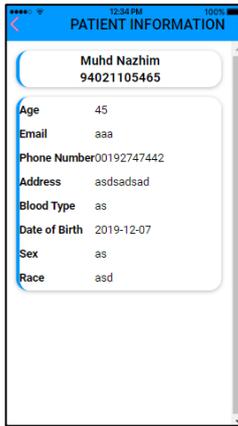
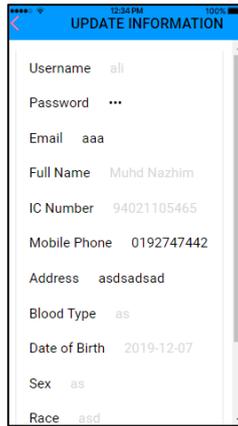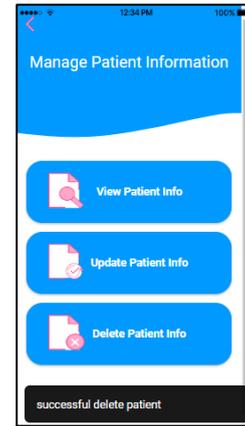Figure 7: View Patient Info   Figure 8: Update Patient Info   Figure 9: Delete Patient Info

Manage Patient Schedule is the appointment set by the Healthcare Officer on the day patient is required to do the hemodialysis treatment. In this module, there four primary functions such as set appointment, view appointment, update appointment, and delete appointment shown in Figure 10 to Figure 13.
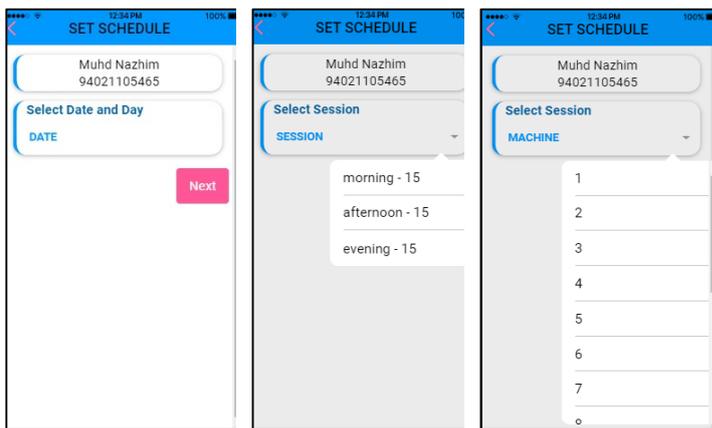

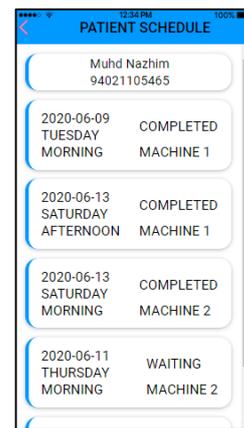Figure 10: Setup Patient Schedule   Figure 11: View Patient Schedule
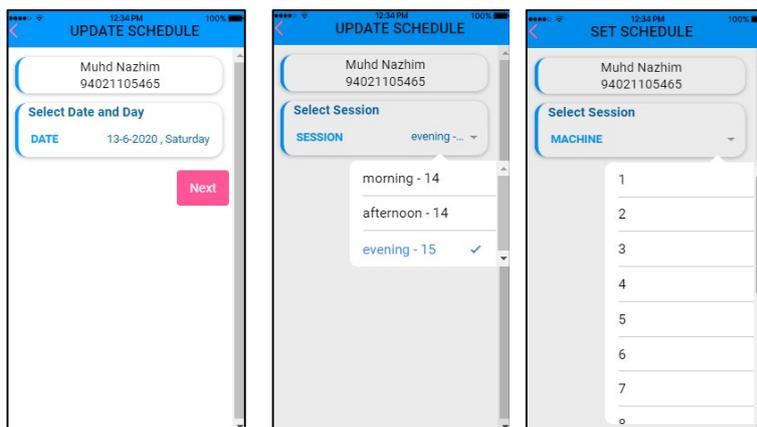

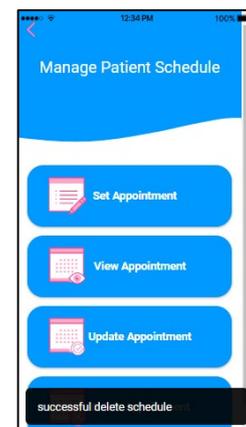Figure 12: Update Patient Schedule   Figure 13: Delete Patient Schedule

Manage patient treatment module where any information about the hemodialysis procedure documented in the program. Administrators and healthcare officers need to setup treatment detail, can

view treatment recorded, and update the status appointment at the end of the treatment process, as shown in Figure 14 to Figure 16.
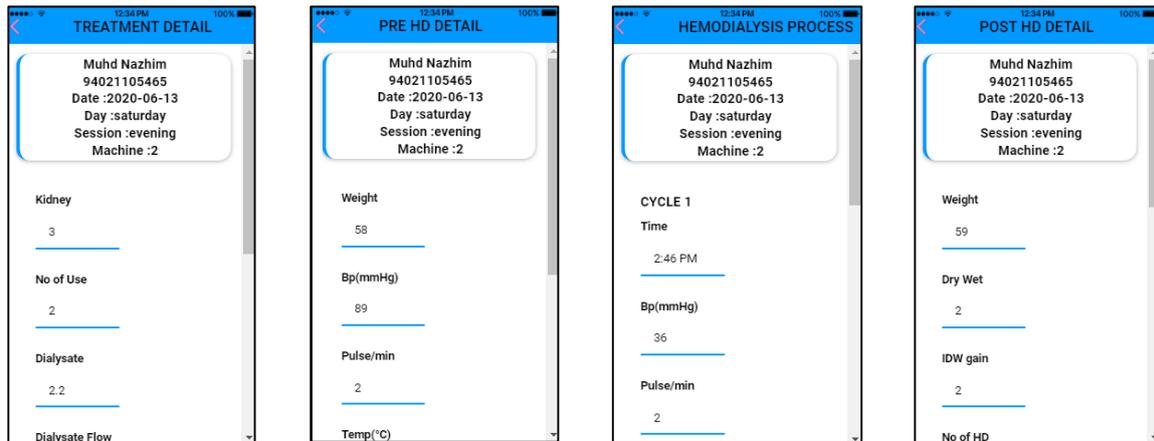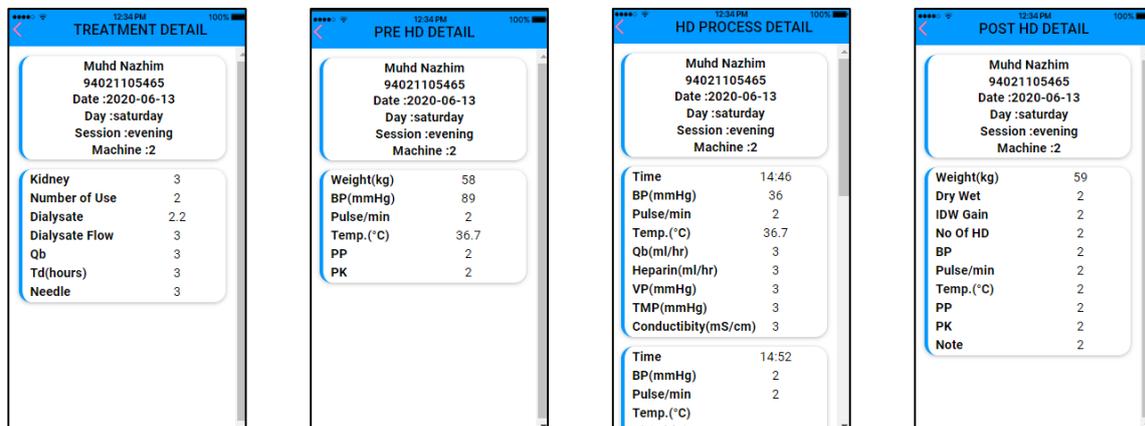

Figure 14: Setup Patient Treatment

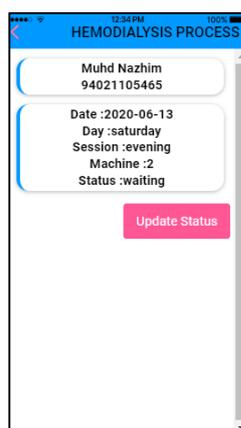

Figure 15: View Patient Treatment

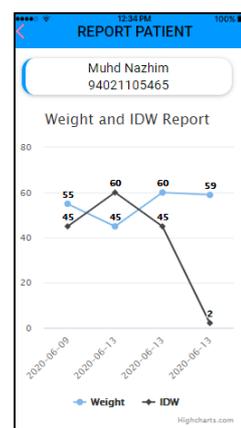**Figure 16: Update Schedule Status**   **Figure 17: Generate Report**

Generate Report module mainly focus on the weight patient after every treatment and IDW for administrator and healthcare officer monitoring each patient condition as shown in Figure 17.

4.   Results and Discussion

Testing phase on Hemodialysis Patient Management System using Mobile Application carried for each of the modules developed. The technique used on the system focused mainly on the system's functionality. The following Table 4 of test cases describes the test cases used to test the system.

Table 4: List of test cases

Test Case	Software Requirement	Description	Status
Test Case Login (STD_TEST_100)			
STD_TEST_100_001	SRS_REQ_101	The user provided the correct username and password	PASS
STD_TEST_100_002	SRS_REQ_102	System redirect user to homepage after verification	FAIL
STD_TEST_100_003	SRS_REQ_103 SRS_REQ_104	User can update the password Invalid email pop up message if the password invalid to updated	FAIL
Test Case Register User (STD_TEST_200)			
STD_TEST_200_001	SRS_REQ_201	Administrator able to choose between healthcare officer or patient to be registered	PASS
STD_TEST_200_002	SRS_REQ_202	Administrator able to fulfil different registration form based on type user registration	PASS
	SRS_REQ_203	The registration data are successful be submitted and store in database	PASS
STD_TEST_200_003	SRS_REQ_204	Pop-up message on successful registration user	PASS
Test Case Manage Patient Information (STD_TEST_300)			
STD_TEST_300_001	SRS_REQ_301 SRS_REQ_302	List of patient name and IC number are display to enable Administrator and Healthcare Officer to view their detail	PASS
STD_TEST_300_002	SRS_REQ_303	Display Patient information	PASS
STD_TEST_300_003	SRS_REQ_304 SRS_REQ_305	Administrator and Healthcare Officer able to update patient information	PASS
STD_TEST_300_004	SRS_REQ_306 SRS_REQ_307 SRS_REQ_308	Administrator and Healthcare Officer able to delete patient information	PASS
Test Case Manage Patient Schedule (STD_TEST_400)			
STD_TEST_400_001	SRS_REQ_401	System will display list of patients before setup appointment been done	PASS
STD_TEST_400_002	SRS_REQ_402 SRS_REQ_403 SRS_REQ_404	Administrator and healthcare officer able to setup appointment by selecting date, session and machine that available and stored in database	PASS
STD_TEST_400_003	SRS_REQ_405	Administrator and Healthcare able to see all the schedule appointment on each patient	PASS

Table 4: (cont.)

Test Case	Software Requirement	Description	Status
STD_TEST_400_004	SRS_REQ_406 SRS_REQ_407	Administrator and Healthcare able to update and change the schedule appointment for the patient	PASS
STD_TEST_400_005	SRS_REQ_409 SRS_REQ_410	Administrator and Healthcare able to delete the schedule appointment	PASS
Test Case Manage Patient Treatment (STD_TEST_500)			
STD_TEST_500_001	SRS_REQ_501	System will display list of patients before setup treatment been done	PASS
STD_TEST_500_002	SRS_REQ_502 SRS_REQ_503 SRS_REQ_504	Administrator and healthcare officer able to setup the treatment detail process on each process and stored in database	PASS
STD_TEST_500_003	SRS_REQ_505	Administrator and Healthcare able to see all the treatment detail on each patient based on the schedule appointment that been selected	PASS
STD_TEST_500_004	SRS_REQ_506 SRS_REQ_507 SRS_REQ_510	Administrator and Healthcare able to update the cycle treatment for every hour patient treatment	PASS
STD_TEST_500_005	SRS_REQ_508 SRS_REQ_509	Administrator and Healthcare able to delete the treatment process detail	FAIL
Test Case Generate Report (STD_TEST_600)			
STD_TEST_600_001	SRS_REQ_601	System will display list of patients before generate the report	PASS
STD_TEST_600_002	SRS_REQ_602 SRS_REQ_603	System display graphical graph on patient weight and IDW	PASS

There are a total 24 test cases have been tested and 87.5% of them passed the testing. The summarization of the result is shown in Table 5.

Table 5: Summarization of testing result

Test Case	Num. of Test Cases Passed	Pass (%)
STD_TEST_100	1/3	33.3
STD_TEST_200	3/3	100
STD_TEST_300	4/4	100
STD_TEST_400	5/5	100
STD_TEST_500	4/5	80
STD_TEST_600	2/2	100
Total Test Case	24	87.5

5.   Conclusion

In conclusion, the hemodialysis patient management system using the mobile app is the system where the clinical dialysis center can manage and monitor their patients via a mobile app. It is easily can be accessed by the three users who are administrator, healthcare officer and the patient once their data are registered into the system. Patient information management, treatment, scheduling and hemodialysis reporting are systematically performed, which may increase the worker's labour productivity. It also reduces the time it takes for the health care worker to record, view and update any information about the patient.

Acknowledgement

References

[1]   F. Gotch. "The basic, quantifiable parameter of dialysis prescription is Kt/V urea; treatment time is determined by the ultrafiltration requirement; all three parameters are of equal importance," Blood Purif, vol. 2, no. 1, pp. 18-26, 2007, doi: 10.1159/000096392

[2]   R. A. Wolfe, V. B. Ashby, E. L. Milford, A. O. Ojo, "Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant," N Engl J Med, vol. 341, no. 23, pp. 1725-1730

[3]   J. T. Daugirdas, "Physiological principles and urea kinetic modelling". [Online]. Available: https://abdominalkey.com/. [Accessed Apr. 8, 2021]

[4]   F. Javed, A. V. Savkin, G. S. H. Chan, J. D. Mackie, et. Al. "Recent advances in the monitoring and control of haemodynamic variables during hemodialysis". Physiological measurement, 2012, doi: 10.1088/0967-3334/33/1/R1

[5]   iNautical Software, "Dialysis Monthly Visit Tracker". [Online]. Available: https://www.patientvisittracker.com/index.php. [Accessed Apr. 8, 2021]

[6]   Cycosoft LLC, "D-Track - Dialysis Tracker". [Online]. Available: https://cycosoft.com/. [Accessed Apr. 8, 2021]

[7]   National Kidney Foundation, "CKD Care Apps". [Online]. Available: https://www.kidney.org/apps. [Accessed Apr. 8, 2021]

[8]   A. Dennis, B. H. Wixom, R. M. Roth, "System Analysis and Design Seventh Edition". NJ: Wiley, 2019.