Design and Implementation of a standardised Clinical Decision Support Algorithm for Fever

Abstract

This study aims to design a decision support tool to assist in providing quality treatment that is consistent with World Health Organization (WHO) and Nigerian National guidelines. The system is designed to allow clinicians to administer care within their competent level working from one algorithm. The system will help them to identify emergencies associated with fever symptoms and to recommend stabilisation actions before a referral is made. This new system allows structured assessment of patients who should receive optimal care and improved data transmission to the next caregiver. In this study, we used an explanatory approach, starting with the quantitative data collection phase which is the administration of questionnaires and Pre and Post questionnaires followed by qualitative data from focus group discussions over the clinician experience using the Clinical Decision Support System (CDSS). Focus group discussions were performed to authenticate the quantitative data to have a more holistic view of the CDSS. Using elements of the decision support system together with the clinician's decision showed thatthe clinicians felt that they worked more systematically and communicated more effectively with others. They felt more professional when using the decision support system.73% of clinicians reported using CDSS in almost every consultation and 93% used the CDSS in the majority of their consultations during the three-month testing period. The mean total test score before the CDSS was 2.5 and this increased by the end of the test period to a mean score of 9.6, an improvement of 74.4%. The results of this study showed that with the help of a decision support system, patients were properly identified and stabilised before they were referred, and the clinicians stayed on their competency level. It allowed caregivers to interact professionally without bias. However, the decision support system requires more extensive testing to enhance the evidence base relating to the vital parameters and the use of the decision support system.

Keywords: Emergency healthcare, Decision-making and referral, Algorithm for Fever, clinical decision support algorithm

Introduction

Disease burden reduction is inhibited as a result of poor quality of caredue to shortages in the number of caregivers andthe poor attitude of healthcare workers.This has adversely affected the quality of care in Primary healthcarecentresin Nigeria originally set up to cater to the rural populace (and small communities such as Universities). World Health Organization (WHO) in its guidelines on health policy and system support to optimize community health worker programs in 2016, articulated thatshortages of health professionals remain a threat to realising the health-related Sustainable Development Goals (SDG) and Universal Health Coverage (UHC). This situation necessitated the endorsements to review current health policies to reflect a sustainable and responsive skills mix of available health professionals.

Over the years, research hasshown factors for the lack of quality care and treatment practices to include infrastructure, lack of equipment, drugs,and inadequate healthcare providers, especially at the community level where community-based practitionerspractice.The high mortality rates reflect the poor state of primary care, especially the lack of qualified healthcare personnel. The provision of quality healthcare is hinged on the knowledge and practice of community-based health practitioners which is crucial to providing quality care.

The measure of the quality of care is in adherence to standardisation in clinical practice,which is the proper usage of approved guidelines and adherence to evidence-based guidelines. It may also include the use of technology by healthcare professionals in their clinical practices such as clinical decision support systems (CDSS). Modern medical practice usually combines technology for the treatment of patients.

This CDSS aimis to deliver the best healthcare and to use the best clinical decisions to improve patient outcomes,combining knowledge, algorithms, and equipment. This is to support health workers in low income and middle income countriesfor the evaluation and management of clinical problems with the main goal of improving the quality of healthcare.

It integrates knowledge-based into the clinical decision-making process. The idea is to provide at the point of care current relevant information to the caregiver. Spreckelsen *et al.* [1] described a CDSS implemented in PDAs as a system in which a knowledgebase is embedded to deliver the required knowledge and monitor given therapy plans for physicians at the point of care. Recent work on mobile clinical support systems addresses different decision support such as knowledge delivery on demand, medication consultant, therapy reminder [1-2], preliminary clinical assessment for classifying treatment categories [2-3], and providing alerts of potential drugs interactions and active linking to relevant medical conditions [4]. Studies have demonstrated that CDSS can be an efficient means for decreasing errors or omissions and improving adherence to practice guidelines.

Gordon *et al*. [5,11] alluded that Mobile technologies have the potential to bridge systemic gaps needed to improve access to and use of health services, particularly among underserved populations in resource-poor countries. The use of mobile and/or electronic devices to support medical and public health practice and research is increasingly being appreciated worldwide. The authors in [6] concluded that mobile penetration coupled with investments from technology companies can provide accessible platforms onto which innovations can establish and offer value-based products, providingan opportunity for its use in providing service at the point of care. Tamrat *et al*[7] and Oluoch *et al* [8] in their publication are of the view that mobile phone innovations are cheap and so can provide fast solutions, especially in areas with poor healthcare infrastructure such as our rural areas which have the potential of improvements in health outcomes.

Shahmoradi*et al* [9] in their reviewon community health workers and mobile technology, concluded by saying programmatic efforts to strengthen health service delivery focus on improving adherence to standards and guidelines, community education and training, and programmatic leadership and management practices should be encouraged. They concluded that studies that evaluated program outcomes provided some evidence that mobile tools help community health workers improve the quality of care provided, efficiency of services, and capacity for program monitoring.[10,11]

The adoption of smartphones and their widespread across the world today has tremendously changed everyday life. Modern-day digital innovations and widespread internet connectivity in the developed world have led to a significant change in human-technology interaction[12]. In Nigeria however, bracing up to improve connectivity to be able to enjoy improved healthcare would be of great essence. The other angel is the exponential development of computer performance and storage capacities, cloud computing and its application and improvement of artificial intelligence (AI) methods have opened new possibilities for the design of Mobile health apps and medical apps which are becoming increasingly popular as digital interventions in a wide range of health-related applications. [13]

2.Methodology:

This study adopted scientific processes of exploration, discovery, confirmation, and dissemination for the development of the research. To achieve the objectives of this study, experts were consulted including medical doctors, nurses, knowledge engineers, and community health workers, knowledge engineers to understand what is required to design a system that conforms to clinical best practices.

A thorough investigation of the present system is required to ensure an understanding of the background data for the development of effective and efficient software.

Literature was reviewed to gain insights into the CDSS processes and to establish the existence of CDSS in the various healthcare delivery levels as well as existing gaps in developed and less developed health systems. Semi-structured interviews were used to extract relevant information from stakeholders. A qualitative research approach was adopted to derive a balanced view of the interrelations that exist among the cadre of healthcare professionals that practice in the PHC.

3. Analysis of the Present System:

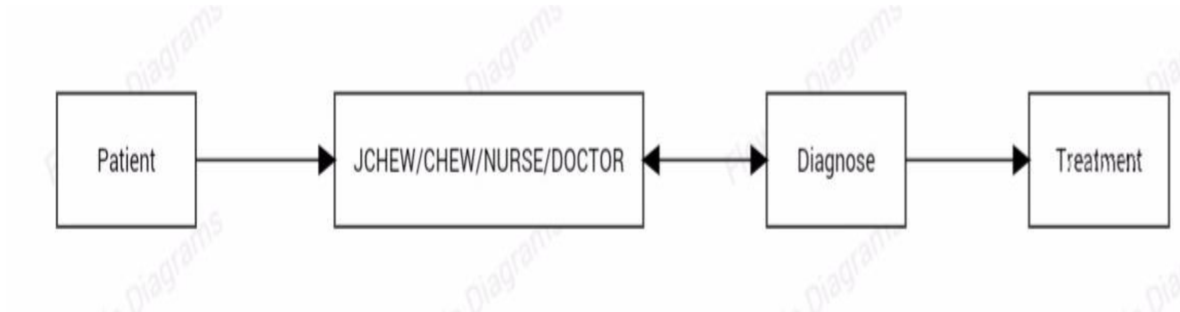

Fig.1: Existing public healthcare system

The present system was analysed systematically, and the information gathered during the analysis was used to recommend improvement of the proposed system. In the present system, patients come to the clinic and are seen by a clinician who first takes their history and examines them after which drugs are prescribed for them to buy. The clinicians rely more on experience without consulting any guide even though there exists a paper guide called standing order which is not readily available in the PHcs visited. Treatments are done on a trial-and-error basis. A mixture of drugs is usually given (Poly pharmacy) hoping one of them will work.
Figure 1 below depicts the structure of the existing system on the ground.

4. Analysis of the proposed system:

In this phase, we gathered information from the survey conducted from the existing system on the availability and usage of information communication technology devices within the medical facility. Also, other useful information relating to the public health care system was gathered as a result of reading downloaded research journals and articles. The qualitative and quantitative data that were collected were analyzed and used to design the concept of solving the identified research problems.

5. Research Design:

Research-based design model was originally proposed by Teemu Leinonen as a design experiment. Design-based research postulates collaborative relationships among researching, designing, and engineering.

Research design has been variously described by different researchers, but the author in [14] described it as a blueprint or outline used in carrying out research in a way that exercises maximum control over factors that affect the validity of the results. It is a systematic and deliberate organized effort to investigate a specific problem to provide solutions. The output is to add new knowledge, develop theories as well as gather evidence. [15] states that scientific research is a systematic, controlled, empirical, and critical investigation of propositions about the presumed relationships between various phenomena.

Following this, this study looked at the relationship between knowledge stored in a database and the efficient way to query and retrieve diagnostics protocols using a decision tree algorithm combined with rules to reduce the time to fetch correct diagnoses from the knowledge base. Research-based design model combines design, research, and practice simultaneously, and has shown very positive potential in improving the quality of care.

Figure 2 below depicts the flow of selected process activities adopted for this research study.

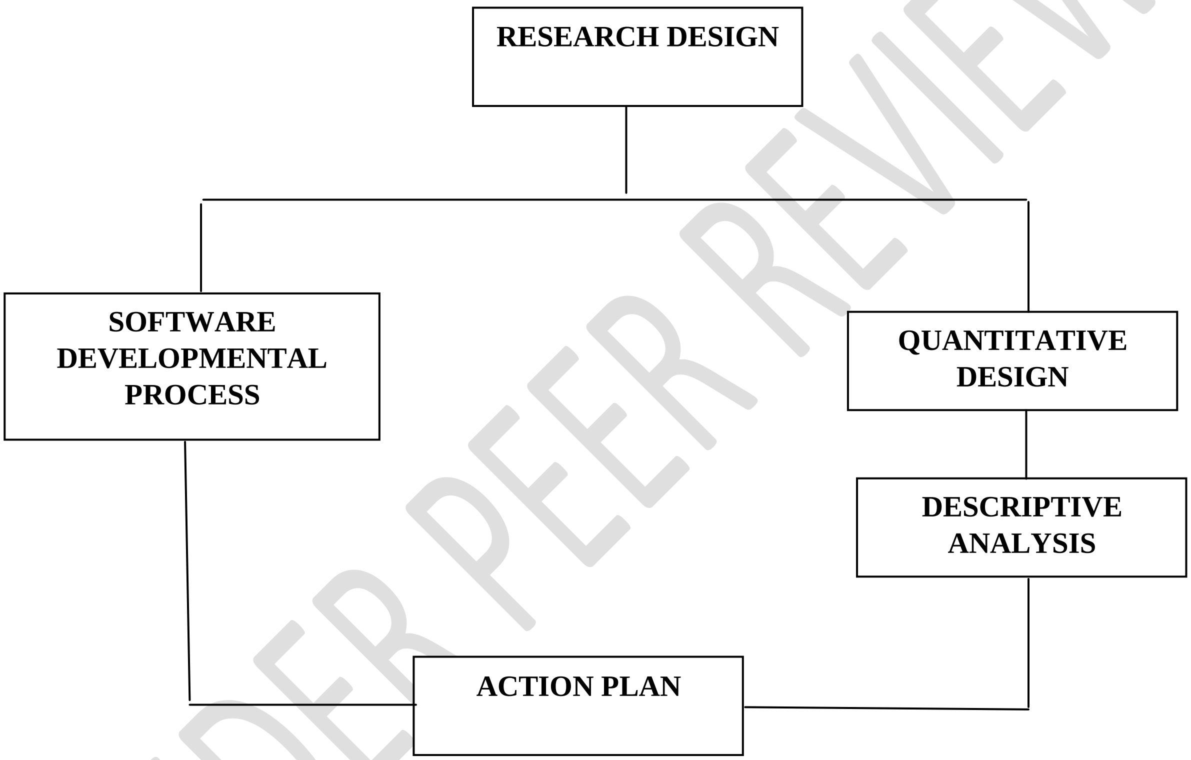

Fig. 2: Research design

6. Research Instruments:

In this study, interviews and Questionnaires were administered to the staff by randomly selected users who are deemed to have comparative experience in health care services (eligible respondents). This is part of eliciting primary sources of data. Most of the respondentscomplained about the volume of information required and the time required for the practical procedure and filling the questionnaire, for people we administered the questionnaires, two weeks was given to complete the questionnaires.

6.1 Review: In the course of this work, World Health Organisation guidelines, Federal Ministry of Health guidelines, professional protocols, and library materialswere reviewed and consulted. A survey was carried out to determine the level of practice and the use of algorithms in consultation and treatments in the selected primary health centers. This was very essential to enhance directions and results achievement for the proposed system. All these were done to get a better background in other to understand the system and process required.

6.2 Observation: Tangible facts and events about operational realities were carefully observed and noted. One day in a week per month was used to observe the clinical practice in the chosen PHCs A total of fifty days was used to observe in the ten PHCs. It was observed that the practice in all the PHCs was the same, a patients come to the clinic, gets his or her cards, moves to get the vital signs, and proceeds to the clinician who attends to them by asking questions and prescriptions are written for the patients, while some are sent to carry out laboratory test. It was observed that clinicians relied more on their experiences without consulting any reference materials.

6.3 Interviews: Individuals, groups, and primary health care clinicians were interviewed asking relevant questions that relate to their experience.This created room to have the views of modern trends required for the proposed system. Interview is a qualitative approach to data collection. We elicited relevant information from the staff of the medical centers who were mostly nurses and community health workers they had fair knowledge of and importance of software in health care. Structured interview questions were prepared for caregivers who were interested in giving responses. The table below is a list of caregivers who agreed to be administered interviews as part of our data collection. Also, unstructured, or informal questions were administered to explore data on personal or emotional issues regarding the topic. The electronic video was recorded conversation using a Samsung tablet and also captured verbatim statements and notes from other caregivers for later review. The entire system test, demo and interviews were conducted on appointments with the clinicians in their respective offices.

6.4 Questionnaire: To solicit information regarding improved interaction and improved quality of care, our aim and research objectives were broken down into 10 questions, prepared and distributed to the target users of the sample population. These questions cover the research aim and objectives. The questionnaires have different contents that must be looked out for carefully as most of them look similar. The questionnaire was prepared according to Likert-like scale to find answers to the various questions indicated.

To further guide our research objectives, the researcher included the first three questions as a support to enquire about the ease of use of the software by the users. Hence, the first three questions seek to know if the respondent can navigate the tool. The researcher also enquired about the perceived real-time interaction and participation of the patient by providing information that will aid in his diagnosis treatment and quality of care. It was meant to enquire if the system can enhance collaboration and knowledge sharing in healthcare. To investigate service delivery, and quality of care since the patient is attended to directly by the clinicians, questions were asked regarding the assessment of overall usability and ideas regarding user satisfaction, real-time experience, and future benefits of the new system, users were asked to freely give the assessment. Finally, we solicited candid opinions regarding quality tests. In a primary healthcare center, we have Junior Community Extension Workers (JCHEW),

Community Health Extension Workers (CHEW), Community Health Officers (CHO), Nurses, Midwives, and Doctors in some cases.
Table 1. shows the list of health workers that were involved in the interview.

TABLE 1
Respondents to the face-to-face interview

SN	Interviewee	Duration (Minutes)
1	CHO	10
2	CHO	20
3	CHO	15
4	CHEW	20
5	CHEW	60
6	JCHEW	60
7	JCHEW	15
8	JCHEW	29
9	JCHEW	30
10	CHEW	20

6.5 Focus Group Discussions at the end:
Focus group discussions were held with ten clinicians who had contributed to the development of the CDSS. The group considered the impact, strengths and weaknesses of the proposed model and provided views on the comparison of the available paper guides. A thematic analysis of the discussions found that they felt the CDSS contained the standard of care required, clearly defined their scope of practice and provided a uniform standard for diagnosing and treating patients, supporting them to deliver effective primary healthcare to their patients. Users reported that the CDSS will result in more appropriate requests for investigations and would help to identify a reduction in wrong prescriptions and polypharmacy, effects that may have significant resource implications for the health system. All ten clinicians indicated a clear preference for CDSS over the hard copy largely because of ease of use and acceptability to patients.

6.6 Sampling /Data Collection Method:
A total of 10 interviews were conducted on a one-to-one approach and respondent's opinions were captured with their permission, in most cases, notes were adequately taken with the best respondents' wordings and were used only for the research. The researcher scheduled various appointments with each of the interviewed staff listed in the TABLE. 1. The efforts made in reaching the respondents were mostly successful. However, we were able to capture the interview from various caregivers.

7 Data Analysis Method:
We started the analysis of the interview by writing down verbatim all the information captured during the interview with caregivers as well as the transcription of the electronic interview data.

These data were later transcribed in unambiguous words to serve as responses for our post-interview responses.
The data collected were analysed using Microsoft Excel formulas. The statistical analysis conducted included simple percentages standard deviation (SD), to measure the relationship between the clinical competency before using the software and the perceived improvement of quality of service in the selected PHCs. Out of about 100 questionnaires that were distributed only 80 were returned correctly filled, the rest were not returned as a result of work schedules, left blank or damaged. Correctly filled questionnaires were collected and the responses were screened for correctness and neatly kept to be the source of information and data analysis for the next stage.

7.1 Tabulation:

The questionnaire was captured and properly tabulated in Microsoft Excel 2016 to serve as the raw data for the various analyses. Each response to the question was tabulated according to respondent numbers 1 to 10 as it appears in the questionnaire.

The questions and their respective responses were tabulated in the Likert scale: strongly, available, neutral, not available, and strongly not available. The questionnaire also contains questions regarding the user response to the interactivity of the interfaces, ease of use, simplicity, and usability of the application whose responses are also tabulated as Likert scale: 5, 4, 3, 2 and each takes the values from very high to very low.

9. Discussion

CDSS offers a complementary service to existing policies of integrated healthcare management. This research has generated a CDSS capable of addressing important issues in primary healthcare management in emergency and non-emergency care. Diagnosis is done by the stratification of clinicians limiting users to the level of their training. The CDSS issues recommendations that have a high degree of accuracy to CHP in identifying emergencies and offers recommendations to stabilise the patient before referral, using rules which when satisfied suggest the stabilisation route before referral is made. Moreover, it has shown the simplicity of integration into healthcare providers' workflow which is demonstrated using a modular design and service-oriented architecture that connects to existing health systems and all primary care workers can work from the same platform.

Clinicaldecisionsupportstudiesinprimary healthcarehavelagged comparedwithotherhealthcarepracticessuch assurgery, and medicine.Inthiswork,wedeveloped aCDSS supportingdecision-makingduringpatientcarefor community healthcare workers andproposedasimpleframeworkcomprising a model for identifying emergency and non-emergency symptoms associated with fever, what to do if certain conditions are present, and what to do before a referral is done but it must be within the competence level of the caregiver. Additionalcomponents of the system include a knowledgerepositoryandreasoning system.

10Design

The design phase looked into specific implementation features of the architecture, interfaces, and algorithms that work together to achieve a user-friendly system for implementation.Itcontains a set of directions to assist healthcare practitioners with patient care decisions about appropriate diagnostic, therapeutic, or procedural steps to follow in specific clinical circumstances. The instructions are derived from systematically and periodically reviewing the literature, and updated or modified to best capture the most up-to-date evidence-based medical knowledge obtainedfrom WHO guides, BMJ evidence center, one of the biggest in the world, various Nigerian guides, and from the community health training guides for community health works regulatory board, etc. This CDSS is a standardised guide for the improvement of practice atthe primary health care level.

CDSS are often represented as flowcharts or algorithms,which theclinician can follow with decision branches based on clinical criteria. An example of a differential diagnosis of FEVER is shown in Figure 3.

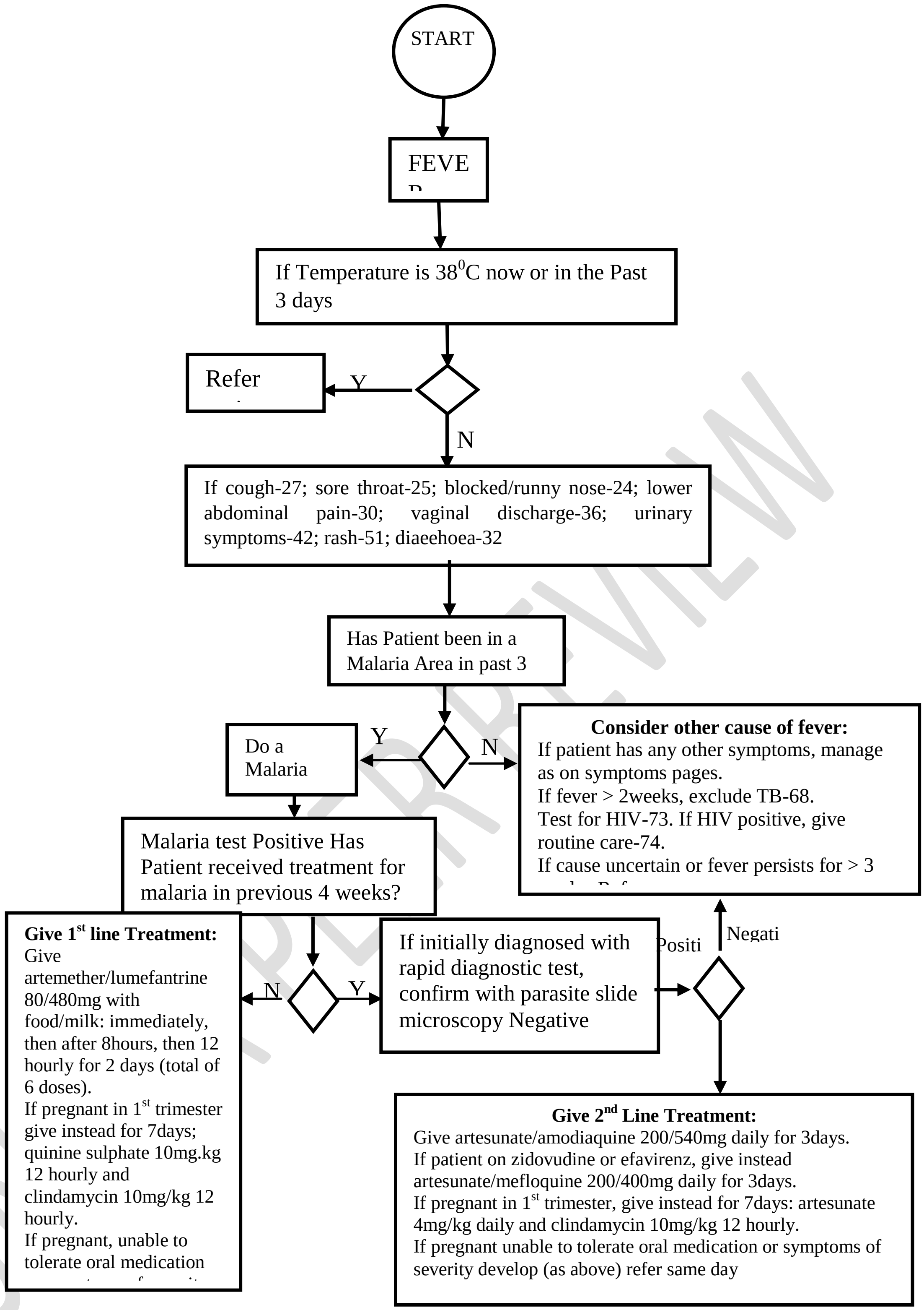

Fig 3. Study protocol

10.1 Architecture

The architectural design model illustrates how the system works. Consequently, the system allows input such as alphanumeric and alphabetical characters from clinicians. The business logic section of the system accepts the specific inputs from the users. Further processing such as diagnosing symptoms and recommending treatment plans for different symptoms is carried out by the logic module. Also, the proposed system consists of a repository that enables clinicians to update and retrieve vital information about patient health records. Finally, the display screen shows strict treatment plans to be carried out according to competence level.

10.2 The Architectural Framework

The architecture consists of components including a reasoning engine, knowledge base (KB) and, a computerised model that is made up of basic medical logic models and management systems.The human-computer interaction is the user interface of the clinical decision support systems and database system made up of data about clinical information/facts.

The KB consists of clinical algorithms and checklists that provide a comprehensive approach to adult care, covering common presenting symptoms, syndromes and chronic conditions. Boosted by evidence sourced from WHO Guidelines and BMJ Best Practice. This is to ensure comprehensive and encompassing clinical data for ease of use at the point of care. It has been adopted for use ensuring that it is aligned with local regulations, clinical protocols and available diagnostic tests, equipment and medications. These include the Nigerian Standing Orders for Community Health Officers and Community Health Extension Workers and the Nigerian Standing Orders for Junior Community Health Extension Workers, 2015 edition (Standing Orders, 2015). The human-computer interaction is the user interface of clinical decision support systems and database systems that contain clinical information about symptoms.

In figure 3the system architecture is laid out to conform to design objectives where the end-user is at the top layer, (interactions with system), the business layer (coding and processing activities) and the data services layer, where database functions were implemented.

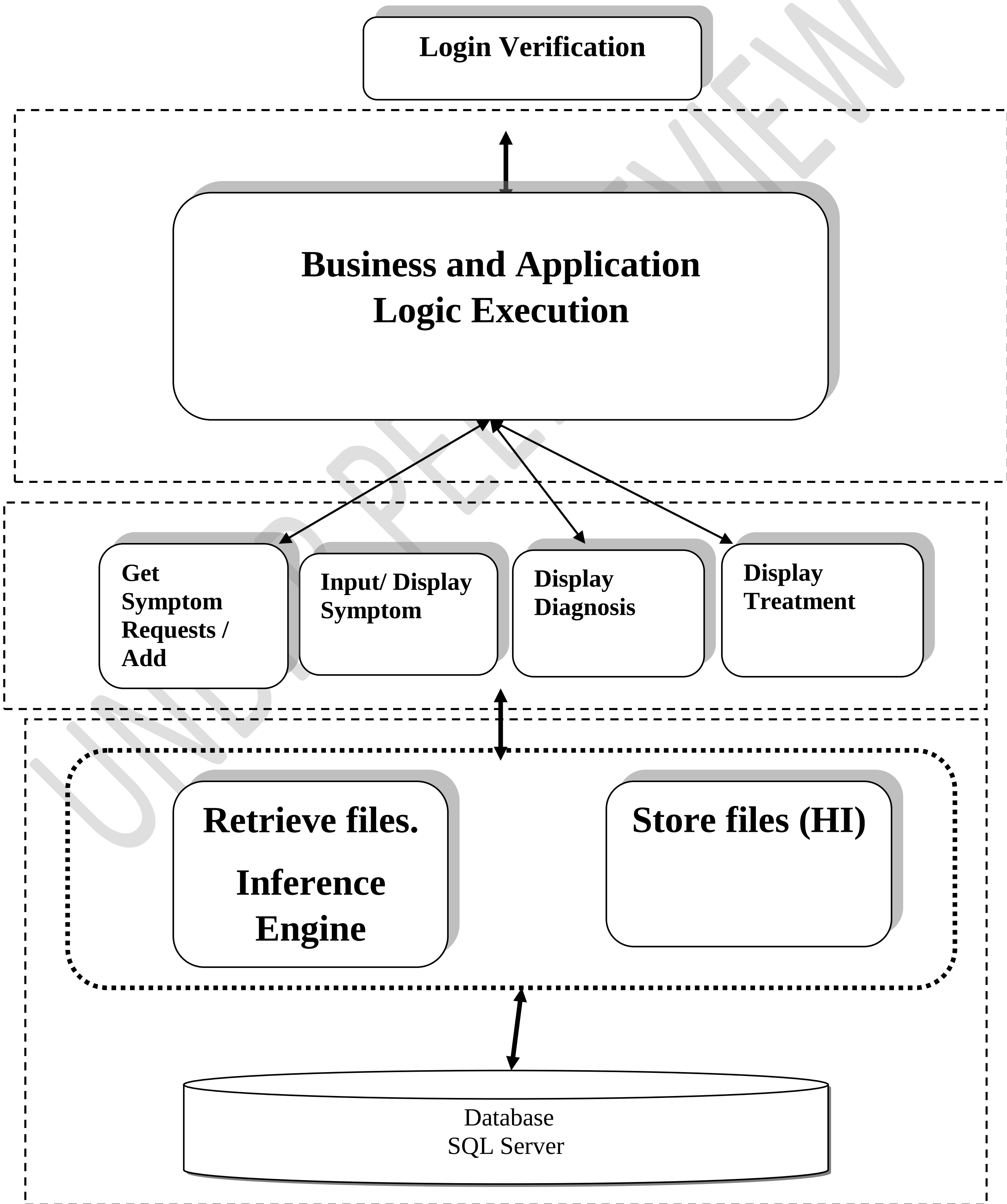
Login Verification
Business and Application Logic Execution
Get Symptom Requests / Add
Input/ Display Symptom
Display Diagnosis
Display Treatment
Retrieve files.
Inference Engine
Store files (HI)
Database
SQL Server

Fig 4. Login verification model

11. Model development

This phase is considered important because all the necessary interactions and logical flow of the system were developed. Medical care management involves a lot of uncertainties that would need to be resolved one way or another to have the desired outcome, this makes it difficult at the different stages of care.

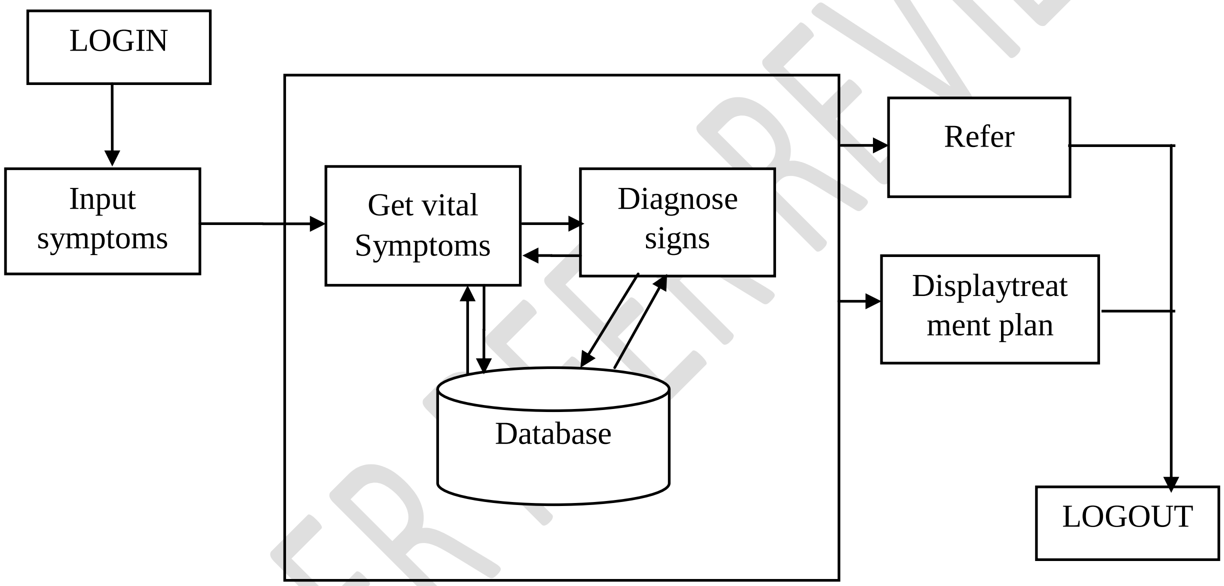

Fig 5. Model development

12 Data Analysis:

The interactions, observations, interviews, and questionnaires at the Medical center, with the healthcare workers enabled the development of the CDSS. Though the requirements gathering and elicitation process was tasking, it gave a better understanding of the process, which led to the accomplishment of the development of the CDSS that satisfied the objectives of the study. The health workers accepted that the model would enhance the process.

12.1 Findings from Interviews:

The narrative interview approach was used and the same sets of questions were administered separately to each respondent. The interview questions and responses from participants are summarised in Table 2. This enabled the researcher to assess the level of understanding and mindset of the participants regarding diagnosis, treatment of emergency cases, testing, and drug prescriptions. It also helped in determining the perception, acceptability, and willingness of participants to use the system.

Table 2: Summary of interviewees' Responses from primary health care providers

Interview Questions	Summary of responses
How do you attend to Emergencies?	Patients are referred to the next secondary or tertiary hospital.
Do you have internal referrals?	No
Do you stabilise patients before referral?	They do not stabilize before referral, it is beyond their scope of practice.
Would you like to stabilize the patient before referral if you are allowed to?	The participants said they would like to if asked to.
Have you used a computer system before?	Some participants had little knowledge and usage of computers. Some have not used a computer before but would be ready to learn. But are familiar with mobile phones and tablets
Do you think there would be any advantage to using CDSS?	The participants believed there would be advantages because of the support and available information for decisions on diagnoses and testing at the point of care.
Can you encourage the government to adopt the system?	YES. Participants recommend government should adopt CDSS. It would solve problems encountered in diagnosis and treatment and would scandalize practice.

Do you normally encounter some problems with the current referral treatment regime?	Participants said they experience some problems with diagnosis
Do you use any treatment guide	Yes
Do you follow the guide?	Sometimes. But Participants mostly rely on their experience.
Do you request for test before treatment	No
Do you give single drugs or multiple drugs	Treat with multiple drugs

The analyses of the CDSS system were carried out to achieve the main objective of the study which is improving and enhancing the diagnostic and treatment accuracy of Clinicians in the medical centre. The usability of the CDSS system was considered.

12.2 Findings from Questionnaires

A total of 50 clinicians across all 5 PHCs were trained on the use of the CDSS, with 90% of them completing all 10 sessions during the short testing period. Response from clinicians, managers and trainers from all 50 respondents was overwhelmingly positive. Clinicians consistently reported that they felt empowered and clear about their scope of practice and how they related to other cadres within primary care, which has encouraged multidisciplinary teamwork in the PHCs. CDSSwas widely praised for its ease of use and the confidence it brings to clinicians in the diagnosis and treatment of their patients: "Using the CDSSbuilds my confidence. There is no ambiguity, it's just straightforward. And it motivates my staff, my colleagues." This has translated into very high usage levels of CDSS: 73% of clinicians reported using CDSSin almost every consultation and 93% usedthe CDSS in the majority of their consultations during the three-month testing period. Clinicians reported that the CDSS improved their clinical knowledge and skills. Concerning clinical decision-making, the mean total test score beforethe CDSS was 2.5 and this increased by the end of the test period to a mean of 9.6, an improvement of 74.4%.

Conclusion

The CDSS represents a single, comprehensive tool, drawing on applicable national guidelines, integrating the roles of all cadres of clinicians at the primary healthcare level. Stakeholders engagement revealed that despite gaps, it enjoyed high levels of acceptance across cadres and was successfully implemented in all facilities, reflecting local clinicians' buy-in and need for user-friendly, up-to-date comprehensive clinical guidance responsive to their requirements.

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Ethical Approval:
The researcher studied and understood the risk involved in patient's private and confidential data, even though the research does not involve medical science procedures or obtaining samples and making medical contact with patients, we are still cautious of the stipulated rules by the ethical committee**.**

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