

# DEVELOPMENT OF A PROTOTYPE OF MALARIA CLINICAL DIAGNOSTIC DECISION SUPPORT SYSTEM

Sudarta Yabesman Harefa<sup>1</sup>, Lutfan Lazuardi<sup>2</sup>, Anis Fuad<sup>2</sup>

<sup>1</sup>Department of Health, Gunungsitoli city. <sup>2</sup> Department of Public Health, Faculty of Medicine, Universitas Gadjah Mada, Yogyakarta.

\*Corresponding author: [sudarta\\_yh@yahoo.co.id](mailto:sudarta_yh@yahoo.co.id)

## ABSTRACT

**Introduction :** Malaria is a public health problem that still causes mortality, particularly in high risk population. Kabupaten Nias is one of the malaria endemic areas. Malaria diagnosis is mainly determined according to physical examination, despite the fact that laboratory examination is the gold standard of malaria diagnosis. To help health workers in diagnosing malaria accurately, it is necessary to develop a decision support system for malaria diagnosis.

**Objectives:** To develop a prototype of malaria diagnostic decision support system.

**Methods:** It was a descriptive study with action research design to explore each phase in the development of a prototype of malaria diagnostic decision support system. Participants of the study consisted of 5 general practitioners in RSU Gunungsitoli and 2 nurses in Puskesmas Gunungsitoli.

**Results:** The study created an application model of computer-based malaria diagnostic decision support system designed using PHP programming language and MySQL database. This system worked by entering malaria clinical symptoms into the expert system, and data of symptoms were processed by the expert system to determine diagnosis and medical advice that was useful to assist health staff in making decision.

**Conclusion:** Malaria diagnostic decision support system that had been developed attracted the interest of health workers and help them in diagnosing malaria clinically.

**Keywords:** diagnostic decision support system, prototype, malaria, computer application, Gunungsitoli

## INTISARI

**Pendahuluan:** Malaria merupakan masalah kesehatan masyarakat yang masih menyebabkan kematian, terutama pada populasi risiko tinggi. Kabupaten Nias merupakan salah satu daerah endemik malaria. Di Nias, diagnosis malaria terutama ditentukan sesuai dengan pemeriksaan fisik, meskipun diketahui bahwa pemeriksaan laboratorium merupakan standar emas diagnosis malaria. Untuk membantu petugas kesehatan dalam mendiagnosis malaria secara akurat, diperlukan pengembangan suatu sistem pendukung keputusan untuk diagnosis malaria.

**Tujuan:** Untuk mengembangkan prototipe sistem pendukung keputusan diagnosis malaria.

**Metode:** Penelitian ini merupakan penelitian deskriptif yang diikuti dengan rancangan action research untuk mengeksplorasi setiap tahap dalam pengembangan prototipe sistem pendukung keputusan diagnosis malaria. Partisipan penelitian terdiri dari 5 dokter umum di RSU Gunungsitoli dan 2 perawat di Puskesmas Gunungsitoli.

**Hasil:** Penelitian ini menghasilkan sistem pendukung keputusan diagnosis malaria berbasis aplikasi komputer yang dirancang dengan menggunakan bahasa pemrograman PHP dan database MySQL. Sistem ini bekerja dengan memasukkan gejala malaria klinis ke dalam sistem pakar. Data gejala diproses oleh sistem pakar sehingga diperoleh diagnosis dan saran medis yang berguna untuk membantu petugas kesehatan dalam mengambil keputusan.

**Simpulan:** Prototipe sistem pendukung keputusan diagnosis malaria yang dikembangkan menarik minat tenaga kesehatan dan membantu mereka dalam mendiagnosis malaria klinis.

**Kata kunci:** sistem pendukung keputusan diagnosis, prototype, malaria, aplikasi komputer, Gunungsitoli

## INTRODUCTION

Malaria has been one of the public health problems which causes mortality, particularly in high-risk population and also decreases work productivity<sup>1</sup>. One of malaria endemic areas is Kabupaten Nias, situated in Pulau Nias, which is around 85 miles from Sibolga (Sumatera Utara). Kabupaten Nias is an area of 27 small islands. The area of Kabupaten Nias is 3,495.39 km<sup>2</sup> (4.88% of Sumatera Utara area), parallel to and situated in the west of Sumatera, and surrounded by Indonesian Ocean. Based on geographic location, Kabupaten Nias is situated at 0°12'-1°32' NL and 97°-98° EL, near the equator, causing high annual rainfall. In 2005, the rainfall was 2,805 mm per year, or on average of 234 mm per month, with 246 rainy days in a year or on average 21 rainy days per month, and sun illumination was on average 53% per month. The highest rainfall was in October (595 mm), with 30 rainy days and sun illumination of 39%. Dry and rainy seasons alternate in a year. Lowest rainfall and total rainy days was in February (52 mm and 14 rainy days, with sun illumination of 61%). Yearly high rainfall causes Kabupaten Nias to be very humid and wet, with average humidity between 89-92%, and it frequently had flood<sup>2</sup>.

Malaria is one the infectious diseases which is anticipated to be emerged after the tsunami. After tectonic earthquake and tsunami in Pulau Nias, another earthquake ensued. The considerable life lost and the migration of the population have caused the change in population and social and economic condition, resulted in the increased risk to be infected. The change in physical environment causing a conducive environment for the growth of vector of diseases also increased the risk to be infected by infectious diseases. Health care was not provided in optimum level, because earthquake and tsunami had caused the loss of infrastructure and human resources<sup>3</sup>. In 2004 and 2005, AMI in Kabupaten

Nias was 85.78‰ and 52.03‰, respectively. Although the number has decreased, it was still included in High Incidence Area (HIA). In 2006 and 2007, AMI of Kabupaten Nias was 42.08‰ and 41.13‰, respectively, which included in Medium Incidence Area (MIA).

In December 2005, Health Office of Sumatera Utara Province together with Health Office of Kabupaten Nias conducted basic Malariometric Survey on 0-9 years old children in 7 villages in 3 areas of Puskesmas. Result showed that the Parasite Rate (PR) of 2-9 years old children was 7.84-59.8%. Species of parasites found in the survey were *P. falciparum* and *P. vivax*, with *P. falciparum* as the dominant species. PR value of 0.9 meant that all surveyed villages were included in HPA (High Prevalence Area). Confirmed vectors of malaria in Sumatera Utara were *Anopheles kocki*, *Anopheles sundaicus*, and *Anopheles tessellatus*, while potential/suspected vectors were *Anopheles maculatus*, *Anopheles nigerrimus*, and *Anopheles umbrosus* (Namru's document). *Anopheles sundaicus* was reported to have breeding site in freshwater, while generally this vector chose brackish water as its breeding site<sup>3</sup>.

Malaria was included in the 10 most common diseases in the patients of Rumah Sakit Umum (RSU) Gunungsitoli in 2006-2007. Based on the result of a study on clinical behavior of health providers about the management of malaria in RSU Gunungsitoli, Kabupaten Nias, it is concluded that clinical behavior of health providers was less supportive to the management and treatment of malaria in RSU Gunungsitoli<sup>4</sup>. It could be observed in the establishment of malaria diagnosis. Some health providers said that when the patient history and clinical symptoms had lead to malaria, antimalarial drugs could be given to the patients. However, there were several health providers who suggested that laboratory examination to establish malaria diagnosis had

to be conducted, although the patients history and clinical symptoms had supported the diagnosis of malaria. There was also a difference in the response between health providers and the result of laboratory examination. It resulted in the treatment of malaria patients tended to follow the inclination of the health provider, and not based on the available standard treatment.

Clinical behavior of health providers which not supportive to the management and treatment of malaria in RSU Gunungsitoli was caused by predisposing, enabling, and reinforcing factors. Result of a study showed that from predisposing factor, health providers in RS Gunungsitoli were not included in training about malaria yet, and it was difficult to find opportunity to join any training. From the aspect of enabling factor, it showed that Standard Operating Procedure (SOP) of malaria was not available in RSU Gunungsitoli, therefore, in managing malaria, health providers only based on books and their experience while managing malaria cases. From the aspect of reinforcing factor, it was known that there was the lack of appreciation and reward from RS Gunungsitoli for their health providers over their work load. Result of a study by Hulu suggested that the prevalence of medical errors in the management of malaria in RSU Gunungsitoli in May 2007 was very high, where medical errors related with the management of malaria was 1.87 times per patient, consisted of diagnosis error in 80 patients (86.96%), treatment error in 92 patients (100%), error of omission in 35 patients (38.04%), and error of commission in 149 patients (161.96%)<sup>5</sup>. Clinical behavior of health providers such as frequently giving antimalarial drugs to the patients without laboratory examination might cause resistance. Report on resistance to the previous antimalarial drugs (for example, chloroquine, sulphadoxine, pyrimethamine, and quinine) in the last decade had become a concern, affecting more than 25%

of the provinces in Indonesia<sup>6</sup>. Effort to decrease the morbidity and mortality rates was conducted through malaria eradication program, which activities included early diagnosis, quick and appropriate treatment, surveillance and control of the vector, which aimed to cut the malaria transmission link. Malaria diagnosis is established based on history taking, physical examination, and laboratory examination. Definitive diagnosis of malaria has to be established by blood microscopic examination or rapid diagnostic test. Early diagnosis of malaria is conducted by history taking and physical examination by identifying clinical symptoms in malaria patients<sup>1</sup>.

This study was conducted with the objective to identify the user's need of prototype of malaria diagnostic decision support system, develop a prototype of malaria diagnostic decision support system, and evaluate the user acceptance of the prototype of malaria diagnostic decision support system.

## **MATERIALS AND METHODS**

This study is a descriptive study with action research design to explore each phase of the development of the prototype of malaria diagnostic decision support system. Total participants in this study were 5 general practitioners in RSU Gunungsitoli and 2 nurses in Puskesmas Gunungsitoli Nias. Samples were taken by purposive sampling. General practitioners were chosen as subjects because they had direct contact with the patients in establishing diagnosis in Puskesmas, while nurses were chosen as subjects because they were establishing diagnosis in Puskesmas in certain conditions. Therefore, in these participants, their needs were identified and their acceptance to the prototype of malaria diagnostic decision support system were evaluated.

The variables of this study were: (a) Clinical malaria, is an infectious disease suffered by a patient who experiences the clinical symptoms of malaria, (b) Malaria diagnosis, is diagnosis established based on clinical symptoms of malaria which experienced by a patient, (c) Malaria treatment, is treatment given to malaria patients with the objective to eradicate all the parasites in the human body, (d) Needs identification, is a stage in identifying problems associated with the needs of the development of a prototype, (e) Prototype design, is a stage to analyze the system appearance and how the system solve the problems, design to determine the aspects (segments) which included in the prototype, and the rules to be used, development process of knowledge base, pilot test, reviewing, and continuing improvement, (f) Implementation, is a stage when the prototype has been tested and improved and received suggestions from the users since the start of application until usage.

Main instrument used in this study was the researcher (human instrument), supported by guideline of indepth interview, recording device (MP4 player), digital camera, computer, and software with operating system Windows/Linux, PHP programming language, and MySQL database.

The study was conducted according to the prototyping approach, with steps as follows: 1. Identify main problems underlying the development of prototype associated with malaria diagnosis, 2. Analyze and design the malaria diagnostic decision support system, 3. Build a prototype of the malaria diagnostic decision support system based on standard management of malaria in Indonesia and the result of indepth interview with the general practitioners and nurses, 4. Evaluate the user acceptance of the prototype of malaria diagnostic decision support system, and 5. Complete the prototype based on the suggestions of users/

participants in prototype trial. This study had received approval from Gadjah Mada University, Director of RSUD Gunungsitoli Nias, and the Head of Puskesmas Gunungsitoli.

## RESULTS AND DISCUSSIONS

RSU Gunungsitoli is a type C (non-education) hospital and the property of government of Kabupaten Nias, with 206 civil workers and 191 non-permanent staff. RSUD Gunungsitoli has outpatient units (specialist polyclinics: internal medicine, surgery, obstetry, dentistry and pediatric polyclinic), inpatient units (internal medicine inpatient unit, surgery inpatient unit, pediatric inpatient unit, obstetry/postnatal unit, and ICU) with total capacity of 105 beds, consisted of 80% class III and 20% class II.

Study was also conducted in Puskesmas Gunungsitoli, one of the technical units of Health Office in Kabupaten Nias, which situated in Kecamatan Gunungsitoli. Puskesmas Gunungsitoli has 11 Puskesmas pembantu (Pustu) which distributed in several villages. Recently, it also has inpatient unit, with 88 staffs.

### 1. Initialization

Initialization phase was the first step in the development of expert system. The objective was to identify the problems and prepare for the next step in the development of prototype of malaria diagnostic decision support system. Based on medical record data of patients in RSUD Gunungsitoli, total malaria cases in January and February 2009 was 52, consisted of 38 cases in January 2009 and 14 cases in February 2009. Total patients who were diagnosed as malaria and treated with drugs, but never had laboratory examinations, were 16 (30.77%), while those with laboratory examination were 36 (69.23%) patients. RSUD Gunungsitoli Nias and

Puskesmas Gunungsitoli did not have SOP to manage malaria, therefore, there was no specific guideline for management of malaria.

*"...mmmmm, kalau di rumah sakit kita belum ada protap resmi atau SOP, dokter biasanya memberikan terapi berdasarkan pengalamannya..."*

(Participant 2)

*"...mmmmm, in our hospital, there are no official prototypes or SOPs, doctors usually give treatment based on their experience..."*

(Participant 2)

*"...gimana ya dek, standaryang ada ya standar nasional dari Depkes, kalau dari puskesmas tidak ada. Puskesmas belum membuatnya secara khusus. Ini pun punya saya yang dari Depkes. Jadi, penjabarannya sesuai kondisi di sini belum ada. Itulah dek kondisi di Puskesmas kita ini"*

(Participant 5)

*"... well, available standard is the one from MoH, there are no standards from Puskesmas. Puskesmas did not develop it specifically. What I have here is the one from MoH. Therefore, there is no explanation which adjusted to the condition here. That is the condition of this Puskesmas."*

(Participant 5)

This is not consistent with the recommendation of MoH, which one of the efforts is to achieve quality-safety, by preventing the medical errors by using hospital service standard, which is described in SOP and appropriate with the situation and condition of the hospital<sup>7</sup>.

Based on in depth interview conducted on participants to identify the needs of the users, the steps obtained to establish diagnosis of malaria were history taking, physical examination, and for definitive diagnosis, blood examination, like

the description of participant as follows:

*"Ya...Kita secara umum.. ya kalau itu sudah prosedur yang baku seorang dokter itu pasti pertama dulu ya menanyakan keluhan-keluhan pasiennya apa, yang berkaitan dengan gejala-gejala malaria. Kemudian setelah dianamnesis, ditanyakankeluhannyaapa, lalu diperiksafisiknya. Adakah tanda-tanda yang mengarah ke penyakit malaria. Kalau masih kira-kira ada keraguan dan untuk mendiagnosis secara pasti, ya kita biasanya periksakan darah di laboratorium, baru kita bisa mengambil kesimpulan, mendignosis malaria atau tidak".*

(Participant 2)

*"Well, generally .. it is a standard procedure when doctors first ask for the complaints from the patients, associated with malaria symptoms. After history taking, they asked for the complaints, and then they had physical examination, if there are any signs lead to malaria. When there is doubt, and to establish definitive diagnosis, we usually do laboratory examination, and after that, we can make a conclusion, whether it is malaria or not".*

(Participant 2)

*"...Biasanya kan kita anamnesis dulu, ditanyakan keluhan pasien saat berobat terutama untuk malaria, kemudian diperiksa keadaan fisiknya, dan untuk faktor penunjang dilakukan pemeriksaan pasien".*

(Participant 1)

*"...We usually take the patient history, and then we ask the patient complaints when they come to visit for malaria, and they have physical examination, and for investigational examination, patient was examined".*

(Participant 1)

This is consistent with the guideline for management of malaria cases in Indonesia which recommends that malaria diagnosis is established like the other diseases, based on history taking, physical examination, and laboratory examination.<sup>1</sup> Clinical symptoms to establish diagnosis of malaria based on indepth interview with all participants, were fever, shivering (feeling cold, particularly on the hand and feet), sweating, headache, body (joints) ache, dizzy, muscle ache, nausea, and vomiting.

*"..secara klinis gejala-gejala malaria itu biasanya demam disertai menggigil, adanya keluhan sakit kepala, adanya mual dan pusing. Secara khusus pengalaman saya kalau anak-anak yang berobat dengan gejala demam dan menggigil setelah dicek darah hampir sebagian besar malaria. Jadi bisa dikatakan gejala klinis yang khasnya malaria itu ya demam dan menggigil."*

(Participant 3)

*"..clinically, malaria symptoms are usually fever and shivering, headache, nausea, and dizzy. In my experience, when children come to visit with symptoms of fever and shivering, after their blood were examined, they mostly had malaria. So, the characteristic symptoms of malaria are fever and shivering."*

(Participant 3)

*"..kalau pengalaman saya pasien yang berobat biasanya gejala klinis yang didapat itu seperti demam, menggigil, berkeringat, sakit kepala, sakit seluruh tubuh, atau sakit di sendi-sendi tubuh."*

(Participant 1)

*"..in my experience, the symptoms of the patients usually are fever, shivering, sweating, headache, whole body ache, or joint ache"*

(Participant 1)

*"...ya...biasanya anak disertai dengan menggigil, sakit semua sendi badan, pegal, muntah, panas dingin atau menggigil yang paling penting."*

(Participant 4)

*"...well...usually the children are shivering, feeling ache in their whole body, muscle ache, vomiting, feeling hot and cold or shivering is the most important symptom."*

(Participant 4)

Clinical symptoms obtained from medical records of patients in Gunungsitoli were fever, shivering, sweating, convulsion, nausea, vomiting, diarrhea, malaise, and sunken eyes. Laboratory examination is the main requirement to establish definitive diagnosis of malaria. All participants agreed on this. Patients with clinical symptoms of malaria were directed to examine their blood in laboratory first, so that the definitive diagnosis could be established, whether the patients had malaria or other diseases. However, in practice, not all patients with clinical symptoms of malaria had laboratory examination before treatment. This was caused by several factors, because sometimes the laboratory examination needed time and more cost, patient who could not bear the pain, the long distance of patient's house, the request (demand) of the patient, and the absence of the staff who were ill.

*"...kalau di rumah sakit dengan adanya fasilitas laboratorium, seharusnya standar sebelum menegakkan diagnosis dan memberikan terapi sebaiknya diperiksa terlebih dahulu laboratoriumnya. Bila memungkinkan, begitu pasien datang diarahkan pemeriksaan lab, karena itu lebih memastikan diagnosisnya Kadang-kadang pemeriksaan lab di Nias butuh waktu*



*lama, kadang-kadang pasien juga tidak sabar, kalau kondisi seperti itu kita terapi berdasarkan gejala klinis aja."*

(Participant 4)

"...when you are in a hospital with laboratorum facility, the standard before establishing diagnosis and giving treatment is laboratory examination. If it is possible, when patient comes, he is directed to the laboratory, to confirm the diagnosis. Sometimes laboratory examination in Nias needs a long time, sometimes the patients are impatient, when this situation occurs, we give treatment based on clinical symptoms only."

(Participant 4)

"...ya itu penting sekali memeriksakan darah pasien di laboratorum untuk menegakkan diagnosis pastinya. Namun dek, ada pasien yang tidak sabar menunggu karena pasien di rumah sakit kita kadang-kadang ada yang datang dari jauh, desa. Atas permintaan pasien tersebut kita langsung memberikan terapi tanpa diperiksa labnya terlebih dahulu."

(Participant 3)

"...yes, it's very important to examine the patient's blood in the laboratory to establish definitive diagnosis. However, sometimes patients can not wait, because sometimes they come from distant villages. At patient request, we give treatment without previously had laboratory examination."

(Participant 3)

"...pemeriksaan laboratorum itu penting dan sudah menjadi syarat utama untuk menegakkan diagnosis pasti malaria. Tapi dek, pengalaman saya kalau mendesak untuk diobati dan sudah yakin sekali, langsung diobati. Kalau masih ragu baru diperiksa labnya."

(Participant 1)

"...laboratory examination is important and has been the main requirement to establish the definitive diagnosis of malaria. However, in my experience, when the condition demands us to give treatments, and we already very certain, we give treatment immediately. When we are in doubt, we asked the patient to have laboratory examination."

(Participant 1)

"...karena banyak pasien yang kondisi ekonominya lemah, masalah biaya, jarak, dan waktu dek. Kadang juga kalau petugasnya sakit, tidak bisa datang ke puskesmas kita ini. Makanya kadang pasien tidak diperiksa dulu labnya. Tapi, saya langsung kasih terapi...Kalau menurut saya pemeriksaan lab itu sangat penting. Tetapi ya pertimbangan--pertimbangan itu tadi makanya kadang kala kami di sini tidak melakukan pemeriksaan darah pasien."

(Participant 5)

"...because there are many patients with low social and economic status, it is the problem of cost, distance, and time. Sometimes the health provider is ill, so that he/she can not come to Puskesmas. Therefore, sometimes patient don't have laboratory examination. However, I give the treatment immediately.... According to me, laboratory examination is very important. But these considerations cause us not to ask for laboratory examination."

(Participant 5)

Treatment for patients with malaria in Nias was by giving drugs such as chloroquine, sulphadoxine, quinine, and Fansidar.

"...kalau saya biasanya pakai kloroquin, Fansidar, sulfadoxin untuk obat malaria."

*Chloroquin berdasarkan pengalaman saya masih manjur kok di pulau kita Nias."*

(Participant 3)

"...I usually use chloroquine, Fansidar, sulphadoxine for malaria. Based on my experience, chloroquine is still sensitive in Nias."

(Participant 3)

*"...ya, obat yang umum aja saya berikan ke pasien. Chloroquin, Fansidar, sulfadoxin, dan pil kina. Tapi pil kina sudah jarang dipakai. Biasanya salah satu aja dari obat itu dipakai bisa sembuh kok."*

(Participant 2)

"...well, I give the usual drugs to the patient. Chloroquine, Fansidar, sulphadoxine, and quinine. But quinine is seldom used. Usually one

of the drug can bring cure to the patient."

(Participant 2)

## 2. Building the Prototype

After indepth interview to the participants to indentify the need of the users associated with the development of malaria diagnostic decision support system, system analysis and design to estimate the system functionality was conducted. Researcher tried to give general idea on the appearance of the system and how the system solved the problems.

### a. Design the DFD (Data Flow Diagram)

DFD is system design tool oriented on data flow with decomposition concept, used to describe the analysis and design of system which easily communicated by system proffesionals to the users and programmer. DFD level 0 in this system design is shown in Figure 1.

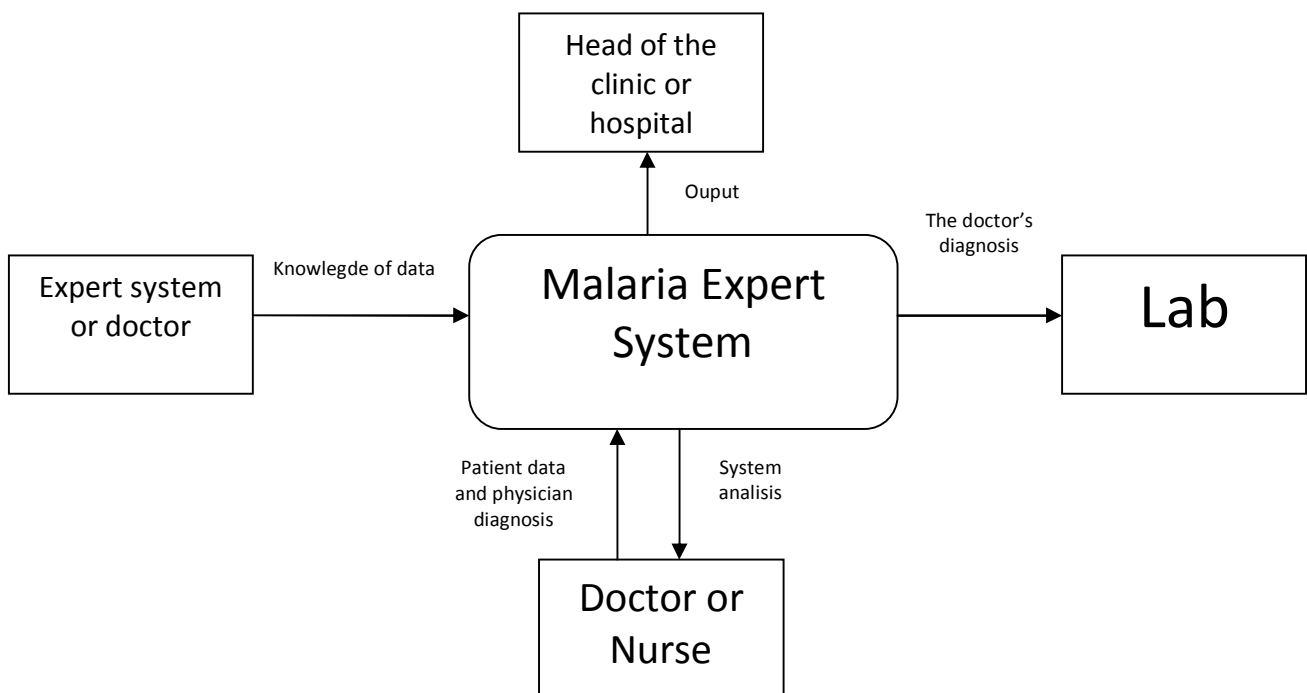


Figure 1. Data Flow Diagram (DFD) level 0 of the prototype of malaria diagnostic decision support system



b. Design the Entity Relationship Diagram (ERD)

Entity relationship diagram shows the relationship between entities (an item data unit which explains an object), and the relationship type. With this entity relationship, all data will be incorporated in one integrated unit (Figure 2).

c. List of diagnostic rules

Diagnostic rules were derived from the experts, previous study results, and scientific literature. Previous study on the development of algorithm for malaria diagnosis was based on clinical symptoms with blood examination of patients with suspected malaria in

Kabupaten Nias<sup>7</sup>. This study was aimed to find out the specific symptoms found in patients who suffered from malaria and dominant parasites found in Kabupaten Nias, and develop algorithm of malaria diagnosis as the reference to determine malaria cases. Subjects of the study were one laboratory staff of Health Office in Kabupaten Nias, one staff in Polyclinic in Puskesmas, one staff who obtained blood samples in Puskesmas, and 50 patients with symptoms of malaria in August until October 2007 who visited Puskesmas Awa'ai. The result of the study is shown in Table 2<sup>8</sup>. Data analysis of the study was

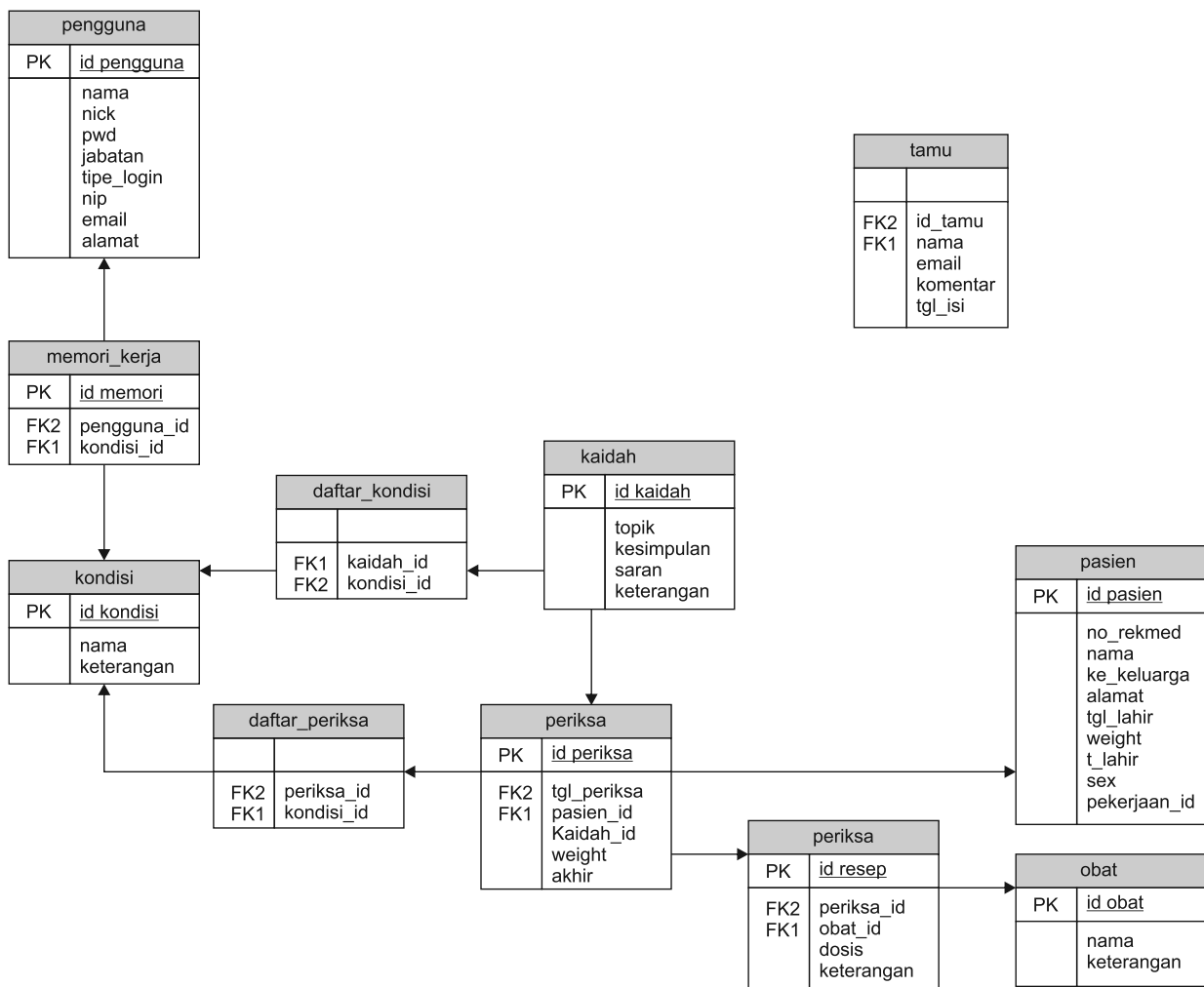


Figure 2. Entity Relationship Diagram (ERD) design for the prototype of malaria diagnostic decision support system

Table 1. Clinical symptoms in patients with clinical and microscopic diagnosis of malaria

Symptom	Clinical Diagnosis (n = 47)	Microscopic Diagnosis (n = 3)
Shivering	0 (0%)	2 (66.7%)
Headache	34 (72.3%)	1 (33.3%)
Sweating	13 (27.7%)	0 (0%)
Malaise	20 (42.6%)	2 (66.7%)
Nausea	1 (2.1%)	3 (100%)
Convulsion	0 (0%)	1 (33.3%)
Diarrhea	0 (0%)	1 (33.3%)
Lazy	9 (19.1%)	2 (66.7%)
Decreased appetite	3 (6.4%)	1 (33.3%)

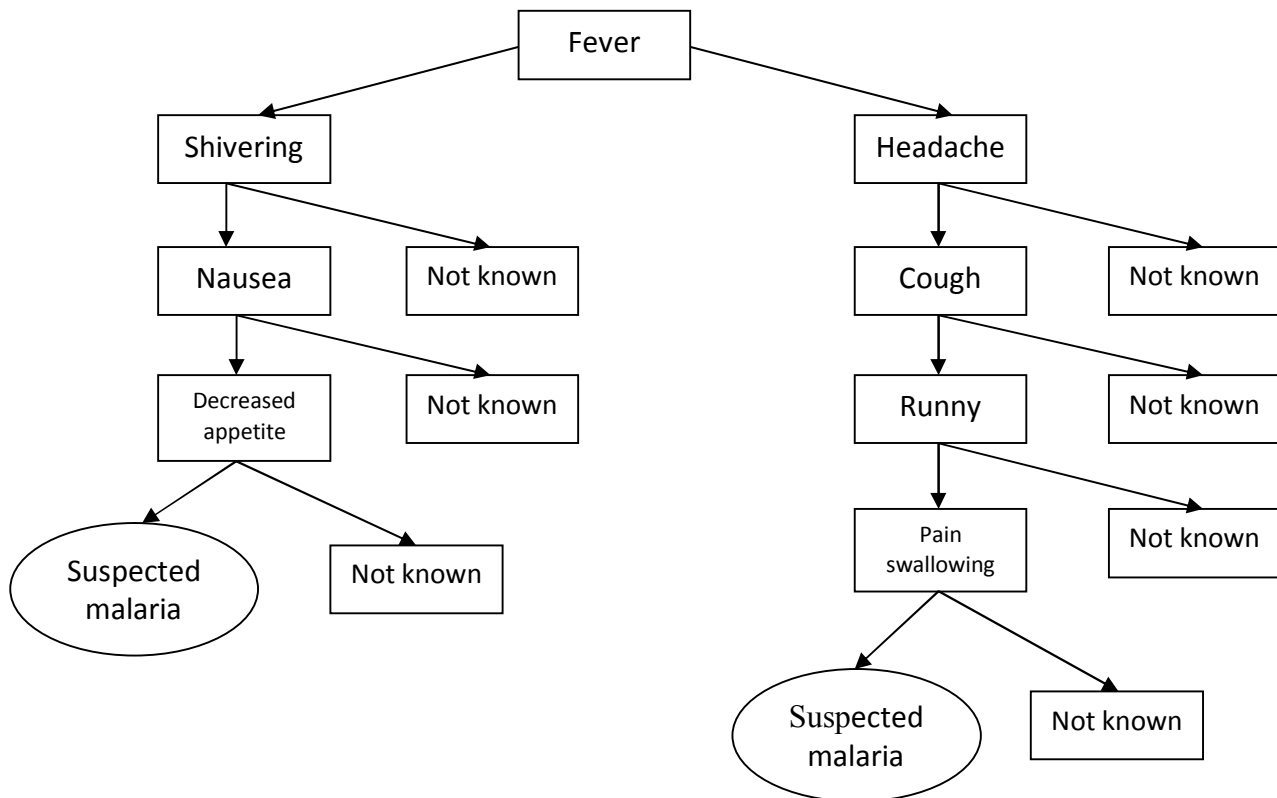


Figure 3. Decision tree in malaria diagnostic decision support system

conducted by testing the probability of malaria before the analysis of symptoms, calculating the sensitivity and specificity of symptoms to count the likelihood ratio, and calculating the probability of malaria after the analysis of symptoms<sup>8</sup>. The study concluded that algorithm of clinical

malaria were fever, shivering, nausea, and decreased appetite. Based on the interview result, they suggested that based on their experience, characteristic clinical symptoms of malaria were fever and shivering (Figure 3).

d. Design of appearance

Design of appearance of malaria diagnostic decision support system was as follows:

1). Login menu. Experts and users had to login first before filling the input of knowledge into the system or conducting consultation. When there was a mistake, the experts or users could not access the system. Design of appearance of login menu is shown in Figure 4.

2). Home menu

Home menu was the first page seen by the users. This page provided links to other available menus, consisted of gallery, profile, logout, login, guestbook, consultation, treatment, expert menu, report, setting, and help. Main page of the web had appearance as shown in Figure 5.



Figure 4. Login menu in malaria diagnostic decision support system



Figure 5. Home menu in malaria diagnostic decision support system

3). Guestbook menu

Guestbook form was functioned to monitor the visitors and gave users the opportunity to gave suggestions for the improvement of appearance and content of this malaria diagnostic application. Data and suggestions from visitors would be saved in this guestbook form. The appearance of guestbook menu is shown in Figure 6.

4). Consultation menu

In consultation menu, users might ask for consultation about malaria by entering patient data and clinical symptoms. Expert system would analyze the symptoms entered, and gave medical advice. The appearance of consultation menu is shown in Figure 7.



Figure 6. Guestbook menu in malaria diagnostic decision support system



Figure 7. Consultation menu in malaria diagnostic decision support system



Figure 8. Diagnosis result menu in malaria diagnostic decision support system

- Final diagnosis menu. In this final diagnosis menu, list of drugs used could be entered and in this feature, doctors would display in detail the identity of the patients to facilitate the medical provider to consider the drugs and the doses given to patients. Treatment menu appearance can be seen in Figure 9.
- Expert menu. In expert menu, there were features such as diagnosis data,

symptom data, update knowledge, and identity data of the expert. Diagnosis data were functioned as the location to name the diagnosis and to give medical advice after the analysis of symptoms were entered. Symptoms associated with malaria were input into symptom data. To change or update the knowledge on malaria symptoms, Update knowledge menu could be used. Identity data of

the expert contained the names of the experts (health providers) who became participants for interview in the study of this malaria diagnostic decision support system. The appearance of several features in expert menu is shown in Figure 10.

7). Report menu. Report menu showed patient data based on age and patient daily visit data, so that the daily total patients and general data of the patients, or yearly patient data based on age could be shown. The appearance of report menu can be seen in Figure 11.



Figure 9. Final diagnosis menu in malaria diagnostic decision support system

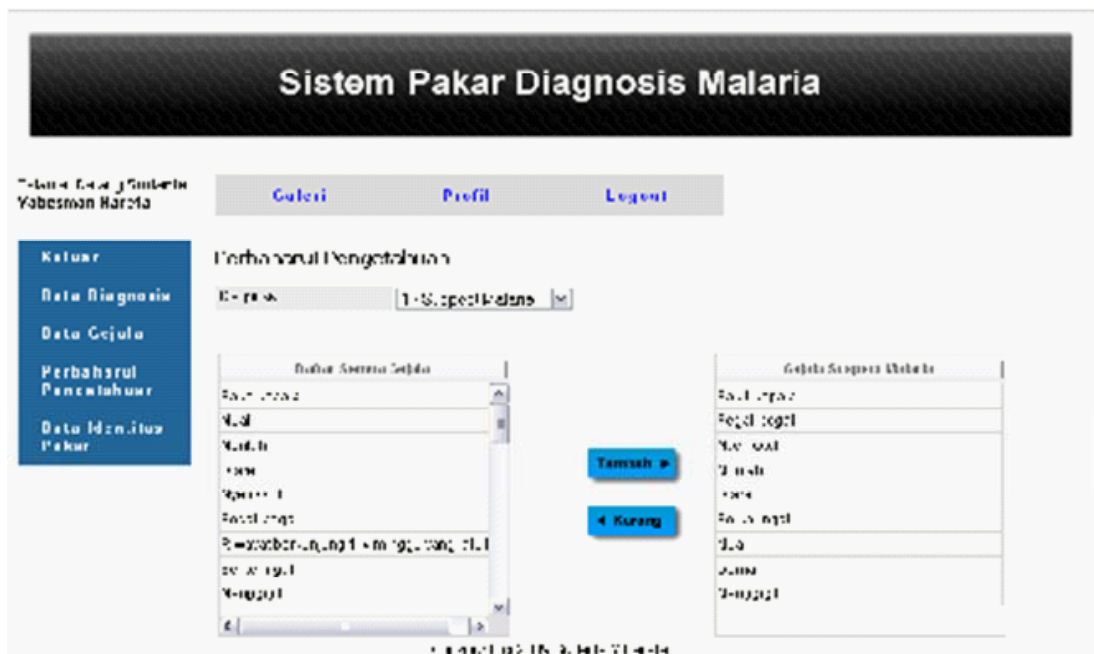


Figure 10. Update knowledge menu in malaria diagnostic decision support system





were not capable to operate notebook. This was because in their daily work, they used computer only once in awhile, therefore, researcher explained first how to use the notebook. It was different with the doctors, who were already used to the notebook, so they did not need any explanation on how to operate notebook.

*"...jaman sekarang sudah enak ya dek, banyak laptop, kalau jaman kami dulu sekolah masih mesin tik.he.he.he...di kantor inilah saya baru belajar komputer, itu pun cuma dikit-dikit bisanya. Kalau laptop kayak yang kamu bawa ini belum pernah saya pake, makanya saya tadi bingung tombol--tombolnya dikit beda tempatnya.he.he.he..."* (Participant 6)

*"...now it's convenient, isn't it, there are laptops everywhere, when we were in school, we still used typewriters... ha.. ha... ha... I only learned about computer in this office, and I know it very little. I never used this laptop, so I am kind of confused because the buttons have rather different locations ha..ha...ha..."* (Participant 6)

*"...ternyata sama aja cara menggunakan laptop dengan komputer biasa ya dek, maklumlah di puskesmas kita ini cuma ada komputer biasa..."* (Participant 7)

*"...it turns out the use of laptop is similar with the use of general computer, isn't it, you have to understand we only have desktop computer in this Puskesmas..."* (Participant 7)

After given explanation on how to use the application, they finally were able to use it smoothly. This trial had attracted the interest of the nurses and doctor and encouraged them to know more of all menu available in the prototype of malaria diagnostic decision support system. Result of indepth interview on the appearance

showed that there were several suggestions, as shown below:

*"..yaaaaaaaaa,secaragumdektampilannya menarik, mmmm...tetapi perlu di tambahkan variasi warnanya, mungkin dengan latar biru atau hijau, jangan putihlah dek..."* (Participant 7)

*"..well, generally the appearance is interesting, mmm... but it needs more variations in colors, probably with blue or green background, not white only..."* (Participant 7)

After trying the consultation menu in this expert system, there were suggestion from the nurses and doctor, so that in general data menu of the patient, the body weight was added, which would be useful in the determination of patient dosage, as mentioned below:

*"...itu lho dek, data berat badan pasiennya belum ada, karena biasanya saya dalam menentukan pasien terutama anak-anak, harus melihat berat badannya..."* (Participant 5)

*"...you know, patient's body weight data is not available, I usually use the body weight for determining the dosage for patients, particularly children..."* (Participant 5)

*"...ada satu lagi dek yang perlu kamu tambahkan pada identitas pasien, biasanya kalau saya ngasih obat untuk anak-anak, selain melihat umurnya, saya juga melihat berat badannya, biar tidak kelebihan dosis nantinya.."* (Participant 7)

*"...one more thing that you need to add in the patient identity, I usually give treatment to children based on their age and their body weight, so that there will be no overdose..."*

(Participant 7)

Generally, participants commented that the application was easily adopted by people who were not capable to use notebook. Prototype developed was easily understood by participants, because all available menus in this expert system were in Indonesian language. Participants also agreed that this prototype might help them reminding the symptoms associated with malaria, and helping them in diagnosis of malaria, and then following the medical advice given by the expert system.

“...mm, ternyata setelah dicoba-coba tidak sulit kali menggunakan aplikasi ini ya. Kalau boleh jangan hanya khusus malaria aja dek, penyakit-penyakit yang lain juga. Tapi itu kan tergantung

kemauan adek. Soalnya, ini bisa mengingatkan kembali gejala-gejala suatu penyakit. Saya sendiri kan dah lama tidak baca-baca buku, ya kalau pake aplikasi ini kan bisa sekalian maen komputer.he..he...” (Participant 6)

“...mm, after trying, it’s not so difficult to use this application. If it’s possible, the application is made not only for malaria, but also for other diseases. But of course it depends on your will. This can remind us of the symptoms of a disease. I haven’t read books so long, and when I use this application, I can play with computer also, ha.. ha...” (Participant 6)

“...untung aplikasi ini make bahasa Indonesia, jadi tidak susah kali lah mempelajarinya. Kalau pake bahasa Inggris tadi baru saya tidak mengerti dek...” (Participant 7)

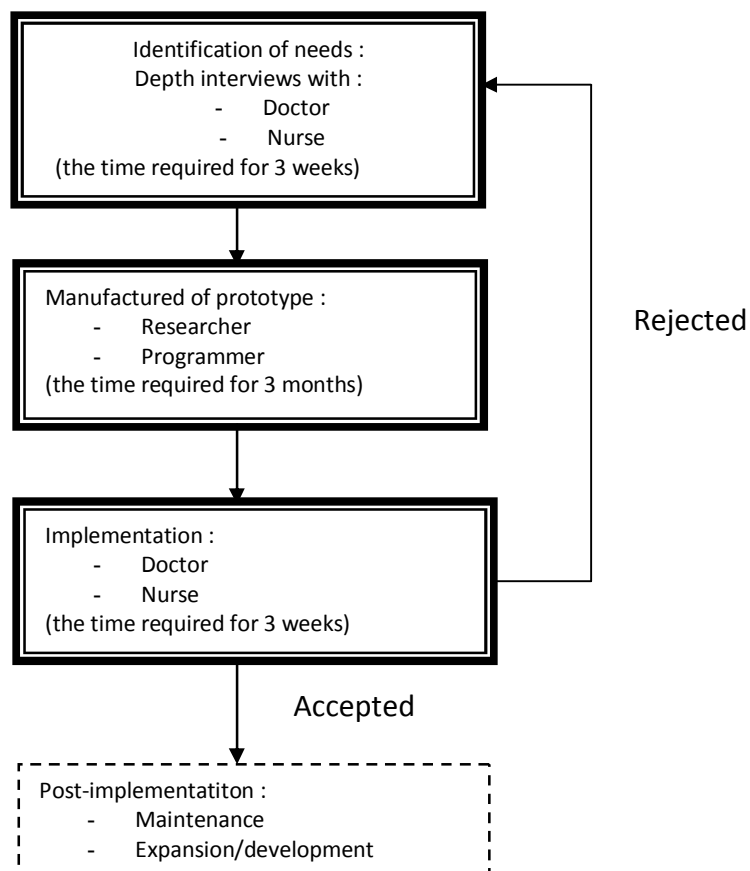


Figure 13. Flow diagram of the stages of development of prototype for malaria diagnostic decision support system

"...fortunately this application uses Indonesian language, so it's not difficult to learn this application. If English is used, I won't understand it at all..." (Participant 7)

Flow diagram of the stages of development of prototype for malaria diagnostic decision support system is shown in Figure 13.

The prototype of decision support system developed was web-based application with PHP programming language and which related to database management program MySQL. The consideration of researcher to use the tools, other than they were open source and freeware, they also supported when one day this application would be put online, both in the intranet environment in the hospital and Puskesmas, and internet network. The addition of deeper knowledge principle may create this system to be more practical<sup>9</sup>. The knowledge base contained relevant knowledge needed to understand, formulate, and solve the problems<sup>10</sup>. Good expert system was designed to solve certain problems by imitating the activity of expert, so that with this expert system, even laymen could solve complicated problems which usually only solved by the help of experts. For the experts, this expert system also would facilitate their activities as experienced assistant<sup>11</sup>. This expert system is expected to be used by health providers in diagnosing malaria clinically, and to receive medical advice from this expert system. There are several methods used to represent the knowledge, namely, semantic nets, frame, production rule, and predicate logic. This is important for decision making in expert system<sup>9</sup>. Several inferential methods that can be used in the development of expert system are tree and graph, AND-OR tree and objective, deductive logic and syllogism, principle of inference, forward chaining and backward chaining, and fuzzy inference. This is useful because they are

general techniques in problem solving expert system<sup>12</sup>.

This expert system used decision tree, which later became production rule in representing the knowledge. Inferential machine used backward chaining, where in internal process always checked the conclusion first as initial presumption, and then later checked the symptoms were fulfilled by the user or not, and when all symptoms were fulfilled, system presumption was true and produced as output, and if there were symptoms which were not fulfilled, the system presumption was false, and system would check the next conclusion. The development of prototype for malaria diagnostic decision support system provided facility to follow the development of new knowledge on clinical symptoms of malaria. Therefore, recent knowledge may be added to the available expert menu in this application. In the development of this expert system, clinical symptoms obtained through in-depth interview, previous studies, and literature were added into this expert system. Clinical symptoms suffered by patients would be processed by this application, and then this application would give medical advice to health providers. It was expected that medical advice produced might help health providers in determining the next action. Effort to decrease the morbidity and mortality rates caused by malaria, which are by early diagnosis, quick and appropriate treatment, surveillance, and vector control, were aimed to cut the transmission link. To establish definitive diagnosis of malaria, microscopic blood examination had to be conducted<sup>1</sup>.

One effort by Innovative Vector Control Consortium/IVCC was by developing the software of Malaria Decision Support System (MDSS), and released it in the conference of Multilateral Initiative (MIM) in Kenya in 2009<sup>13</sup>. This software integrated the requirements

of continuing surveillance, monitoring, and evaluation of malaria control. MDSS included malaria cases, entomological surveillance, planning and monitoring intervention, household survey, stock control, and data from other sources. Output of this software was in the form of reports, graphics, and maps which could be used as the support to make decision. In 2009 conducted study on the development of malaria surveillance information system in Health Office in Kabupaten Bulungan, Kalimantan Timur, which aimed to help the staff in increasing the efficiency and effectivity of P2 Malaria program in processing, analyzing, and interpreting malaria data<sup>14</sup>. Software developed may be used as early detection tool for the possibility of malaria outbreaks, through monitoring of disease distribution based on epidemiological variables. With this software, malaria control activity will be more directed, effective, and efficient, because of the availability of accurate malaria situation information as the basis of decision making for determining the program activities, so that it may decrease the waste in funding. One example of clinical decision support system developed by Shortliffe et al. was MYCIN. MYCIN was rule-based expert system which diagnosed infectious diseases caused by bacteria in the blood<sup>15</sup>. By asking and performing backward chaining on the rule basis which consisted of around 500 rules, MYCIN could recognize around 100 causes of bacterial infection, so that MYCIN could recommend effective drug prescription. In controlled test, its performance was considered similar with human specialist.

Development of software by IVCC and Iwandi was very useful in helping the staff making decision based on data produced by the software, particularly in malaria control program planning. Different than that, this study developed software which was useful to diagnose malaria clinically. Sometimes health providers establish

diagnosis of malaria based only on clinical symptoms, without any laboratory examinations. Result of a study in RSU Gunungsitoli Nias showed that generally respondents knew about the procedure of care for malaria patients, starting from history taking, physical examination, laboratory examination, and treatment<sup>4</sup>. But in reality, there were respondents who gave antimalarial drugs to patients without laboratory examination (did not follow the procedure), or when laboratory result showed malaria negative. Their reason was that if history and clinical symptoms were suggestive, antimalarial drugs might be given to the patients. Other factors were because sometimes laboratory examination needed extended time, more cost, patient could not bear the pain, long distance to the patient house, requested (demanded) by patient, and the staff was not available in Puskesmas, because of illness. These conditions sometimes caused health providers gave treatments based only on clinical diagnosis of malaria. Implementation trial of malaria diagnostic decision support system was applied to the nurses, because in Puskesmas Gunungsitoli, sometimes nurses gave treatment when the doctor was not available. From the interview, nurses told the unavoidable condition when patient was used to be treated by nurses instead of doctors.

*"...gimana ya dek, ini kan puskesmas perawatan, kadang kalau malam dokter tidak ada di puskesmas, jadi pasien yang datang mendesak supaya dikasih aja obat. Kasihan kan kalau pasien kita suruh datang lagi besok, apalagi kalau pasien dari kampung yang rumah mereka jauh-jauh. Alasan kemanusiaan lah dek. Mungkin juga kalau kamu berada pada posisi kami akan melakukan hal yang sama lah dek..."* (Participant 7)

*"...well, how to say this, this is Puskesmas with*

inpatient unit, sometimes at night the doctor is not available, so that the patient demands to be given treatment. I can't asked them to come again tomorrow, particularly when they come from the distant village. Humanity reason, you know. Probably you will do the same when you are in my position ...” (Participant 7)

*“...gitulah dek, saya kan dari dulu sudah jadi perawat sebelum dokter mulai banyak di daerah kita Nias ini. Pasien-pasien yang sudah terbiasa berobat kepada saya masih banyak sampai sekarang. Pasien banyak yang sudah percaya kepada saya karena dulu-dulu mereka sembuh dengan obat yang saya kasih. Jadi kalau mereka sakit lagi, kemungkinan mereka akan berobat lagi kepada saya.”* (Participant 6)

“...that's how it is, since old times when doctors are not available here in Nias, I have been a nurse. These patients had been used to be treated by me until now. Patients put their trust in me because they were cured before with drugs I have given them. So when they get sick again, probably they will come to me.” - (Participant 6)

Available menus in malaria diagnostic decision support system used Indonesian language, so that it was easier for the health providers to use it. Researcher had find no difficulties when conducting implementation trial on nurses and doctor. Nurses who had educational background of SPK and had used computers only once or twice could adapt quickly to operate the application. The main objective of this expert system was knowledge shift from the experts to non-experts<sup>12</sup>. By the acceptance of this application, main objective of this expert system was expected to be achieved. Potential of next improvement of this expert system is by adding Bayesian probability and machine

learning. Bayesian probability is a way to solve the uncertainty when using Bayes formula, and it may also be useful to show the possibility value and the correctness of diagnosis<sup>9</sup>. Machine learning is aimed to make computer/machine to have intelligence<sup>16</sup>.

## CONCLUSION

The users wanted expert system that help them in diagnosis of malaria clinically, and received medical advice. Available clinical symptoms were consistent with the guideline of malaria case management in Indonesia and result of indepth interview with doctors and nurses.

Prototype of decision support system produced was a web-based application with PHP programming language with database management program MySQL. By entering clinical symptoms suffered by patients associated with malaria, this system would analyze and generate medical advice for users.

Implementation of malaria diagnostic decision support system stimulated interest from participants, because of its interesting appearance, easy to understood, and might help health providers to diagnose malaria clinically.

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