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PORTABLE TELEPRENATOLOGY SYSTEM FOR MIDWIVES IN RURAL AREAS

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ABSTRACT

Decreasing Maternal Mortality Rate (MMR) to improve global health has been a big issue for most developing countries. Limited accesss to health care facilities especially for the poor in rural areas gives a hard declining for MMR around the globe. Midwife as the closest health provider for pregnant women in rural areas, is given a new solution to provide a better care toward community, hence improving maternal health and reducing MMR in the future. By using a computerized clinical pathway and an integrated ultrasound machine, a new portable teleprenatology system for midwives is being proposed. Multi-channel wireless network is also introduced in this system to prevent any interruptions during teleprenatology application.

Keywords: teleprenatology, midwife, wireless network, rural area.

INTRODUCTION

Recent study shows that maternal and fetal mortality rate has been a major problem in Developing Countries (UNICEF, 2008). In Malaysia, maternal mortality has been decreased from 44 in 1991 to 28.1 per 100.000 live births in 2000. However, this number has been plateaued until 2008, and the maternal mortality rate (MMR) was only decreasing by 0.8 until 2008 (UNCTM, 2011). In Indonesia, the maternal mortality rate has gradually been reduced from 390 in 1991 to 228 per 100.000 live birth in 2007 (BAPPENAS, 2010). With current trends, it will require extra efforts to achieve 102 deaths per 100.000 live births by 2015 as one of the Millenium Development Goals (MDGs).

Several reasons of why the MMR Ratio remains high is due to limited access to quality health care facilities, especially for the poor in disadvantaged areas, remote, border, and island areas (BAPPENAS, 2010), as well as limited availability and inadequate or insufficient healthcare (Moszynski, 2011). In these cases, midwives hold the important role as the health provider in a village with limited access to health care facility. In Takalar District, province of Sulawesi Selatan, Indonesia, partnership between midwives and Traditonal Birth Attendants (TBA) has been proven succeed in decreasing maternal mortality (BAPPENAS, 2010). It has been proven that most women in Indonesia prefer having delivery assisted by midwife, as shown by Figure-1 and Figure-2 (Utami et al., 2011).

Being far away from the healthcare facilities, midwives in rural areas are required to do diagnosis and make a quick decision. They need a proper assisting system. Ultrasound machine is one example of equipment commonly used in prenatal screening, and has been proven well in detecting high risk pregnancies (McKenna et al., 2013). Although there is high number of midwives worldwide, unfortunately they are not well trained to handle ultrasound machine. As mentioned by United Nations Population Fund, if the improvement in midwifery services is upgraded by 2015, up to 3.6 million pregnant women death can be saved each year (Mozynski, 2011). However, because of low education and the scarcity of training, help and guidance from obstetric and gynecologists to midwives are really needed and these issues should be given high attention and deep concern.

Regarding this issue, a new portable teleprenatology system for midwives is proposed. As one of Telemedicine branch, it can be a bridge for midwives to

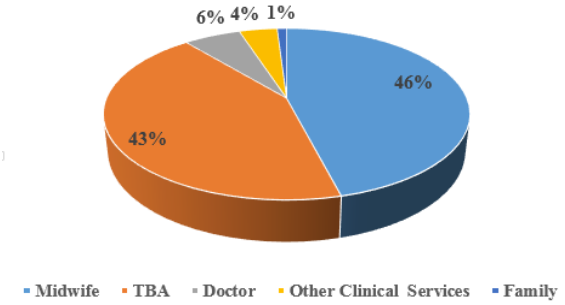

Figure-1. Preferred delivery attendants for first time delivery in 2007, rural areas, Indonesia.

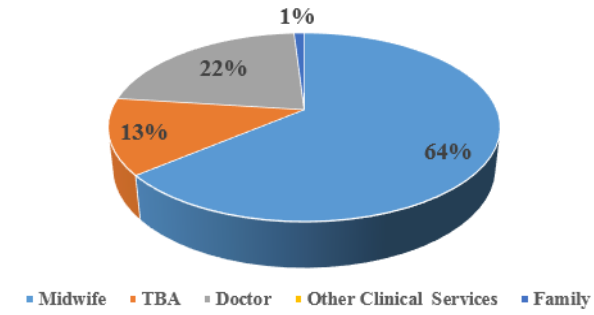

Figure-2. Preferred delivery attendants for first time delivery in 2007, Urban areas, Indonesia.

be assisted by specialist from a vast distance, thus providing a better care. Diagnosis can be improved and patient can receive treatment better due to comprehensive digital data that is available to them offline and online. In addition, multi-channel wireless network is used for telecommunication, as single wireless network is less reliable and might end up in interruptions in teleprenatology application.

TELEPRENATOLOGY OVERVIEW

Teleprenatology is born from telemedicine, a cross breed between healthcare instrumentation, informatics, and telecommunication technologies in prenatal care application (Di Lieto et al., 2011). It is practiced across distances and involves the electronic transfer of information (Krupinski et al., 2008). Telemedicine in prenatal examination is becoming important especially in rural areas, since vast distance between patient and healthcare facilities is commonly found. Many researchers are aware regarding this matter, shown by these studies which propose some methods for introducing teleprenatology in rural areas

There are three types of teleprenatology (Rodrigues et al., 2012). First is store-and-forward. This type is used for non-emergency situations. The data can be provided during offline and not requiring the presence of health provider and patient at the same time. This involves the remote patients passing on her medical data like medical history, scans, reports, past diagnoses and etc. Second type of teleprenatology is remote monitoring. It is including a telemedical facility actively monitoring the pregnant women over remote locations using telemedicine equipment and devices. Lastly, two way real time teleprenatology, which can provide consultations, diagnosis and treatment over real-time, videoconferencing, live transmission of diagnostic images/videos, phone conversation and other synchronous interactive technology. For this case, midwife obstetric-gynecology specialist remotely connect and interact with each other at a given time.

In rural areas of Pakistan, store-and-forward teleprenatology has been introduced to prenatal care as a system called Remote Patient Monitoring System (RPMS) (Khalid et al., 2008). Midwife contributes in this system by placing sensors and a module for gathering some signals from the patient including pulse, temperature, blood pressure, heart beat, hemoglobin, blood sugar, and albumin. These signals are then sent to the Electronic Medical Record (EMR) server through a PDA application. In this this server, CDSS (Clinical Decision Support System) is also available for automated response, in case of emergency. Such system can also be available in a mobile phone, with the pregnant women as the end user (Onashoga et al., 2011).

Cardiotocography is also becoming one point of interest in teleprenatology. A system focusing on cardiotocography called TOCOMAT (Di Lieto et al., 2011) has been through many developments since 1998. It gives an extension for specialists to monitor high risk pregnant women who requires electronic fetal monitoring, but live in a vast distance (Di Lieto et al., 2001). In its early establishment, TOCOMAT uses modem for transfering fetal heart traces to an operational centre, from peripheral units consisting of traditional cardiotograph in rural areas. It is now updated into a simplified configuration by using smart phones and the last generation fetal monitor unit, shown by Figure-3.

Remote monitoring in teleprenatology ensures the healthiness of the fetal condition, whether it is done continuously or intermittently. Monitoring Fetal Heart Rate (FHR) can use textile electrodes for abdominal ECG recording which is wearable and capable of sending it to the healthcare facility (Fanelli et al., 2010). Another similar wireless technology uses a doppler ultrasound sensor unit connected to a communication unit, allowing data visualization and transmission (Roham et al., 2011). Medical doctor can monitor these patient data through an accessible internet platform with an integrated expert system (Antohi et al., 2010). The internet platform keeps in track the medical record and risk factors inside EMR server, which is able to give alert to the physian as well as giving treatment suggestions.

Ultrasound scanning in teleprenatology

Ultrasound scanning is important for maintaining a healthy pregnancy. Performing ultrasound scan in low risk population of pregnant women during late pregnancy may reduce the risk of growth-restricted infant and increase the frequency of prenatal intervention (McKenna et al., 2013). Higher surveillance by doing ultrasound scanning can

a)

b)

Figure-3. TOCOMAT peripheral unit consisting cardiotocograph in a) early establishment, and b) latest development (Di Lieto et al., 2011).

detect high-risked fetus among low risk prenatal population. Routine ultrasound scanning during early pregnancies also has been proved to reduce failure in detecting multiple pregnancies and reduce labor inductions (Whitworth et al., 2010).

Being known that using internet to stream near real- time and transfer image data for ultrasonography is actually feasible (Bassignani et al., 2004), some has introduced ultrasound scanning in teleprenatology. A web-based synchronous teleprenatology system, which is composed of a portable ultrasound machine, laptop, and a server (Solano et al., 2009), is built to make communication between midwife and obstetric specialists easier. This system is named Personal Health Management System (PHIMS), as a web-based personal health record with midwife as the main user. Similar set of tools is also used by DeStigter et al. (2011), but without featuring live consultation. There is also an effort to combine ultrasonography with TOCOMAT network, by adding Picture Archiving and Communication System (PACS) for the ultrasound images management (Di Lieto et al., 2011). In this study a portable teleprenatology system with real-time ultrasound image transmission is proposed specifically for midwives in rural areas.

DESIGN AND DEVELOPMENT

Midwife's clinical pathway

As the content of prenatal guidelines may be different to each other, three prenatal guidelines from different sources are used: World Health Organization (WHO, 2006) as proposed system's main and standard guideline, GroupHealth (2012) for comparison and complements, with ultrasound scanning protocol delivered by American Institute of Ultrasound in Medicine (AIUM, 2007). One new prenatal care procedure was then extracted, summarized, and cross-checked by medical expert. This becomes the clinical pathway for midwife, as shown by Figure-4, which is readily integrated with the flow of the proposed system.

System framework

For framework design, the harsh rural area setting is considered. At first, as the midwives need to travel a vast distance for visiting patients, a portable toolkit is needed. A portable ultrasound machine is also needed and integrated to the system, since it is crucial for higher pregnancy surveillance. The system is aimed for assisting midwife on doing a complete and thorough prenatal examination, thus it contains all of midwife's need for conducting prenatal examination. Based on the prenatal care procedure, some complimentary devices are needed for midwives to do complete examination. It includes blood pressure monitor, ruler tape, fetal doppler, stethoscope, weight scale, urine reagent, and portable blood analyzer. Expert system is also included, giving automatic alert for possible diseases, so that midwife can take necessary actions immediately or connect to the specialist for a guided treatment. Furthermore, the Graphical User Interface (GUI) allows midwives to view results, ultrasound images, manage patients, and create reports. These reports then also

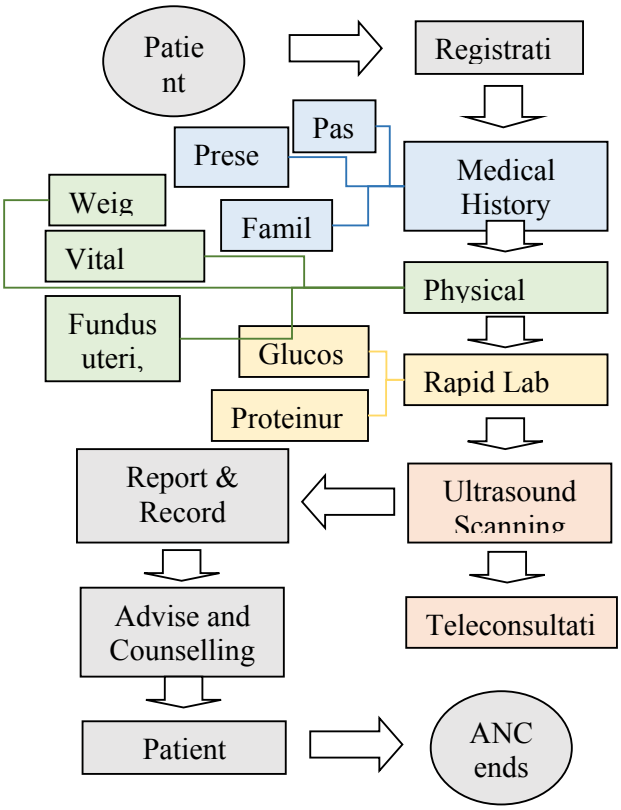

Figure-4. Midwife's clinical pathway during ANC.

can be sent to arranged specialist for further verification. This system framework is shown by Figure-5.

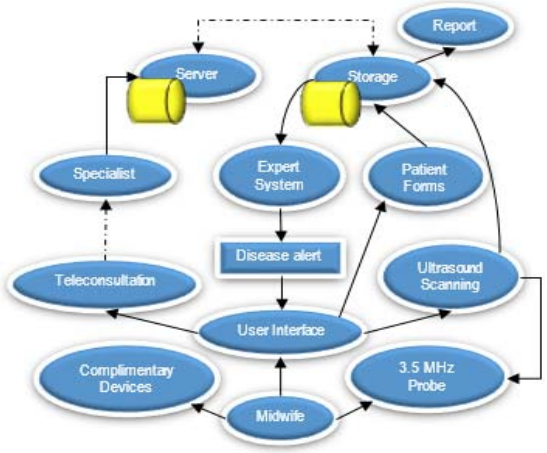

Figure-5. System framework of portable teleprenatology system.

Developing user platform

The user platform of the system is developed by using Microsoft Visual Studio 2010 in C# languange. It is mainly based on GUI which allows midwife to interact with the system, by using images (such as buttons) rather than just texts. Platform for this system is made user friendly and easy to be understood by midwifes.

System platform is developed in several windows, each of which representing one main step in the prenatal care procedure. The flow of this platform is shown by Figure-6. User interface starts by popping up the user login window. It is to ensure that only the midwife can use and access patient data inside of the teleprenatology system. Then it continues with patient registration form. In this part, midwife can search patient ID inside database to automatically fill in the registration form. After registration, midwife can directly proceed to the medical history check, and do the prenatal examinations, ended with examination report.

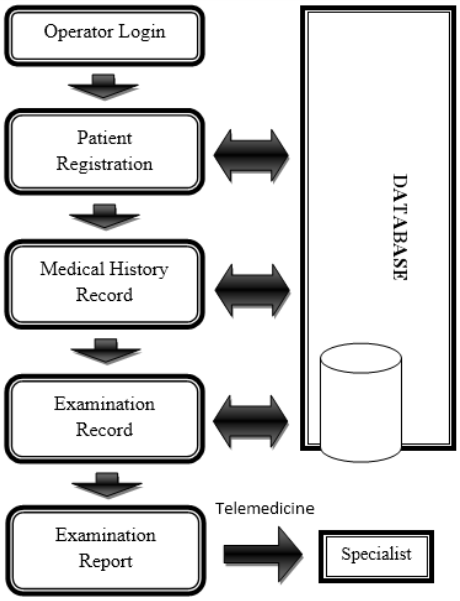

Figure-6. User Interface Flowchart.

Teleprenatology platform

In emergency case, when midwife finds any complication or abnormalities on pregnant women, they can directly call the specialist or doctor via real-time teleconsultation and start to tell the current condition of the patient. Otherwise, the midwife can just use the store and forward mode. The system is able to show specialist who currently online along with their informations. During real-time teleconsultation, specialist can review the information of the patient medical history through the system and guide midwife in ultrasound scanning from a far. The specialist is also capable of doing diagnosis, giving prescription, and giving referral letter to patient. The referral letter then shall become a proof for the appointment with the specialist when they need to come to the hospital for higher level of care. This process is shown by Figure-7.

Multi-Channel wireless network

The proposed system uses multi channels for telecommunication. By considering the rural areas setting, this includes Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunication System (UMTS), General Package Radio Service (GPRS) and Satellite. WiMAX will be useful if midwife is located near a suburban or urban area, while UMTS, GPRS, and

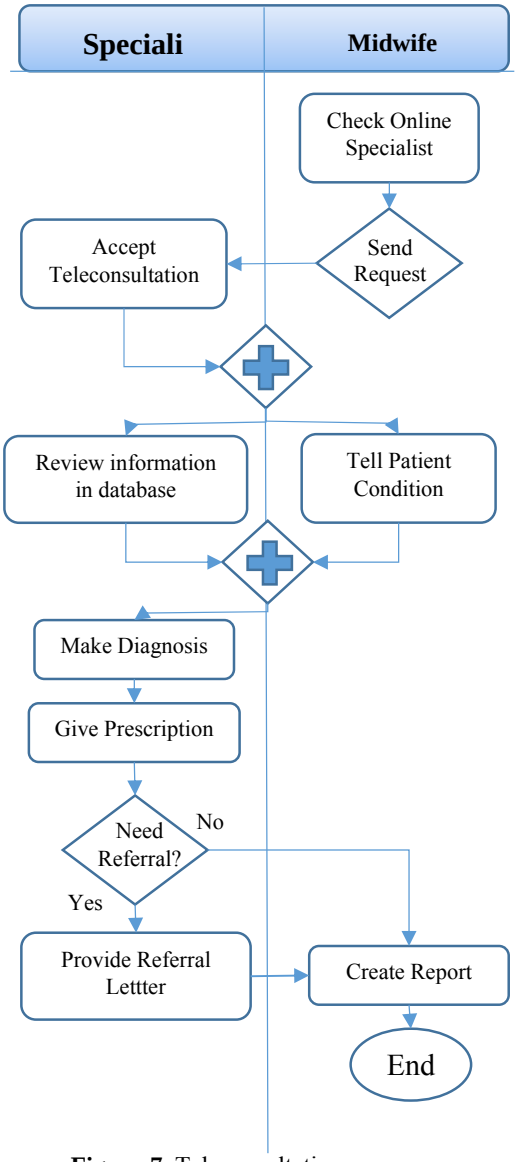

Figure-7. Teleconsultation process.

satellite are used for wider coverage area. Table-1 shows characteristics of these wireless technologies.

The multi-channel telecommunication system is shown by Figure-8. By using this multi-channelling network, teleprenatology platform is able to connect to different type of wireless networks based on the Received Signal Strength (RSS), thus increasing the coverage and reliability of the system. Even if one or more networks are satellite are used for wider coverage area. Table-1 shows characteristics of these wireless technologies.

Table-1. Wireless technologies characteristics.

	Satelite	WiMAX	UMTS, GPRS
Bandwidth (Mbps)	Up to 10Mbps	Up to 54Mbps	Up to 5 Mbps
Distance (km)	Depend on frequency and transmission power		
	Worldwide	35	50
Cost	Very High	Medium	High
Speed	High	High	High

The multi-channel telecommunication system is shown by Figure-8. By using this multi-channelling network, teleprenatology platform is able to connect to different type of wireless networks based on the Received Signal Strength (RSS), thus increasing the coverage and reliability of the system. Even if one or more networks are

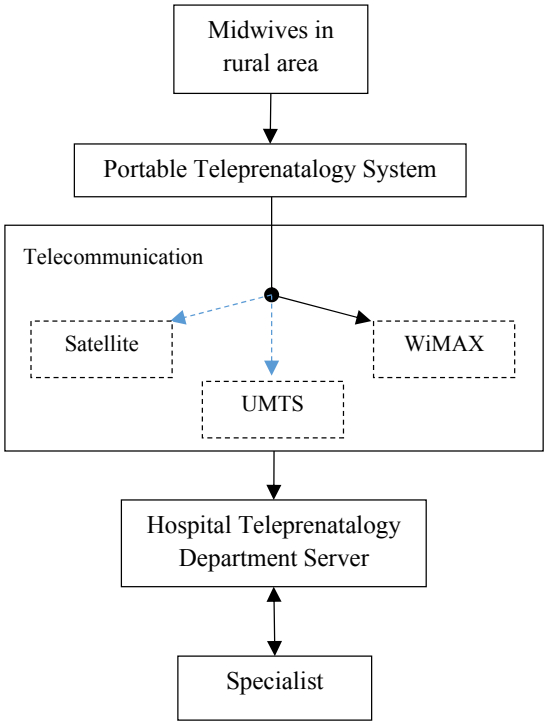

Figure-8. Portable teleprenatology telecommunication system.

failed; the system is still able to connect to the most appropriate network among the available alternatives.

RESULTS

Portable teleprenatalogy system platform

The Portable Teleprenatology System for midwives has been developed with an integrated portable ultrasound machine as the platform base. The user platform is shown by Figure-9. VGS 1000-1 ultrasound manufactured by Chengdu Vigorous Science & Technology Co. Ltd is used with a new casing design.

Figure-9. Portable teleprenatology platform.

The specification for this teleprenatology system is listed as below:

- Dimension: 30cm x 35cm x 30cm.
- Probe Type: Mechanical Sector.
- Probe Frequency: 3.5 MHz.
- Display depth ≥ 200mm.
- Dead Zone ≤ 7mm.
- Image greyscales 256 scales.
- Zoom: 1.0x, 1.5x, 2.0x.
- Ultrasound measurement function: distance, area, circumference, femur length (FL), biparietal diameter (BPD), head circumference (HC), crown-rump length (CRL), abdominal circumference (AC).
- Image reference available for guided fetal measurement.
- Applicable from 1st trimester until delivery.
- System including teleprenatalogy platform with integrated ultrasound machine and complimentary devices for introducing complete examination.
- Complimentary devices: fetal doppler, stethoscope, rapid blood analyzer, weight scale, ruler tape, urine test kit, thermometer, and blood pressure monitor.
- Features: computerized clinical pathway, automated alert system for abnormalities, teleconsultation with multi-channel wireless telecommunication system.

Computerized clinical pathway

A computerized clinical pathway for midwife has been developed with GUIs shown by Figure-10. It shows patient registration window as in Figure-10(a). and examination window as in Figure-10(b). In examination window, it can be seen that the system is capable of giving

automatic alert on possible disease as the midwife typing in the examination results.

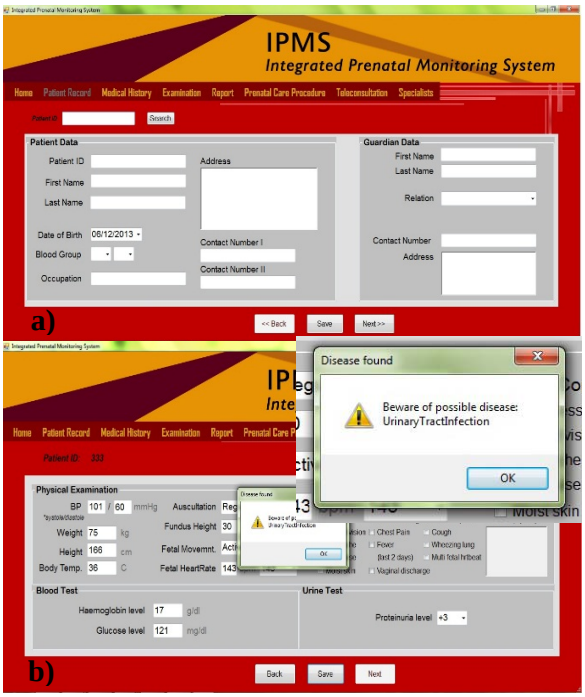

Figure-10. Graphical user interface, a). Patient registration form, b) Abnormality alert pop up during examination.

Some parameters need to be taken and entered to the system by midwife during prenatal care as shown by Table-2. This includes patient's medical history, vital signs and several parameters related to physical condition, rapid laboratory test results, as well as fetal parameters. These parameters can be entered into the system by using the GUIs provided.

Table-2. The computerized clinical pathway parameters.

No.	Procedure	Parameters to be taken	Time of Pregnancy
1.	Medical History Check	Medical history	1st Trimester
2.	Physical Exams	Blood Pressure	Every visit
		Weight	Every visit
		Height	1st trimester
		Temperature	Every visit
		Auscultation	Every visit
		Fundus Height	Begin in 2nd trimester
		Fetal Movement	Begin in 2nd trimester
		Fetal Heart rate	Begin in 2nd trimester
3.	Rapid Laboratory Test		
a.	Blood test	i. Haemoglobin	1st trimester
		ii. Glucose	1st trimester
b.	Urine Test	Protein level	1st trimester
4.	Ultrasound Examination		
a.	Confirm normal pregnancy	Normal /abnormal	Every visit
b.	Check Multiple pregnancy	Yes/no	Every visit
c.	Evaluate Cervix and Uterus	Problems present /notpresent	Every visit
d.	Check Cardiac activity	Present/not present	Every visit
e.	Check Placenta condition	Anterior /posterior, previa/notpreviа	Begin in 2nd trimester
f.	Check amount of amniotic fluid	Normal /abnormal	Begin in 2nd trimester
g.	Check Fetal motion	Active/passive	Begin in 2nd trimester
h.	Determine baby position	Breech/cephalic/transverse	Begin in 2nd trimester
i.	Determine baby gender	Male/female/unknown	Begin in 2nd trimester
j.	Measure parameters and estimate fetal weight	i. BPD	Begin in 2nd trimester
		ii. CRL	Begin in 2nd trimester
		iii. HC	Begin in 2nd trimester
		iv. AC	Begin in 2nd trimester
		v. FL	Begin in 2nd trimester

Teleconsultation trial

As the system running, the midwife is able to do teleconsultation. The system was tested using Biometric Fetal Ultrasound Training Phantom by CIRS shown in Figure-11. It is able to transmit the real-time ultrasound imaging from the system in Johor Bahru, Malaysia to the distance specialist in Indonesia. As shown in Figure-12, live ultrasound imaging is being displayed in android-based tablet owned by the specialist. During this teleconsultation, specialist can assist midwife in doing ultrasound scanning, give diagnosis as well as prescription.

Figure-11. Fetal ultrasound phantom.

Figure-12. Videoconference between midwife and specialist.

During transmission, some parameters including line speed, data rate, delay, packet loss, and jitter were measured. The result is shown by Table-3, and it meets the Quality of Service (QoS) minimum requirement for video (Gallego et al., 2005). Some ultrasound image samples were also obtained simultaneously from both side: the midwife and specialist, as shown by Figure-13. From these images, it can be seen that there is no noticeable difference between the two sides. The image received by the specialist is still considered similar as the image viewed by midwife, and it is diagnosable. For this far distance setting, UMTS is used as wireless channel, as for WiMAX it is believed that it will also meet the minimum requirement since the bandwith is higher than UMTS.

Table-3. Measurement result for ultrasound real-time imaging transmission.

	Line speed (kbps)		**Data rate** (kbps)	**Delay** (ms)	**Packet loss** (%)	**Jitter** (ms)
	Transmitter	**Receiver**				
Minimum requirement	>384 kbit		32-384	Max 150-400	1	Small jitter
Measurement result	29335	9435	210	353	0.1	33

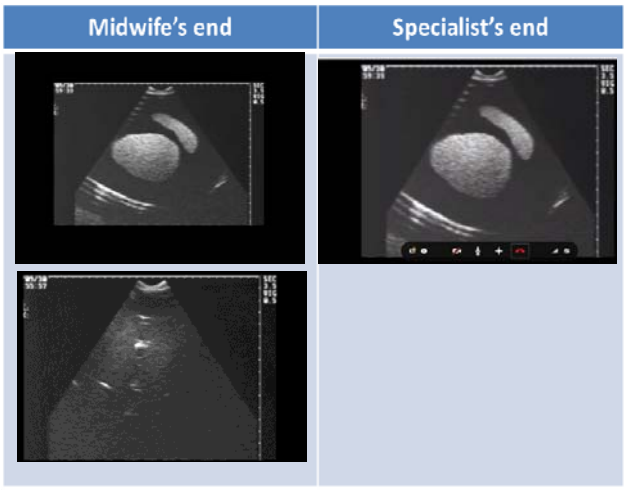

Figure-13. Received ultrasound image comparison between midwife and specialist.

CONCLUSIONS

Midwives need to be in the center of attention as the closest health provider in rural areas. They may become the key solution to decrease the number of MMR ratio which remains high until now. There is a high number of midwifes worldwide and they need a proper assisting system. Because of low education and the scarcity of training in handling ultrasound machine, help and guidance from obstetric and gynaecologists to midwives are really needed deep concern.

Thus a new portable teleprenatology system is developed for midwives to becoming a bridge towards specialist in healthcare facilities. A computerized clinical pathway is developed, and a portable ultrasound machine is integrated in the teleprenatology system. In addition, multi-channel wireless network is used for wider coverage and avoiding interruptions in teleprenatology real-time application. The system is able to give automatic alert on abnormalities and enabling midwives to contact specialist by videoconference, thus providing a better quality service of prenatal care. However, some legal aspects still need to be considered in the future, since midwives still need a license for using ultrasound machine. There is still a wide range of methods in improving prenatal care. Some new considerations may be obtained through this study for the future research.

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REFERENCES

AIUM. (2007). AIUM practice guideline for the performance of obstetric ultrasound examination. US: AIUM.

Antohi R., et al. (2010).Computerized system for medical decision in the perinatal period. In: Automation Quality and Testing Robotics (AQTR), 2010 IEEE International Conference.

Bassignani M.J., et al. (2004). Review of Technology: Planning for the Development of Telesonography. Journal of Digital Imaging. 17(1): p. 10

DeStigter K.K., et al. (2011). Low-cost teleradiology for rural ultrasound. IEEE Global Humanitarian Technology Conference. p. 6

Di Lieto A., et al. (2011). Prenatal Telemedicine: A New System for Conventional and Computerized Telecardiotocography and Tele-Ultrasonography, in Advances in Telemedicine: Applications in Various Medical Discipline and Geographical Regions. Grashcew and T.A. Roelofs. Editors. p. 36

Fanelli A., et al. (2010). Prototype of a wearable system for remote fetal monitoring during pregnancy. 32nd Annual International Conference of the IEEE EMBS : Buenos Aires, Argentina. p. 4.

Gállego J.R., Hernández-Solana A., Canales M., Lafuente, J., Valdovinos A. and Fernández-Navajas J. (2005). Performance Analysis of Multiplexed Medical Data Transmission for Mobile Emergency Care over the UMTS Channel. IEEE Transactions on Information Technology in Biomedicine, 9(1), pp. 13-22.

GroupHealth. (2012). Prenatal care screening and testing guideline. Group Health Cooperative.

Khalid M.Z., et al. (2008). Using Telemedicine as an Enabler for Antenatal Care in Pakistan. 2nd International Conference, E-Medical System, Tunisia. p. 8.

Krupinski E., Pak H., Bocachica J., Earles L., Edison K., Goldyne M., et al. (2008). American telemedicine association's practice guidelines for teledermatology. Telemedicine and e-Health. 14:289-302.

McKenna D., Tharmaratnam S., Mahsud S., Bailie C., Harper A., Dornan J. (2013) A randomized trial using ultrasound to identify the high risk fetus in a low risk population. Obstetric & Gynecology, 101(4): p. 7.

Moszynski P. (2011). Number of midwives is critically low in many poor countries, study shows. BMJ 2011; 342:d3881

National Development Planning Agency (BAPPENAS). (2010). Report on The Achievement of The Millenium Development Goals Indonesia 2010. BAPPENAS: Indonesia.

Onashoga S.A, S.A.S., Omilani T.O, Ajisegiri, H.O. (2011). A Mobile phone based antenatal care support system, in 21st International Conference on Systems Engineering IEEE Computer Society.

Rodrigues J.P.C., et al. (2012). Telemedicince and E-Health Services, Policies, and Applications: Advancements and Developments. IGI Global : US.

Roham M., et al. (2011). Wireless Fetal Monitoring System. p. 31.

Solano M., et al. (2009). Asynchronous Telemedicine with Ultrasound: Improving Maternal Health in Developing Countries. IEEE International Ultrasonics Symposium Proceedings. p. 4.

UNICEF. (2008). Maternal and newborn health. UNICEF: New York, USA.

United Nations Country Teams Malaysia. (2011). The Millenium Development Goals at 2010. UN : Kuala Lumpur, Malaysia.

Utami E.A., et al.. (2011). Potret Ketersediaan dan Kebutuhan Tenaga Bidan. Ditjen Dikti Kementrian Pendidikan dan Kebudayaan Indonesia.

Whitworth M., et al. (2010). Ultrasound for Fetal Assessment in early pregnancy. Cochrane Databese of Systematic Review Issue 42010: John Wiley & Sons, Ltd.

WHO. (2006). Pregnancy, childbirth, postpartum and newborn care: A guide for essential practice. WHO: Geneva.

WHO. (2012). Maternal mortality. Fact sheet N348.