Abstract: - The rapid development of information and communication technology (ICT) provides an opportunity to improve the quality of patient life. The availability of sustainable telecardiology system in Malaysia is essential to overcome shortage of cardiology services in rural area. This paper elaborates the framework including requirements of telecardiology technology to meet the current condition of telecommunication infrastructures in Malaysia rural area. Furthermore, a new infrastructure of wireless telecardiology technology is proposed for rural area. This new infrastructure will help cardiologist to remote monitoring their patient in rural area and remote supervising the medical doctors at public non-specialist hospitals.

Key-Words: - Cardiologist, Information and communication technology (ICT), Telecardiology, Framework, Wireless, Rural, Malaysia

1 Introduction

According to the World Health Organization (WHO) report, cardiovascular diseases (CVDs) is a world leading cause of noncommunicable diseases death in 2008 and over 80% of deaths from low and medium income countries. CVDs also a main cause of death in Malaysia in last two decades [1].

Amongst 199 cardiologists, only 49 cardiologists are working in public hospitals [3]. The rest are serving in Ministry of Defence, universities and private hospitals. Fig 1 shows the number of patients treated at public hospitals’ cardiology specialist clinic from year 2004 to 2011. The number of inpatients and outpatients were increased double from 2004 to 2011 [3].

In 2011, there were only 199 cardiologists in Malaysia, which was equivalent to overall density of 0.07 per 10000 populations [2]. Royal College of Physicians and British Cardiac Society recommends one cardiologist per 50,000 populations [31]. This means Malaysia at least require additional 381 cardiologists to support the population in year 2012.

In addition, concentration of cardiologists in urban has caused rural areas seriously lacking of cardiologists. NHEWS 2011 report [2] shown that 121 out of 199 (60.8%) cardiologists were found in West Coast Peninsular Malaysia (Wilayah Persekutuan Kuala Lumpur, Wilayah Persekutuan Putrajaya, Selangor and Pulau Pinang). There were...
29% of the population lived in the rural area Malaysia [4]. This group of people are majority from East Malaysia (Fig. 2). According to the outcome of NCVD-PCI Registry 2007-2009, 27% of patients who underwent Percutaneous Coronary Intervention (PCI) lost to follow-up after discharge from hospitals [18]. These may due to unwillingness to travel long distance, lack of time and monetary constraints [19].

The issue of lack of specialists has been highlighted by Minister of Health and president of Malaysia Medical Association [5][6]. Although large number of doctor are graduating yearly, the rural area in Sabah and Sarawak still short of doctors and specialists [7]. The lack of specialty care for the rural population is remaining a main concern and this problem has not been solved for long time.

The store-and-forward has been widely used in telecardiology to follow-up the chronic cardiac disease. It is more convenient than real-time especially for the countries which lack of cardiologists. However, the real-time consultation allows a result to be obtained immediately. Furthermore, real-time consultation could be a strong educational component for the remote practitioners [32].

Telecardiology was shown useful in the management of acute coronary syndrome, atrial fibrillation, syncope and even in implementing strategies of cardiovascular primary care [16]. It also reduced the door-to-balloon time of ST-elevation myocardial infarction (STEMI) [8][9][11][12][15][16]. In addition, AM Paus et al [20] had proved telehealth is feasible for cardiovascular patients living in remote region and improved the follow up rate. The other benefits of telecardiology are improvement in patient compliance with medication [13], reduce mortality and morbidity [8][9][10][11][12], better utilize the resources such as ambulance, tertiary beds, consultant less travel [14], improve hospitals’ clinical administration workflow, and environment friendly (paperless, less travel).

In order to overcome the barrier of healthcare such as distance, time, and cost, implementation of telecardiology is necessary. Thus, areas with less developed healthcare facilities, for example, rural area in East Malaysia, can capitalize on the expertise available in the West Coast Peninsular by centrally managing patients across the nation through telecardiology. This would help to improve the overall healthcare quality across the whole country.

2 Telecardiology

Telecardiology is a mechanism that delivers cardiovascular services by using information and communication technology (ICT) at distance. The most common part of telecardiology is dealing with transmission of electrocardiography (ECG) signal and echocardiography image over different types of telecommunication technologies from home or clinics to cardiology specialty centres. These ECG signal and echocardiography image can be transmitted in two ways, which are store-and-forward and real-time transmission.

The store-and-forward is the user sends pre-recorded health information to hospital information system and healthcare professionals check the patients’ electronic health record some time later. In this application, sender and receiver does not need to present simultaneously. On the other hand, the real-time telecardiology requires both parties (patient and healthcare professionals) to presence at the same time.
A new telecardiology system was launched in February 2010 [21]. According to the report [21], total 359 cardiology cases registered in new telecardiology system from 2010 to 2012. The hospitals involved in this service are shown in Table 1 and Fig. 3. The receiving stations are the tertiary hospitals with cardiologists while the sending stations are consist of non-specialist hospitals. The result showns that the public hospitals involved in telecardiology are low.

Table 1 Telecardiology sending and receiving stations in Malaysia [3]

<table>
<thead>
<tr>
<th>Receiving Station (Cardiologist)</th>
<th>Sending Station (Medical officer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Pulau Pinang</td>
<td>Hospital Tuanku Fauziah, Perlis</td>
</tr>
<tr>
<td></td>
<td>Hospital Sultanah Bahiyah, Kedah</td>
</tr>
<tr>
<td></td>
<td>Hospital Taiping, Perak</td>
</tr>
<tr>
<td>Hospital Queen Elizabeth, Sabah</td>
<td>Hospital Duchess of Kent, Sandakan</td>
</tr>
<tr>
<td></td>
<td>Hospital Tawau</td>
</tr>
</tbody>
</table>

Fig. 3 Telecardiology network in Malaysia [21]

3.2 Telecardiology in Developed Countries
Telecardiology system in developed countries such as United States and United Kingdom are more reliable and sustainable because there have better telecommunication infrastructure, sufficient fund, and adequate healthcare professionals in hospitals. In addition, they provide free and easy-access training resources to specialists, medical staff, administrator, and other users across the country. Furthermore, the telecardiology system in developed countries is partnership with medical devices manufacturers, telecommunication companies and human resource companies to form a strong support team.

The comparison of health expenditure (funding), physicians per population (human capital), and internet users (knowledge and skill) between Malaysia and few developed countries have been done based on the statistic from the World Health Statistic Report 2013 [30] and Broadband Commission Annual Report 2013 [34].

The Fig. 4 shows that the developed countries internet users and broadband penetration rate were at least twice over Malaysia. The higher the number of internet users probably means more potential telecardiology users. This user group is the one who will gather health information from internet and easier to adapt to telecardiology technologies.

The comparison of expenditure per capita and physician density between Malaysia and developed countries showed in Fig 5 and Fig 6, respectively. It is shown that the density of physicians per 10,000 populations in developed countries was two time higher than Malaysia. In fact, Malaysia physicians per 10,000 population and health expenditure per capita were both lower than world averages which were 13.9 physicians per 10,000 populations and USD 1,017 per capita, respectively.

Fig. 4 Broadband penetration rate per 100 inhabitant and percentage of individual internet users in year 2012 [34]

Fig. 5 Total health expenditure per capita (USD) in year 2010 [30]
4 Factors Affecting Sustainability of Telecardiology in Malaysia

The main factors affecting the sustainability of the telecardiology are ICT infrastructure, resources and policy.

4.1 ICT Infrastructure

The growth of telecardiology is very much in line with the development of ICT infrastructure. In 2011, Malaysia broadband and cellular telephone (2G) coverage has reached to 81% and 95% of populated areas, respectively [22]. Table 2 shows the 2G and 3G mobile network coverage by three main mobile internet service providers in Malaysia in year 2012.

Table 2 Mobile network coverage in Malaysia [25][26][27].

<table>
<thead>
<tr>
<th>Internet Service Provider</th>
<th>% Coverage of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2G</td>
</tr>
<tr>
<td>CELCOM</td>
<td>95.0</td>
</tr>
<tr>
<td>DIGI</td>
<td>95.0</td>
</tr>
<tr>
<td>MAXIS</td>
<td>95.0</td>
</tr>
</tbody>
</table>

Based on the latest report published by Malaysian Communication and Multimedia Commission [23], the total number of household broadband subscribers in Malaysia was 4.5 million or 67.2% penetration rate which was ranked within the world top ten highest household broadband penetration rates.

Although broadband penetration rate is increasing every year, the broadband services at rural areas broadband services are still the main concern of Malaysia government. Under government Universal Service Provision (UPS) program, four projects (1Malaysia Community Broadband Centres, Mini Community Broadband Library and Wireless Village) have been done to bridge the digital divide between urban and rural communities. These projects allowed the rural communities to enjoy the benefits of the internet.

In budget 2014 [24], Malaysia government invests RM1.8 billion on high-speed broadband (more than 10Mbps) project, RM1.5 billion to build 1,000 telecommunication transmission towers to increase internet coverage in rural areas, and RM850 million to lay new underwater cables to increase internet access in east Malaysia. Hence, the development of ICT infrastructure in Malaysia is expected will grow rapidly in next five years.

4.2 Policy and Resources

Apart from ICT infrastructure, other factors that affecting the sustainability of telecardiology include policy and various resources such as knowledge and skills, human capital management, and funding. The impacts of these factors in Malaysia have been studied by Maarop et. al. and the results are summarized in Table 3 and Table 4 [28][29]. It is showed that the users were no or less concern about the medico legal, security, privacy and reliability issues in telecardiology because all these are managed and monitored by Ministry of Health Malaysia.

Table 3 Resources condition [29].

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject</th>
<th>Survey Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network and Infrastructure</td>
<td>Bandwidth</td>
<td>No standard bandwidth size among the hospitals.</td>
</tr>
<tr>
<td>Resource</td>
<td>Funding</td>
<td>Based on MoH</td>
</tr>
<tr>
<td></td>
<td>Manpower</td>
<td>Lack of healthcare professionals in sub-urban and rural area.</td>
</tr>
<tr>
<td></td>
<td>Equipment and workstation</td>
<td>Limited.</td>
</tr>
<tr>
<td>Training Programs &amp; Awareness Program</td>
<td>Training Programs and Awareness Program</td>
<td>Helpful and necessary.</td>
</tr>
</tbody>
</table>
Table 4 Users’ concern with using telecardiology technologies [29].

<table>
<thead>
<tr>
<th>Factors</th>
<th>Survey Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concern About Legal and Policy</td>
<td>No Concern</td>
</tr>
<tr>
<td>Network Security</td>
<td>Less Concern</td>
</tr>
<tr>
<td>Privacy and Confidentiality</td>
<td>Less Concern</td>
</tr>
<tr>
<td>Reliability in Medical Executing</td>
<td>Fairly Concern</td>
</tr>
<tr>
<td>Tasks</td>
<td></td>
</tr>
</tbody>
</table>

In addition to that, the continual financial support from MoH is very essential to improve the hospitals’ health equipments, ICT infrastructure, network system, and also support the cost of human resource development (doctors, trainers, IT support staff, and management staff). A standard training program for the telecardiology users is important to ensure all users are familiar and confidence with the telecardiology infrastructure. Furthermore, the awareness program to promote the benefits of telecardiology to community is necessary in order to increase the number of participants (public and private hospitals). The community need to be convinced that the telecardiology is the fastest tool to expand cardiology specialty care to rural area.

5 Proposed Telecardiology Framework for Rural Area

Based on the comparison studies, an optimal telecardiology system for rural area is proposed. Fig. 7 shows the new proposed telecardiology system. The proposed telecardiology will apply both store-and-forward and real-time methods. The store-and-forward method is priority because it is more reliable and suitable for data transmission through 2G network. The proposed telecardiology system is featured as below.

Wireless communication: The mobile cellular network is chosen because it has the widest coverage in Malaysia. The design will focus on data transmission through 2G mobile cellular network and satellite network because rural area possibly covered by 2G network only. The satellite communication required as a backup network for emergency purpose.

Reliable: Ensuring the wireless communications method chosen is able to transfer the health data effectively. A new algorithm will be designed to compensate for imperfections in the 2G network such as unpredictable delay and packet drop to ensure the health data integrity.

![Fig. 7 Proposed new telecardiology system for rural area in Malaysia.](image-url)
**User friendliness:** The applications of the telecardiology must be simple and easy to use. It should be convenient to all parties (healthcare professionals, patients and administrators). The patients could upload or send their health data to hospital information system (HIS) periodically by themselves. On the other hand, doctor could monitor the patients’ health record at anytime without any appointment in advance. This is to avoid overburden healthcare professional in public hospital.

Network security, policy and legal factors are excluded because proposed framework focus on the telecardiology technology only. The general workflow of the proposed framework is shown in Fig. 8.

In this framework, every cardiac patient at rural area is attached with a battery powered portable cardiac pulmonary medical device, as shown in Fig. 9. This device is 24 hours standby and always ready to connect to HIS. The key function of this device is to collect ECG signal and vital signs from patient’s body and transmit the health information to HIS. The general workflow of this proposed cardiac pulmonary medical device is shown in Fig. 10. Its features included:

**Universal Interface:** Able to interface with various types of cardiac medical sensors from different manufacturers and generate a standard format of electronic health record (EHR) such as DICOM.

**Integrated with self-interpretation function:** The device should able to perform self-analyses and interpret the ECG rhythms and vital signs. This is to allow patient knows his/her health status from time to time; for example, device will display “Normal” or “Non-normal” after analysed the first screening vital signs or ECG signal before meeting the healthcare professionals. The patients are still need consultation from healthcare professionals periodically through phone call or video-conferencing depending on network availability.

**Communication system:** The device is equipped with different type of wireless communication technologies such as satellite, 2G, 3G, and 4G to allow the device adapt to the different network. This system is competent to search for the ability of network and select the best available network. If network Quality of Service (QoS) is below the predetermined parameter, health data will be stored in the memory and send when network is meet the predetermined QoS requirement based on [35]. The satellite communication is only activated when there is no wireless network detected during emergency. However, it also can be activated manually if user needed especially in emergency situations. The QoS for emergency state should focus on the robustness of data rather than the integrity issues.

**Emergency Alert:** If device detects an abnormal ECG or vital sign, it will send an emergency alert to healthcare professional and next-to-kin for attention. The emergency message should enclose the essential information. This information contains patients’ details, patient location and current vital
record. The quality of patient treatment is depended on the highest guarantee of data transfer delay and rapid diagnosis.

Patient Location Tracking: It provides the location tracking of patient’s positions for providing a fast action during emergency, such as ambulance transfer from nearest hospital. This feature is significant to the patients live in East Malaysia (Sabah and Sarawak) which has a large geographical area.

6 Conclusion
This paper reviews the current condition of telecardiology and ICT infrastructure in Malaysia. The strong health fact has proved that a new telecardiology is essential for rural area. Hence, a new telecardiology system is proposed to improve quality of patients’ life in rural area. This new telecardiology technology system is also able to further extends the cardiology specialty care service to the population in the rural area. The future work is to implement a proposed portable cardiac medical device and test it in the real environment.

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