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Evaluation of "Portable Health Clinic" with BAN standard for 10K subjects in Bangladesh

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***Abstract*— Management system of chronic diseases in developing countries and post-disaster situation has been required. Body area network (BAN, IEEE 802.15.6) is expected to be useful in medical field. To evaluate BAN standard, we are implementing BAN in our attaché case type sensor set named "Portable Health Clinic" (PHC), and conducting systematic health checkup in rural and urban areas in Bangladesh. (Methods) In the PHC, we packed weight scale, blood pressure meter, blood sugar meter, body thermometer, pulse oxymeter, as electrical devices, and tape measure (for height, waist and hip), urine test tape (for urine sugar, urine protein and urobilinogen) as no-electrical devices. We provided checkup in rural villages and urban companies in Bangladesh by PHC, and transmitted data by cellphone network to the data center in Dhaka. Individual health condition was categorized into 4 grades, green (healthy), yellow (caution), orange (affected), and red (emergent) by international diagnosis standards of diseases. We provided telemedicine for orange and red, and tele-prescription for hypertensive patients. We are making all sensor devices implemented with BAN. (Results) The health checkup was provided to 5498 subjects until the end of 2012 and categorized green 14%, yellow 66%, orange 17%, and red 3%. The result shows its potency as an effective healthcare system in developing countries and in a chronic phase after disaster. We continue to provide the e-health service for 10K-15 K people each year until March 2014.**

I. Introduction

The earthquake which hit Tohoku area of Japan on 11th March, 2011, afflicted high aged people and patients with chronic diseases who left any medicine at home, lived in evacuation centers or temporary housing, and lost access medical service for several months. Some of them were suffered from serious acute diseases as stroke. The local situation of Tohoku area at that time was following;

1) High stress by aftermath of the tragedy, coldness and no privacy situation worsened chronic diseases as hypertension or diabetes mellitus.

2) Nutritionally poor diet as high salinity also worsened chronic diseases

3) Medical staffs also run short absolutely as a result of falling victim to the disaster

4) Evacuation centers were scattered and traffic was damaged, thus, access from/to medical service was difficult

5) Difficulty to manage physical condition without common healthcare devices as weight scale and thermometer

6) Network of cellphone was available right after the disaster

If we could setup usable healthcare sensor devices in appropriate sites and unify data management by cellphone network, we could figure out where, how many, how serious patients existed, and we could deliver medicine and appropriate diet to cure more patents.

Recently, some articles have proposed the needs of management system about chronic diseases after serious disaster, and many papers were published on mental care, serious injury and acute disease cares [1-2]. However, few papers have been published for chronic diseases so far.

On reflection, cellphone network covers 98% national land of Bangladesh. Developing countries like as Bangladesh had suffered from communicable diseases. But recently, main problem has been shifted to non-communicable diseases as chronic diseases. Therefore, especially rural area in Bangladesh shows similar situation of after the disaster as described above by 2) – 6).

Thus, we developed healthcare sensors network system which we can use in developing countries and also in area hit by a disaster. In this paper we present results of a health checkup in rural and urban area with the system in Bangladesh on trial basis.

II. System Requirements

System requirements to be usable in the situation of developing countries and post-disaster are following;

A. Interoperability

System should be compatible to international standards, to realize interoperability of sensors as ISO/IEEE 11073 personal health data standards, and IEEE 802.15 series for data transmission from sensor devices.

B. Scalability

System should function after it accepts a new kind of sensor.

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C. Stability

System should be precise, stable in tough conditions (high humidity, high/low temperature, and heavy dust). It should also be electric power saving

D. Usability

Both sensor devices and communication equipment should be usable by non-professional person without supports of professional medical staffs or engineering staffs.

E. Security

System should be considered enough to deal sensitive privacy information.

F. Compatible for regulations

System should comply with regulations as radio wave law, pharmaceutical law and medical practitioner law in each country.

G. Affordable cost

System cost including communication expenses should be affordable to be installed especially in developing countries. Also in Japan, it should be affordable to be diffused in peacetime before disasters.

III. SYSTEM ARCHITECTURE

A. PHC

At the local site of health checkup, we developed attaché case type package of sensor devices and data coordinator in PHC. Our PHC package consists of following sensor devices.

· Diagnosis tools and sensors

- ✓ Weight Scale (A&D; UC-321PBT)
- ✓ Blood Pressure (A&D; UA-772PBT)
- ✓ Pulse Oxymeter (OXiM; S-101)
- ✓ Blood Sugar (Terumo; MEDISAFE FIT)
- ✓ Body Temperature (Terumo; W520DZ)
- ✓ Non-electrical devices (urine tester tapes for urine-sugar, urine-protein and urine-urobillinogen, and a measure for height, waist and hip)

We selected sensor devices in viewpoints of international information standards and approval in pharmaceutical law in Japan. If device did not have any standard transmission, we attached BAN interface on the sensor outside.

B. System Configuration

Local sensor servers (Local-SS) stores data from sensor-boxes and synchronize its data with the master sensor server (Master-SS) in the data center in Dhaka when the internet connection is available. Master-SS stores all data sensors and provides data to the Personal Health Record Sever, and also doctors in telemedicine center. The interface of the local-SS is the same of that of the master-SS (transparency), therefore sensor-boxes can directly connect to the master-SS only changing the configuration of the address of SS.

C. Stratification Logic

TABLE I. STRATIFICATION LOGIC (BANGLADESH LOGIC)

	Green	Yellow	Orange	Red
Waist	Male: <90cm	≧90cm		
	Female: <80cm	≧80cm		
Waist/Hip Ratio	Male: <0.90	≧0.90		
	Female: <0.85	≧0.85		
Body Mass Index (BMI)	<25	25≦ <30	30≦ <35	35≦
Blood Pressure (mmHg)	<140 mmHg	140≦ <160	160≦ <180	180≦
	<90 mmHg	90≦ <100	100≦ <110	110≦
Blood Sugar	<100mg/dl	100≦ <126	126≦ < 200	≧200mg/dl
Postprandial Blood Sugar	<140mg/dl	140≦ <200	200≦ < 300	≧300mg/dl
Urine test				
Urine Protein	-	±	≧+	
Urine Sugar	-	±	≧+	
Urobilinogen	±		≧+	
Pulse Ratio	60≦ <100 bpm	50≦ <60 100≦ <120	<50 120≦	
Arrhythmia	None		+	
Smoking	None	+		
Body Temperature	<37℃	37≦ <37.5	37.5≦	
SpO2	≧96%	93≦ <96	90≦ <93	<90

We established a logic (Bangladesh-logic, B-logic) by international diagnosis standards to determine risk stratification into 4 grades, green (healthy), yellow (caution), orange (affected), and red (emergent) in results of each health checkup items. The individual health condition was also determined by integrating results of questionnaire into the 4 degrees by the worst color of all health checkup items.

Data of pulse rate is sent from blood pressure meter, although pulse oxymeter (SpO2) also shows pulse rate. Arrythmia is determined by local staffs when they find arrythmia during blood pressure test or pulse oxymeter test. Smoking data comes from questionnaires.

D. Tele-medicine and tele-prescription

We provide telemedicine to orange and red subjects after health checkup by cellphone network by telemedicine center in Dhaka. In the telemedicine center, a male doctor and a female doctor are ready to provide telemedicine because female often does not like to talk with male doctors about medical matters by Islamic teaching. Telemedicine is provided by Skype system. Doctors can access to the results of subject's health checkup, and provide advices about the disease, encourage visiting a clinic if possible, and provide tele-prescription for hypertensive patients by the network.

Subjects who get tele-prescription by the telemedicine should visit pharmacy in the village to purchase medicines.

E. Operation of the system

PHC is a healthcare service including 1) health checkup by sensor devices, 2) data preservation in the data center, 3) provide health situation by paper and healthcare guidance according to situation of individuals, and 4) telemedicine by doctor in the telemedicine center.

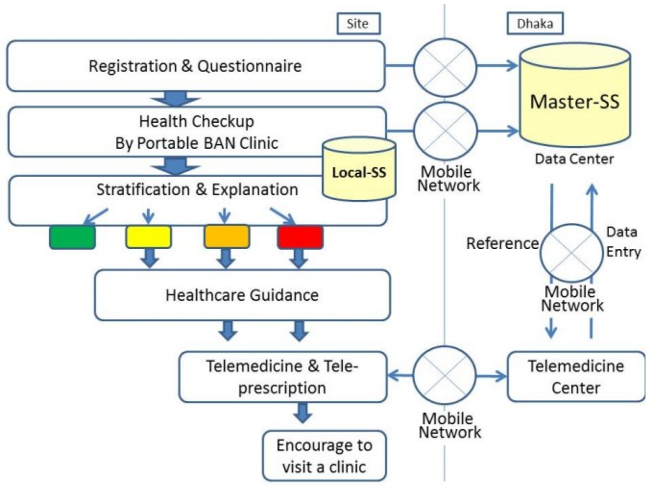

Figure 1. Work flow and data flow of the service in a visit

In the first visit, a subject gets an ID card with barcode after registration. After finished questionnaire, he/she is checked up by sensor devices so on. The data are preserved both in local-SS and main-SS in Dhaka, and automatically categorized into 4 grades from green to red according to the B-logic. Results are printed out and used for explanation to the subject by local staffs. In the explanation, the booklet is provided to the subject if he/she is not green. We provided telemedicine for only orange and red subjects from Dhaka. Then, we asked orange and red subjects to visit again 2 months later to get second health checkup (Figure 1).

2 months later, the subject is checked in by barcode on ID card, and gets questionnaire survey and health checkup.

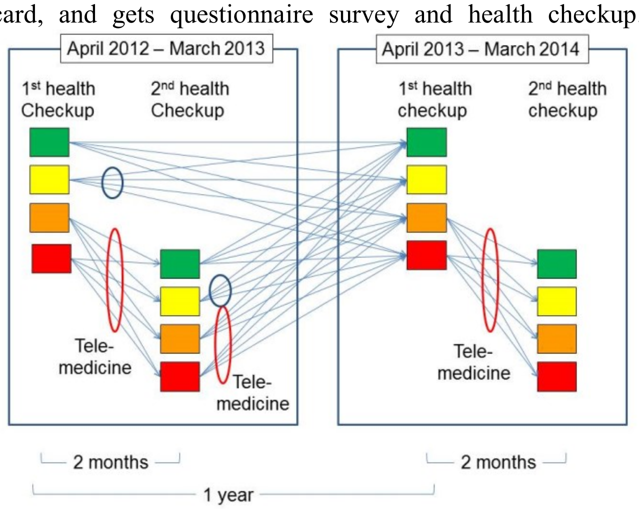

Figure 2. The protocol of the study for two year (2012-2013 fiscal years)

As shown in Figure 2, we have continued for a two years verification study with this protocol in 2012 fiscal year. 10K subjects are expected in 2012 fiscal year, and 15K subjects including the 10K subjects in the first year are planned in 2013 fiscal year as number of the first visit.

F. Ethical considerations

The protocol of this study was admitted by the ethical committee in the postgraduate school of medicine, Kyushu University.

IV. RESULTS

A. Detail Results of Risk Stratification by B-Logic

We conducted a health checkup 2153 subjects in rural villages and 3345 subjects in companies, total 5498 at the end of 2012 as the first health checkup in Bangladesh. The results are shown in Table 2.

In the first health checkup subjects, number of male was 3,300 (60%), and female was 2,148 (40%). Age of male was 36.4 $\pm$ 12.2 (years old, average $\pm$ SD), and female was 38.7 $\pm$ 13.5.

3828 (70% of total) were yellow in waist-hip ratio, and 2109 (38.4%) were "grade 1 hypertension" or higher in blood pressure test (yellow, orange and red). Diabetic patients (orange and red) were only 7.3%. Red subjects were seen in BMI (13 subjects), blood pressure (119 subjects), blood glucose (52 subjects) and SpO_2 (4 subject). By the assessment of total health condition, we could find 20% affected subjects (orange and red), 66% with yellow, and 14% with green.

TABLE II. RESULTS OF THE FIRST HEALTH CHECKUP UNTILL THE END OF DECEMBER 2012 (N=5498)

Color	Green	Yellow	Orange	Red	Sub-total
Waist	3649	1849	-	-	5498
Waist Hip Ratio	1670	3828	-	-	5498
BMI	4172	1168	145	13	5498
Blood Pressure	3389	1715	275	119	5498
Blood Glucose	5090	255	94	52	5491
u-Protein	3567	1576	348	-	5491
u-Sugar	4154	1090	247	-	5491
u-Urobillinogen	5389	-	102	-	5491
Pulse Rate	4937	534	27	-	5498
Arrythmia	5484	-	14	-	5498
Temperature	5127	344	27	-	5498
SpO_2	5405	82	7	4	5498
Overall Result	**746**	**3642**	**926**	**184**	**5498**
	14%	**66%**	**17%**	**3%**	**100%**

B. Risk factors related with symptoms and chronic diseases

We checked the risk factors with symptoms and apparent chronic diseases checked by PHC at the end of 2012. As shown in Table 2, 24% of all subjects were mild obesity or heavier（BMI ≧25; yellow or worse by B-Logic）. Table III shows risk factors related with obesity. Hypertension, diabetes mellitus and rural life were significantly related with obesity.

Table II shows 38.4% of total subjects were hypertensive (SBP ≧ 140mmHg or DBP ≧ 90mmHg, yellow or worse). TableI V shows that obesity and age were related with hypertension.

Table II also shows 2.7% of total subjects were apparently diabetic (postprandial ≧ 200mg/dl, fasting ≧ 126mg/dl; orange and red). Obesity, age and rural life were significantly related with diabetes mellitus as shown in Table V.

TABLE III. RISK FACTORS RELATED WITH OBESITY

	OR	95%CI	p-value
Age	1.005	(1.00, 1.01)	0.07
Sex (male)	1.002	(0.87, 1.15)	0.98
Location (rural)	1.30	(1.10, 1.53)	0.002**
Hypertension	2.38	(2.06, 2.74)	<0.001***
Diabetes Mellitus	1.78	(1.25, 2.53)	0.001**

TABLE IV. RISK FACTORS RELATED WITH HYPERTENSION

	OR	95%CI	p-value
Age	1.04	(1.04, 1.05)	<0.001***
Sex (male)	0.96	(0.83, 1.12)	0.62
Location (rural)	0.89	(0.75, 1.05)	0.18
Obesity	2.43	(2.11, 2.81)	<0.001***
Diabetes Mellitus	1.20	(0.83, 1.73)	0.34

TABLE V. RISK FACTORS RELATED WITH DIABETES MELLITUS

	OR	95%CI	p-value
Age	1.06	(1.05, 1.07)	<0.001***
Sex (male)	1.22	(0.83, 1.79)	0.31
Location (rural)	1.68	(1.06, 2.64)	0.03*
Obesity	1.97	(1.39, 2.80)	<0.001***
Hypertension	1.21	(0.84, 1.75)	0.30

TABLE VI. RISK FACTORS RELATED WITH PROTEINURIA

	OR	95%CI	p-value
Age	1.01	(1.01, 1.02)	<0.001***
Sex (male)	0.60	(0.53, 0.68)	<0.001***
Location (rural)	1.46	(1.27, 1.70)	<0.001***
Obesity	1.89	(1.66, 2.16)	<0.001***
Hypertension	1.03	(0.89, 1.18)	0.69
Diabetes Mellitus	1.10	(0.78, 1.56)	0.58

TABLE VII. RISK FACTORS RELATED WITH TACHYCARIDIA

	OR	95%CI	p-value
Age	0.99	(0.98, 1.00)	0.04*
Sex (male)	0.43	(0.34, 0.55)	<0.001***
Location (rural)	0.48	(0.37, 0.62)	<0.001***
Obesity	1.44	(1.14, 1.80)	0.002**
Hypertension	2.62	(2.09, 3.27)	<0.001***
Diabetes Mellitus	2.48	(1.54, 3.98)	<0.001***

Proteinuria （± or more) is a major symptom of renal dysfunction. Table 2 shows that 35.0% of total subjects had proteinuria. Obesity, female, rural life and age were related with proteinuria significantly as shown in Table VI.

Tachycardia （pulse rate≧100） is a symptom of cardiac diseases, pulmonary diseases dehydration, and also of hyperthyroidism. 6.9% of total subjects had tachycardia (data not shown). Hypertension, diabetes mellitus, urban life, female and age were related with tachycardia (Table VII).

V. DISCUSSION

In this paper, we presented system requirement of the PHC with BAN, a new standard of wireless sensor network to use for health checkup in Bangladesh. Although we may complete the requirement after we finish the health checkup trial until March 2014, we already found our attaché case type PHC works well at least for 6 months in rural and urban area.

We have felt certain that interoperability is the most important in the system requirement of the sensor networks, when we developed a system in the previous project to manage daily life style of chronic disease patients, which consisted of sensor network with Zigbee, IEEE802.15.4 [3].

The first short-range medical BAN standard IEEE802.15.6 is expected to be used for secure and easy-to-use sensor network for medical equipment, because it can work in bandwidths for medical purpose, gathering QoS data in hub devices on strict security basis, having order relations to transmit serial data in real time, consuming less power, safer electromagnetic wave by low specific absorption ratio [4].

From the beginning of the project we have used BAN standard partially in our system (pulse oxymeter) and we have replaced all connection with sensors to BAN standard.

We also introduced results of simple analysis of the health checkup data at the end of 2012.

We found a lot of known relations as between obesity and hypertension/diabetes mellitus, or between age and hypertension/diabetes mellitus. Interestingly, we also found original relations as between rural life and obesity/diabetes mellitus/proteinuria/tachycardia. Of course we have to consider about confounding factors to complete this analysis, we are expecting we can approach original factors in Bangladesh also. For example, rural area has more obese people compared with urban in Bangladesh. Thus we can guess rural people may take in more sugar and fats.

With this kind of IT system, it easily makes us enable not only to install social healthcare system, but to analyze data as a cohort study in the future (all subjects were asked to have an annual health checkup). We should evaluate detail of health situation in Bangladesh, appropriateness of B-logic, intervention methods, and cost-effectiveness of our e-health service.

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