A Patient Status Classification Method for Metabolic Syndrome Care Based on Service Level Agreements

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Abstract. Chronic disease is a long term disease that requires life time care. Physicians need to keep tracking patients' status over time including routine medical examinations. There are a lot of medical resources and it is inadequate for physicians to review the huge number of medical information for a chronic patient. Thus, the results from these examinations and patients need to be classified according to patients' service level agreements. In this paper, to efficiently manage chronic disease patients, we propose a patient status classification method for chronic disease care based on service level agreements. We evaluate the proposed method using data obtained from the third Korea National Health and Nutrition Examination Survey among non-institutionalized civilians in the Republic of Korea, which was conducted by the Korean Ministry of Health and Welfare in 2005.

Keywords: healthcare, chronic disease, metabolic syndrome, service level agreement.

1 Introduction

Advances in patient caring and monitoring technologies have allowed physicians to track a patient's physiological state more closely and more accurately. In addition, these technologies enable out-of-hospital health monitoring. With the increasing amount of electronic medical data, system assisted medical decision should be adopted to effectively provide health care services. One of mostly popular systems for medical services is health information systems. Health information systems are being used to support key medical care procedures and to make medical decision and prescription, to manage patient's health conditions or even for hospital administration, respectively. In general, the traditional health information systems have been developed to generate raw patient examination results and have not provided expert advice for managing a patient's specific condition. Improved rules of a series of concerning preventive care tests and procedures, testing, drug therapies, and hospital stay status are used in a clinical practice process to manage a disease over time. However, the physicians usually overlook to examine the recommendations, or they

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hardly cooperate with the clinicians who disagree with the recommendations. Most of clinical expert systems have not directly integrated into the care process to provide suggestions about patient management when medical staffs visit a patient. To solve these service problems, it entails enormous cost to pay for human labor, to spend time and share information with other remote physicians and so on. The traditional systems that were available during the patient visit are used to disrupt the routine care process by requiring the clinician to enter additional data into the computer [1].

To efficiently manage chronic disease patients, we propose a patient status classification method for chronic disease, particularly metabolic syndrome care based on service level agreements. The proposed method classifies the status of patients' tier having metabolic syndrome using areal similarity degree analysis model and chronological distance function proposed by Jeong et al. [2][3]. The proposed method is evaluated using data obtained from the third Korea National Health and Nutrition Examination Survey among non-institutionalized civilians in the Republic of Korea, which was conducted by the Korean Ministry of Health and Welfare in 2005 [4].

2 Architecture of Patient Status Classification Method (PSCM) for Disease Care Service Levels Support

Systems which assist medical decision-making in hospitals are known as the health information systems. This systems support disease care procedures, medical decision-making, writing of prescriptions, and management of patients' health status. Among the health information systems, Jeong et al. proposed a preliminary Patient Status Classification Method (PSCM) to provide preliminary chronic disease diagnosis functionality [5]. The PSCM method has been further elaborated to quantify and predict the risk of having chronic disease, particularly metabolic syndrome (MS) in the future [6]. In this section, we describe an extended PSCM method with ambient visualization support for metabolic syndrome. Figure 1 shows the extended PSCM model with ambient visualization support. The extended model supports visualization of chronic disease status using ambient visualization interface. This model can aid physicians to deliver better healthcare services to their patients and better analyses of the patients' diseases, as it makes the workload manageable. The extended PSCM model for patients with chronic diseases offers automatic medical service procedures in the form of an effective medical information visualization system. It reduces the workload by offering readily available data. The PSCM process contains three parts: the Patient Tier Classifier, the Disease & Complications Identifier, and the Health Risk Quantification [5]. Our visualization system can be divided into an ambient information system and patient device. This visualization system can help a physician to manage each individual patient better and more efficiently than the conventional PSCM system. As the proposed visualization systems are extended to mobile devices by means of 'mobile interaction' technology and a 'widget interface', it can eventually generate more effective interaction with the health information system. Also, through the mobile widget on a device and with the order communication system interface, we can use data in conjunction with the medical diagnosis system as

a progressive medical service. Additionally, the individual patient receives an examination at their respective hospitals. The results of the examination are filtered to find whether or not the person who underwent the examination is a patient. The actual inspection ratio and the results of the Personal Examination Result set and the Disease database can then be utilized.

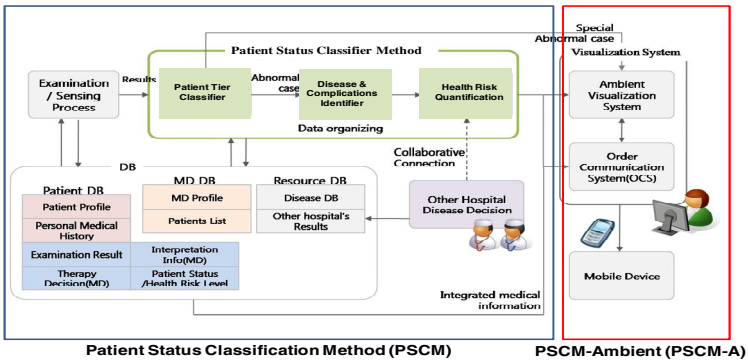

Fig. 1. The model system architecture for the extended PSCM supporing disease care service levels

To determine patient tier, we process patient status decision as shown in Fig 2. The results by Disease and Complications Identifier module can be generated at each individual hospital. The results obtained from the remote hospitals can be integrated with web-based system and can be calculated with the mapping module in the Health Risk Quantification module. In this step, the medical information analysis is shown in the health information system, and then physician can use the data at the examining time [7].

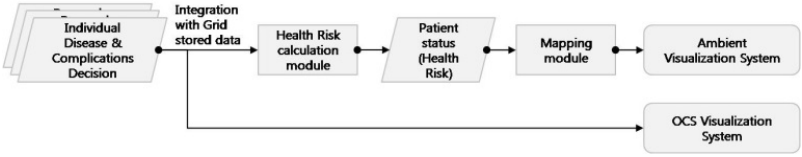

Fig. 2. Health risk quantification process

After a physician reviews all needed information from the health information system, they make a decision about the patient status. The patient status defined by physicians is to visualize on the health information system and ambient visualization system. The patient's condition can be mapped and compared to that of the normal levels in manual and then check it to see if the patient is at the risk of the chronic illnesses out of the normal levels and the mapping threshold are shown in Table 1. This risk is based on the patient, and this judgment depends on the physician's decision.

3 Determination of Thresholds for Patient Tier Classification for Service Levels Agreement Using Sensitivity Level

This section describes the determination of patient tier classification thresholds based the sensitivity level of the metabolic syndrome risk quantification (*ASD*; *Areal Similarity Degree*) model and the temporal change analysis ($d_N(2)$; *Chronological Distance Function between two medical examination result*) model proposed by Jeong et al. [2][3]. Figure 3 shows the three service levels based on patient tier classification thresholds. In the figure, the green graph indicates that the current medical report has not been changed since the previous report. The blue and the red graph indicate that there are minor and major change between the current and the previous reports, respectively. Thus, a physician can easily recognize the temporal change on patient's disease status with ambient interface. In the basic service level, the sensitivity level α is determined as TH_1 to indicate major change of patient disease status. We chose 0.5 for the value of TH_1, so when the distance value $d_N(2)$ of the current report value and the previous one is greater than or equal to 0.5, it is notified to the physician that the patient disease status was changed since the last examination. When the $d_N(2)$ is less than 0.5, the examination results are not notified to the physician. For the standard service level, sensitivity level α is determined as TH_2 to indicate moderate and major change of patient disease status. We chose 0.75 for the value of TH_2. So, when $d_N(2)$ is greater than or equal to 0.25, the patient's status change is notified to the physician. For the premium service level, the sensitivity level α is determined as TH_3 to indicate changes including minor change of patient disease status. We chose 0.95 for the value of TH_3. So, when $d_N(2)$ is greater than or equal to 0.05, the patient's disease status change is notified to the physician.

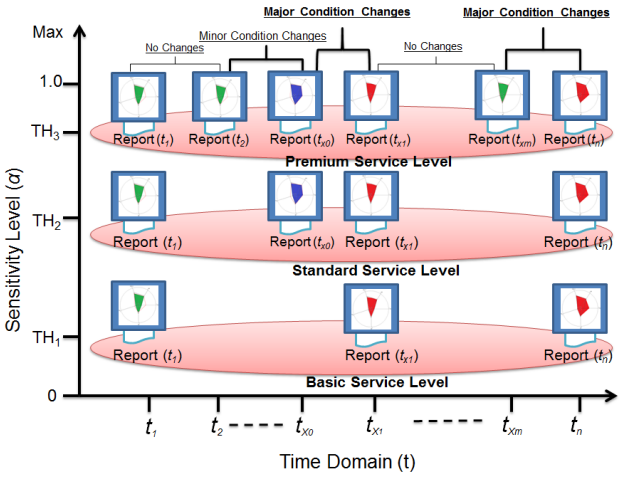

Fig. 3. Sensitivity for temporal change of disease status according to different values of α

According to the disease care service levels of metabolic syndrome shown in Fig. 2, we classify at-home services into three levels according to the patients' disease tiers, basic for *TIER(1)* and *TIER(2)*, standard for *TIER(3)*, and premium for *TIER(4)*, respectively. Table 1 lists the criteria for patients tier classfication. We consider metabolic syndrome only in this paper, so the Table 1 describes criteria for metabolic syndrome patients. However, the criteria may be applicable to other chronic diseases, if risk quantification models for other chronic diseases are established. Each patient's tier is determined based on the proposed tier classification criteria. The high risk patient is classified into *TIER(4)* group. A patient with medium risk is classified into *TIER(3)* group, while low or very low risk patient is classified into *TIER(1)* and *TIER(2)*, respectively.

Table 1. Patient's Tier Classification based on Metabolic Syndrome Risk Thresholds

Patient TIER (Threshold)	*TIER(1)* ($ASD < TH_1$)	*TIER(2)* ($TH_1 \leq ASD < TH_2$)	*TIER(3)* ($TH_2 \leq ASD < TH_3$)	*TIER(4)* ($TH_3 \leq ASD$)
Patient Health Risk	Very Low	Low	Medium	High

To establish the values of the thresholds for patient tier classification, we performed metabolic syndrome patient tier classification analysis using a large number of clinical data. The analysis is based on data obtained from the third Korea National Health and Nutrition Examination Survey (KNHANES III) among non-institutionalized civilians in the Republic of Korea, which was conducted by the Korean Ministry of Health and Welfare in 2005. This survey was a nationwide representative study using a stratified, multistage probability sampling design for the selection of household units. The survey consisted of the following 4 components: the Health Interview Survey, the Health Behavior Survey, the Health Examination Survey, and the Nutrition Survey [4]. A total of 34,145 individuals from these sampling frames were included in the health interview survey; among them, 25,161 subjects aged over 20 years were identified as potential participants in our study. We excluded those with incomplete data for the standardized analysis. This resulted in a final analytical sample of 5,355 subjects (2276 male, 3079 female), aged over 20 years. A total of 5,355 subjects (aged over 20 years) were included in this paper. The proportion of female subjects was higher than male (57.47% vs. 42.53%). The mean ages of the male and female subjects were 47.22±14.61 and 46.99±15.62 years, respectively. The average BMI was 23.99±3.10 and 23.52±3.38 kg/m2 for male and female subjects, respectively. The percentage of subjects with diabetes mellitus in the male group was higher than that in the female group (6.90% vs. 4.48%). Also, 22.98% of the male subjects had hypertension, whereas 14.68% of the female subjects did. In this paper, we have classified total subjects into two subject groups by gender and further classified each subject group into three sub-groups by age: young-adult (from 20 to 39 years old), middle-aged (from 40 to 64 years old), and old-aged (more than 65 years old), respectively. Therefore, we use a total of six sub-groups for the evaluation of our proposed risk quantification model [2]. To perform in-depth analysis regarding the determination of ASD thresholds, we further divided each sub-group into four Cases, as listed in Table 2. Since the objective of patient tier classification is to categorize chronic disease patients according to disease risk, we

chose thresholds for patients tiers based on the incidence of MS disease, i.e., the percentages of patients over given ASD values. Table 3 shows the criteria for determining tiers' thresholds.

Table 2. Detailed Sub-cases of Each Subject-group [2]

Case 1	A subject whose ASD value exceeds ASD threshold and having MS
Case 2	A subject whose ASD value exceeds ASD threshold and NOT having MS
Case 3	A subject whose ASD value does NOT exceed ASD threshold and having MS
Case 4	A subject whose ASD value does NOT exceed ASD threshold and NOT having MS

Table 3. Criteria for Determining Thresholds of Patients Tiers

Patient TIER	*TIER(1)* ($ASD < TH_1$)	*TIER(2)* ($TH_1 \leq ASD < TH_2$)	*TIER(3)* ($TH_2 \leq ASD < TH_3$)	*TIER(4)* ($TH_3 \leq ASD$)
Criteria for ASD values	Incidence of MS(Metabolic Syndrome) patients is			
	Less than 50%	Less than 75%	Less than 95%	Greater than or equal to 95%

Figure 4 shows the percentages of MS subjects over ASD values for each male subject.

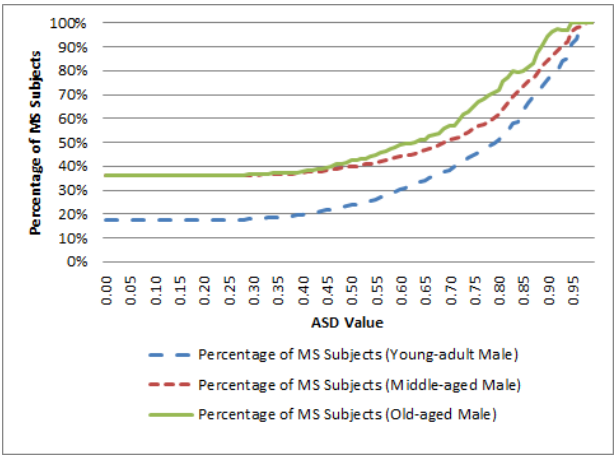

Fig. 4. ASD thresholds for TIER classification of male subjects

Figure 5 shows the percentages of MS subjects over ASD values for each female subject. Table 5 lists the determined ASD thresholds. To sum it up, the rate of MS is higher in female than in male for all ages, especially women are more susceptible to MS as they get older.

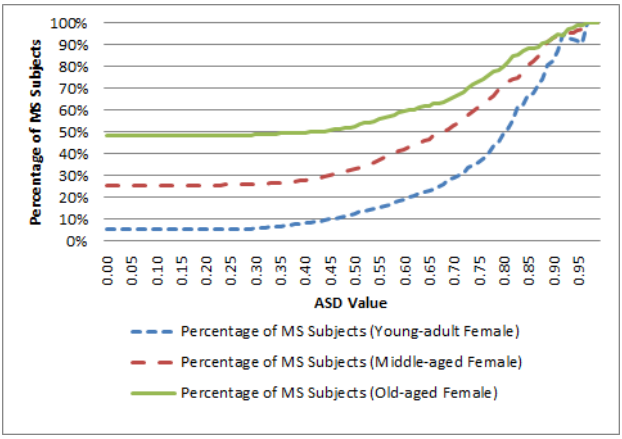

Fig. 5. ASD thresholds for TIER classification of female patients

As described in Table 3, we chose ASD thresholds according to the percentages of MS subjects. Table 4 and Table 5 list the determined ASD thresholds for male subjects and female subjects, respectively.

Table 4. ASD Thresholds for Male Subjects Sub-groups

Patient tier	TIER(1)	TIER(2)	TIER(3)	TIER(4)
Young-adult	$ASD<0.80$	$0.80\leq ASD<0.90$	$0.90\leq ASD<0.97$	$0.97\leq ASD$
Middle-aged	$ASD<0.69$	$0.69\leq ASD<0.86$	$0.86\leq ASD<0.95$	$0.95\leq ASD$
Old-aged	$ASD<0.63$	$0.63\leq ASD<0.81$	$0.81\leq ASD<0.91$	$0.91\leq ASD$

Table 5. ASD Thresholds for Female Subjects Sub-groups

Patient tier	TIER(1)	TIER(2)	TIER(3)	TIER(4)
Young-adult	$ASD<0.81$	$0.81\leq ASD<0.89$	$0.89\leq ASD<0.97$	$0.97\leq ASD$
Middle-aged	$ASD<0.68$	$0.68\leq ASD<0.84$	$0.84\leq ASD<0.92$	$0.92\leq ASD$
Old-aged	$ASD<0.43$	$0.43\leq ASD<0.77$	$0.77\leq ASD<0.93$	$0.93\leq ASD$

The gender differences on the MS related factors have been discussed in many literatures. Among them, Regitz-Zagrosek et al. reviewed on gender differences in the metabolic syndrome. They discovered the gender difference of the components in MS like glucose intolerance pattern, different lipid accumulation pattern in male and female, and its morphological change for postmenopausal women. These factors

affects higher incidence of MS in female group. Also the high development rate of MS in postmenopausal women can be related to sex hormone. The sex hormone which determines the physical and functional characteristics in male and female is thought to be the factor that affects the gender different glucose intolerance and lipid metabolism. Among them, it was revealed that estrogen has an important role in energy homeostasis and metabolic syndrome in both men and women from the studies using estrogen deficient animal models and in estrogen deficient men. A deficiency of estrogen like menopause and/or aging leads to higher incidence of metabolic syndrome in female than in male [8-9]. The distributions of frequency counts and percentage of MS subjects over *ASD* value shown in this sub-section indicate difference pattern among gender and age groups, which complies with the literatures. Therefore, we can claim that our proposed method effectively representing the risk of MS disease.

4 Conclusions

To efficiently manage chronic disease patients, we proposed a patient status classification method for chronic disease, particularly metabolic syndrome care based on service level agreements. The proposed method classified the status of patients' tier having metabolic syndrome using areal similarity degree analysis model and chronological distance function. We evaluated the proposed method using data obtained from the third Korea National Health and Nutrition Examination Survey among non-institutionalized civilians in the Republic of Korea, which was conducted by the Korean Ministry of Health and Welfare in 2005. The evaluation results showed that our proposed method could classify patients' metabolic syndrome risk status.

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References

1. March, R.: Delivering on the promise of personalized healthcare. Personalized Medicine 7(3), 327–337 (2010)
2. Jeong, S., Jo, Y.M., Shim, S.-O., Choi, Y.-J., Youn, C.-H.: A Novel Model for Metabolic Syndrome Risk Quantification Based on Areal Similarity Degree. Under Review on IEEE Transactions on Biomedical Engineering (2013)
3. Jeong, S., Youn, C.-H.: A Method for Identifying Temporal Progress of Chronic Disease Using Chronological Clustering. In: Under Review on 15th International Conference on E-Health Networking (2013)
4. Korea Centers for Disease Control and Prevention (KCDC). The Third Korea National Health and Nutrition Examination Survey, KNHANES III (2005), `http://knhanes.cdc.go.kr/knhanes/index.do`
5. Bae, S., Lee, M.K.: Definition and Diagnosis of the Metabolic Syndrome. Journal of the Korean Medical Association 48(12), 1157–1164 (2005)

6. Jeong, S., Youn, C., et al.: An Integrated Healthcare System for Personalized Chronic Disease Care in Home-Hospital Environments. IEEE Transactions on Information Technology in Biomedicine 16(4), 572–585 (2012)
7. Hunt, K., Resendez, R.G., Williams, K., Haffner, S., Stern, M.: National Cholesterol Education Program versus World Health Organization metabolic syndrome in relation to all-cause and cardiovascular mortality in the San Antonio Heart Study. Circulation 110, 1251–1257 (2004)
8. Regitz-Zagrosek, V., Lehmkuhl, E., Weickert, M.: Gender differences in the metabolic syndrome and their role for cardiovascular disease. Clinical Research in Cardiology 95(3), 136–147 (2006)
9. Simpson, E.R., et al.: Estrogen—the Good, the Bad, and the Unexpected. Endocrine Reviews 26(3), 322–330 (2005)