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Integrating Geographic Information into Diabetes Disease Management

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***Abstract*—**Background: Traditional chronic disease management did not pay attention to effects of geographic factors on the compliance of treatment regime, which resulted in geographic inequality in outcomes of chronic disease management. This study aims to examine the geographic distribution and clustering of quality indicators of diabetes care. Method: We first extracted address, demographic information and quality of care indicators (number of visits, complications, prescription and laboratory records) of patients with diabetes for 2014 from medical information system in a medical center in Tainan City, Taiwan, and the patients' addresses were transformed into district- and village-level data. We then compared the differences of geographic distribution and clustering of quality of care indicators between districts and villages. Despite the descriptive results, rate ratios and 95% confidence intervals (CI) were estimated for indices of care in order to compare the quality of diabetes care among different areas. Results: A total of 23,588 patients with diabetes were extracted from the hospital data system; whereas 12,716 patients' information and medical records were included to the following analysis. More than half of the subjects in this study were male and between 60-79 years old. Furthermore, the quality of diabetes care did indeed vary by geographical levels. Thru the smaller level, we could point out clustered areas more specifically. Fuguo Village (of Yongkang District) and Zhiyi Village (of Sinhua District) were found to be "hotspots" for nephropathy and cerebrovascular disease; while Wangliau Village and Erwang Village (of Yongkang District) would be "coldspots" for lowest proportion of ≥80% compliance to blood lipids examination. On the other hand, Yuping Village (in Anping District) was the area with the lowest proportion of ≥80% compliance to all laboratory examination. Conclusion: In spite of examining the geographic distribution, calculating rate ratios and their 95% CI could also be a useful and consistent method to test the association. This information is useful for health planners, diabetes case managers and other affiliate practitioners to organize care resources to the areas most needed.

***Keywords*—**Geocoding, chronic disease management, quality of diabetes care, rate ratio.

I. Introduction

DIABETES mellitus (DM) is a chronic condition of the metabolic system; once contracted, it is life-long, affecting patients' quality of life as well as taking a heavy toll on medical resources [1]. Nevertheless, the prevalence of DM is ever on the increase all over the world [2], including Taiwan [3]. Numerous studies point out ineffective management of diabetes can lead to many complications; in contrast, when efforts are made towards timely and appropriate blood sugar management, complications can be delayed or prevented altogether [4]. Therefore, diabetes management is the topmost priority in both national health insurance providers and in the institutional case management of patients [4]-[7].

Analyses of chronic disease care have traditionally followed the natural course of the disease, mostly focusing on patient characteristics and the progression of the disease throughout time. Rare studies have investigated the effects of geographical characteristics on care; Macintyre et al. summarized the following five geographical characteristics that affect health:

(1) Physical features of the environment, such as air quality, water, climate, etc.;
(2) Availability of healthy environment at home, work and play, such as secure and non-hazardous employment, decent housing, safe play areas for children, etc.;
(3) Public or private services provided to support people in their daily lives, such as education, transport, street cleaning and lighting, health and welfare services;
(4) Socio-cultural features of a neighborhood, such as the degree of community integration and the religious history of a community; and
(5) The reputation of an area – namely how areas are perceived by their residents, by service of amenity planners and providers, may influence the infrastructure of the area as well as the self-esteem and morale of the residents [8].

There is still a paucity of research on the effects of geographic features on the care of DM [9]. An Australian study published in 2015 analyzed the care elderly diabetics by statistical areas and found the quality of care were poor in some areas [10], but was unable to represent their findings in a map form due to the small size of the statistical areas, thus limiting the study's usefulness for municipal health planners to draft and implement policies to improve care.

Since the level of village can represent differing geographical areas and at the same time preserve patient privacy, this study will therefore use village as an administrative unit, as well as its next higher geographical level – districts, to investigate the quality of diabetes care by different geographical regions.

II. Methods

A. Data Sources

This study utilizes data retrieved from a data warehousing system in a medical center located in Yongkang District, Tainan City, Taiwan. Tainan City is located in northwestern Taiwan, with an area of 2,192 km^2 and a population of

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1,886,000. It is located on the flat Jianan Plain flanked by several hills and mountains on the eastern parts. Yongkang District is located in the southwestern end of the city center and is currently the most populated area in Tainan. The data warehousing system was designed for the purpose of query, analysis and rapid reporting. Therefore, researchers could retrieve and utilize the care-specific data from various departments of the institution, as well as extensive patient basic information and care records.

B. Data Collection and Preparation

Diabetes patients with any out-patient visits during January 1st-December 31st, 2014 were identified using the data warehousing system. Diabetes was defined as ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) 250. Encrypted chart numbers, birthdates, date of first out-patient visit in 2014 and current residential address of these individuals were retrieved. The encrypted chart numbers were used to link to the following databases for the retrieval of patients' clinical data: 1) outpatient medical orders database, 2) inpatient medical orders database, 3) clinical examinations database, and 4) outpatient prescription database.

Geocoding was performed on the residential addresses of the subjects using the census tract from NGIS [11] website provided by the Ministry of the Interior, which converts the address to its corresponding coordinates and the levels of districts and villages. Once the district and village level of the patients' addresses were obtained, the data were checked and revised for errors or repeats. Since some diabetes patients may not be consulting for diabetes per se at the medical center in this study, this study will only include patients who were residing in Tainan City, had four or more outpatients visits with diagnosis of diabetes, and had prescription for diabetes medications (medications with Anatomical Therapeutic Chemical code A10 [12]) for further analysis. Fig. 1 shows the selection of geocoded study subjects.

C. Data Analysis

Quality of diabetes care was assessed using the following parameters:

(1) Compliance to medication: calculated as total days of out-patient diabetes prescription in one year, divided by 365 days, multiplied by 100%, then dichotomized as being ≥80% or not.
(2) Orders for laboratory examination: estimated by the total number of medical orders for blood glucose, lipid profile, and renal function from out-patient visits in one year.
(3) Compliance to laboratory examination: calculated as the number of laboratory examinations in (2) actually performed, divided by the number ordered in (2), multiplied by 100%, then dichotomized as being ≥80% or not.
(4) Complications: presence of out-patient or in-patient diagnosis codes (ICD-9-CM) for nephropathy (250.4, 585), retinopathy (250.5, 362.0), neuropathy (250.6, 357.2), cardiovascular disease (401-405, 140-414, 428), cerebrovascular disease (431-438), and peripheral vascular disease (250.7, 443.8, 443.9) in one year [13], [14].

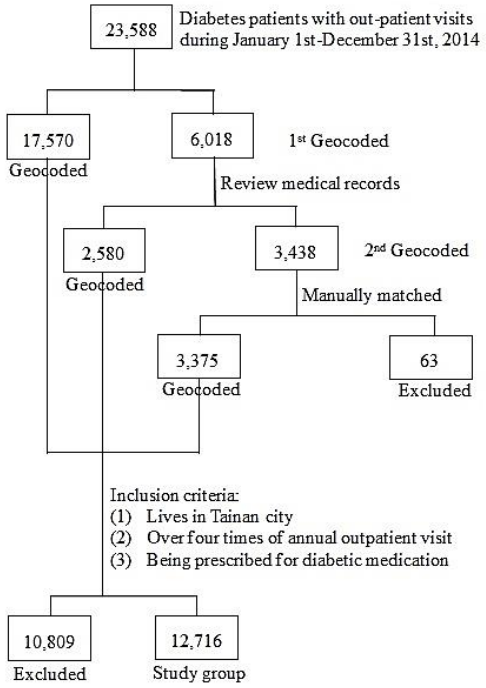

Fig. 1 Geocoding of patients with type 2 DM

Once the above individual parameters were estimated for each village, district and for Tainan City, rate ratios with 95% CI of each village and district to Tainan City were estimated [15] for comparison of the quality of diabetes care between different regions. Analyses were performed using SAS 9.4 (Cary, NC, USA) and Microsoft Office Excel (2010) for data processing and rate estimation, and Tableau Public (10.2) for mapping and presentation. The study was approved by the hospital's institutional review board.

III. Results

23,588 DM patients were identified from the hospital data system and their corresponding basic information, out-patient and admission records in 2014 were likewise retrieved. Among these patients, 17,570 (75%) were successfully geocoded. For the remainder, hard copies of medical records were reviewed for their residential address to revise the data for a second attempt at geocoding. Of those who were still not successfully geocoded at the second attempt, their addresses were manually matched to the level of village using the Doorplate Change query website provided by the Department of Household Registration, Ministry of the Interior [16]. Lastly, 99.73% of DM patients were matched and then selected using the following three criteria: 1) Residing in Tainan City, 2) four or more out-patient visits (regular treatment), and 3) prescription for diabetes medication. A total of 12,716 patients were included for this study (Fig. 1).

A. Patient Characteristics

More than half of the subjects in this study were male (53.22%) and between 60-79 years old (54.18%). The second most common age-group was 40-59 years (30.68%).

For indices of quality care, the mean compliance rate was 78.07% (SD 31.78%), and seven out of ten patients were highly-compliant (compliance rate □80%). Rates for four or more orders for laboratory examinations of blood glucose, blood lipids and renal function were 63.35%, 18.76% and 43.97%, respectively, and three out of four patients were □80% compliant to these examination orders. In terms of complications, around 70% had cardiovascular disease, 30% had nephropathy, 5% had peripheral vascular disease and 5% had retinopathy (Table I).

B. Patient Geographical Distribution

As can be seen in Fig. 2, at the level of districts, most (around one in five) patients resided in Yongkang District, the district where the hospital is located in, followed by Annan District and North District. At the level of villages in Yongkang District, most patients reside in Fuhua Village, Yanxing Village, and Erwang Village.

C. Spatial Analysis of Diabetes Management

In order to compare the quality of diabetes care among different areas, rate ratios and 95% CI were estimated for indices of care. Because of the large number of villages as well as the differing population sizes renders a geographical representation unsuitable, results of spatial analysis of care is instead represented in table form – Table II lists the three poorest (lowest compliance, highest complications) diabetes care areas with population over 20. Table II demonstrates that quality of diabetes care does indeed vary by geographical levels. However, it is worth noting that Fuguo Village (of Yongkang District) and Zhiyi Village (of Sinhua District) were found to be "hotspots" for nephropathy and cerebrovascular disease, which were considered complications of diabetes. On the other hand, Wangliau Village and Erwang Village (of Yongkang District) were found to be "coldspots" for lowest proportion of □80% compliance to blood lipids examination. Furthermore, Yuping Village (in Anping District) had the lowest proportion of □80% compliance to all laboratory examination.

TABLE I
CHARACTERISTICS OF PATIENTS WITH TYPE 2 DM

		Number (%)
Sex	Male	6768 (53.22)
	Female	5948 (46.78)
Age group	<20	57 (0.45)
	20-39	437 (3.44)
	40-59	3901 (30.68)
	60-79	6889 (54.18)
	≧80	1432 (11.26)
Compliance rate of medication	≧80%	8525 (67.04)
≧4 times of laboratory examination ordered	Glucose	8056 (63.35)
	Lipid	2385 (18.76)
	Renal function	5591 (43.97)
≧80% Compliance of laboratory examination	Glucose	9554 (75.13)
	Lipid	9413 (74.02)
	Renal function	9789 (76.98)
Complication	Nephropathy	4207 (33.08)
	Retinopathy	696 (5.47)
	Neuropathy	1961 (15.42)
	Cardiovascular disease	9020 (70.93)
	Cerebrovascular disease	2453 (19.29)
	Peripheral vascular disease	625 (4.92)

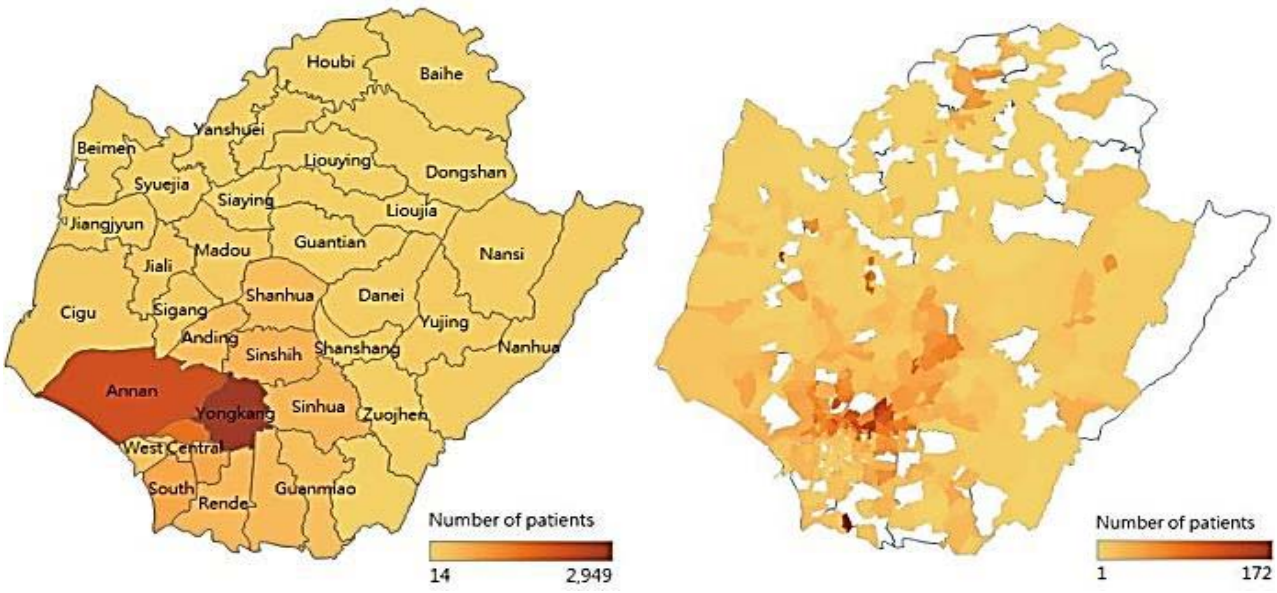

Fig. 2 The geographical distribution of the number of diabetic patients

TABLE II
TOP THREE POOREST QUALITY AREAS IN INDICES OF DIABETES MANAGEMENT, ESTIMATED BY DIFFERENT GEOGRAPHICAL LEVELS

Indices		District[a] (rate, %)	Village, District[a] (rate, %)
Complication	Nephropathy	Danei (44.59)*	Dongsheng, East (56.00)*
		Yongkang (35.47)*	Fuguo, Yongkang (50.00)*
		Nanhua (35.94)	Huaxing, North (47.50)
	Retinopathy	West Central (8.41)*	Liujia, Anding (19.05)*
		Sinying (10.29)	Chongxing, North (16.00)*
		Madon (8.87)	Guozhai, South (16.00)*
	Neuropathy	Beimen (26.09)*	Huwei, East (33.33)*
		Anping (21.09)*	Quanxing, Sinhua (33.33)*
		Lioujia (23.53)	Zongtou, Annan (32.35)*
	Cardiovascular disease	Syuejia (83.33)*	Yuanxi, Annan (88.24)*
		Anping (77.45)*	Dongsheng, East (88.00)*
		North (73.28)*	Dianxi, Annan (85.71)*
	Cerebrovascular disease	Nanhua (32.81)*	Zhiyi, Sinhua (39.39)*
		Yujing (27.27)*	Yuping, Anping (39.29)*
		Sinhua (24.94)*	Zongtou, Annan (38.24)*
	Peripheral vascular disease	Shanshang (8.24)	Sicao, Annan (24.00)*
		Guantian (7.69)	Wennan, South (16.00)*
		Beimen (6.52)	Dianxi, Annan (14.29)*
Compliance rate of medication	≧80%	Yongkang (64.63)*	Daliang, West Central (38.46)*
		Siaying (57.89)	Daan, Annan (52.54)*
		Nanhua (59.38)	Chongxing, North (52.00)
≧80% Compliance of laboratory examination	Glucose	Lioujia (58.82)	Dawan, Syuejia (58.62)*
		Guantian (66.67)	Yuping, Anping (53.57)
		Sinying (69.12)	Xuedong, Annan (55.17)
	Lipid	Yongkang (72.06)*	Yuping, Anping (50.00)*
		Sinying (64.71)	Wangliau, Yongkang (60.47)*
		Yujing (68.18)	Erwang, Yongkang (65.56)*
	Renal function	Yanshuei (66.67)	Yuping, Anping (53.57)*
		Sinying (67.65)	Diandong, Annan (53.85)*
		Sinhua (72.66)	Wangliau, Yongkang (65.12)*

Poorest quality areas: The highest rate of complications, lowest rates of compliance. a Areas with population over twenty. * 95% CI shows statistically significant difference between specific district/village and overall Tainan city.

IV. CONCLUSION

This study estimated rate ratios and their 95% CI to identify districts or villages with poorer diabetes care in comparison to Tainan City as a whole: indices of care in some areas were found to be significantly different from those overall. Furthermore, since the smallest administrative unit in this study is at the level of village, findings of this study not only can be clearly represented in an easy-to-understand map form, but can also be used directly by municipal health planners, diabetes case managers and other affiliated practitioners to organize and allocate care resources to the most needed areas.

However, this study still has limitations in its inability to explain its findings in a more extensive manner. Future similar studies may incorporate other factors such as socio-economic data, or conduct qualitative studies such as in-depth interviews. Further and better-developed diabetes care studies with geographical information are needed to achieve the most appropriate allocation of limited healthcare resources.

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