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Original Article

Spatial Distribution of Total Number of Medical Devices in Turkey: A Classification Analysis

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ABSTRACT

Introduction: Unbalanced distribution of medical technologies and devices between rural and urban parts of the country is a major problem for developing countries like Turkey. In Turkey, after the establishment of Public Hospital Unions (PHUs), legislative changes were made to ensure the autonomy of public hospitals. **Aims:** This study aims to analyze the spatial distribution of medical devices in Turkey using PHUs as a decision-making unit. **Methods:** Data came from the 2014 PHUs statistics year book. The total number of PHUs is 89. A hierarchical cluster analysis was performed to classify PHUs according to the total number of different kinds of medical devices. A Euclidean distance measure and Wards method were used in the analysis. **Results:** Study results show that, in Turkey, PHUs consist of 2 different clusters. The first represents PHUs in rural Turkey, and the second represents PHUs in urban Turkey. PHUs which represent big cities of Turkey and have high population density are in the first cluster, and all other PHUs are in the second. **Conclusions:** It is advisable for health policy makers and health technology assessment authorities in Turkey to focus on the differences between rural and urban parts of the country during the re-evaluation of medical technology resource allocation decisions. Further studies could explore the accessibility, safety, and usability of medical technologies. We anticipate that these efforts will form a basis to improve the surveillance and efficiency of the medical devices market in developing countries.

Key words: Medical Devices, Developing Countries, Turkey, Public Hospital Unions (PHUs), Hierarchical Cluster Analysis.

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INTRODUCTION

The global economy is becoming more integrated, even though big differences still exist between developed and developing countries.[1] Changing market demands and patient expectations are shaping health care and other service industries. As health care costs increase, health care companies must be able to develop products that best meet patient needs.[2] Health technology is expanding quickly, and the medical device industry plays a major role. Innovation in the medical device industry has brought many benefits to patients, especially those in developing countries. Furthermore, integration of the medical device industry will improve policies and increase cooperation between various stakeholders.[1] Studies have shown that incorporate patient's expectations into the innovation process improves public health in many countries.[3]

A medical device can be described as "a health care product that does not achieve its purpose by chemical action or metabolization." The medical device industry is comprised of an extremely large variety of products and technologies.[4] Therefore, financing is a key element for continued medical device innovation.[5] These devices play a major role in the practice of medicine[1] and are an important part of the European manufacturing sector. They provide a key input into the health care system.[4] The main purposes of medical devices are the diagnosis, prevention, monitoring, and treatment of diseases.[6]

The worldwide medical devices market is still improving, but an imbalance between developed and developing countries still exists.[1] As a candidate of European Union (EU) membership, Turkey arranges its medical device industry closely with those in the EU.[7] In Turkey, health care is predominantly financed by the public sector, which is responsible for 63% of its total expenditures. The Ministry of Health (MoH) in Turkey is the largest provider of preventive health care services in the country.[8] The healthcare system in Turkey has been under the "Health Transformation Program" since 2003. According to the World Bank Classification, Turkey has a growing medical technology market and health care services system.[8] Moreover, MoH regulates medical devices market in the country. In 2012, MoH made managerial changes in the health system. With these changes, the prima-

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ry aim of MoH was to become "a policy maker and supervisory" body. These reform policies have concentrated on the utilization and financing of health care services. As a part of these improvements, 2 new directorates were established under MoH in Turkey. These are the Public Hospital Institution and the Turkish Pharmaceutical and Medical Device Agency. PHUs were generated under the Public Hospital Institution, and this improved the financial and managerial autonomy of health care organizations. In addition, the Pharmaceutical and Medical Device Agency was established to regulate the pharmaceutical and medical device market.[7]

The US Commercial Service[8] prepared a summary report about the medical device industry in Turkey. This report states that there are about 6,000 companies operating in Turkey in the medical equipment and devices market. Furthermore, there are about 100 medical equipment manufacturers throughout the country. These companies are manufacturing surgical instruments. When we look at national institution reports about health technologies in Turkey, the Turkish Patent Institute (TPI) is an independent institution with a special budget under the Ministry of Industry and Trade. The major aim of this institution is to support and develop technological development in Turkey.[9] TPI also supports development in the medical device industry. According to the statistics of TPI, the total number of patent applications for medical and surgical equipment and orthopedic appliances increased between 2000 and 2014.[9]

According to the classification of the Organisation for Economic Co-operation and Development (OECD), the major types of medical devices are Magnetic Resonance (MR), Computed Tomography (CT), Mammography (MAM), Ultrasonography (USG), and Electrocardiography (ECO). MR is a medical imaging technique. This technique used in radiology for medical diagnosis and treatment; it helps physicians diagnose some conditions by producing images of organ structures of the body. Another well-known medical device is CT. This is one of the diagnosis techniques that produces images of organs and other parts of the body.[10] MAM is another type of medical device, commonly used for the early detection of breast cancer in most OECD countries. Medical ultrasound is a medical device used to find a source of a disease or to exclude any pathology.[6] Finally, ECO is the process of recording the electrical activity of the heart for some period of time by using electrodes placed on the skin. It is a well-known cardiology test method.[6]

Studies shows that big manufacturing companies exist in the medical device market, while a number of small players also exist. Population density affects the medical device market of any country. The number of new medical devices is increasing in countries with a high population density, yet there is still a need to improve access to medical devices in these countries.[11] Local production and technology transfers are one of the ways to improve accessibility.[12] Nowadays, many developing countries are improving their health care system in terms of accessibility to new health technologies in order to support their poorest citizens.[13] This is especially important for developing countries, because these technologies have the potential to speed up clinical procedures, medical devices and clinical decision support systems.[14] Having professional authority is one of the ways of improving technologies. According to the 2014 Public Hospital Institutions statistics year book, there are a total of 89 (PHUs) throughout the country.[15] This system allow PHUs to outsource some medical and non-medical services such as laboratory, diagnostic imaging, cleaning, laundry, and food services.[15]

One of the aims of PHUs is to develop an autonomy of health decision-making authorities in rural and urban parts of the country because literature suggests that large inequalities between rural and urban parts of Turkey exist interms of general health indicators. In one of these studies, Yikilkan *et al.* (2013)[16] have found statistically-significant differences in diagnosis, gender, age, and consultation time between clinics in rural and urban parts of the country. Ergin and Kunst (2015)[17] examined regional inequalities in self-rated health, and study results indicate differences between rural and urban parts of the country. Another study, done by Oguzturk (2008),[18] analyzed the differences in quality of life between rural and urban populations. The results suggest that people living in rural areas of the country have poorer scores of quality of life. In addition to the difficulties with access to basic health care services, literature supports the idea that one of the major health problems for developing countries is the scarcity of medical devices in rural parts of the country. These accessibility and unbalanced distribution problems have affected the spatial distribution of health services and health technologies. This is especially important for Turkey, which is both a developing country and a candidate for full membership of the EU.[19] Even though there are some studies about spatial distribution of general health care services in Turkey, medical devices are neglected. To fill this gap in the literature, the main focus of this study is to analyze spatial distribution of medical devices in Turkey using PHUs as a decision-making unit.

MATERIAL & METHODS

Dataset

In this study, data came from the Republic of Turkey, MoH, and the 2014 Public Hospitals Agency statistics year book. The types of medical devices included in this study are MR, CT, MAM, USG, and ECO. In this study MR refers to medical imaging technique used in hospitals and clinics for medical diagnosis and treatment. CT techniques help physicians diagnose a range of conditions by producing images of organs in the body. MAM is a method to detect breast cancer early, when it is most treatable. USG is a method that uses high-frequency sound waves to produce images of internal organs and other tissues. ECO is the process of recording the electrical activity of the heart over a period of time using electrodes placed on the skin.[4,6,11] In this study the dataset includes the number of medical devices from each of the 5 different types, which combine for a total of 89 PHUs.

Data Analysis

Cluster analysis was performed to classify PHUs into groups based on the number of different medical device types. The agglomerative hierarchical clustering method was used in order to analyze the spatial distribution of PHU medical devices. Hierarchical cluster analysis is a useful method to find analogous groups in data sets.[20] This method connects data points based on a measure of distance between data points in order to form clusters. This can be expressed visually as a dendrogram.[21] Before performing hierarchical cluster analysis, a Z transformation was performed in order to bring the coefficients to zero-one range.[22] This prevented the differences between variables measurement units from affecting the study results. A Euclidean distance measure and Wards method were used to determine the natural number of relevant clusters.

RESULTS

Descriptive Statistics

Table 1 shows descriptive statistics of the 89 PHU medical devices. The mean value for MR is 2.88 (± 2.30), CT is 5.24 (± 3.78), MAM is 3.61 (± 2.75), USG is 30.70 (± 24.38), and ECG is 10.13 (± 9.02).

Cluster Analysis Results

Cluster analysis results shows that there are 2 clusters according to the total number of medical devices of PHUs. According to these results, Cluster 1 consists of 60 PHUs and Cluster 2 consists of 29. Moreover, study results highlight that PHUs representing rural parts of the country are in the first cluster, and those representing urban parts of the coun-

Table 1: Descriptive Statistics.

All Public Hospital Unions (n=89)		
Indicator	**Mean**	**Sd.**
Magnetic Resonance (MR)	2.88	2.30
Computed Tomography (CT)	5.24	3.78
Mammography (MAM)	3.61	2.75
Ultrasonography (USG)	30.70	24.38
Electrocardiography (ECG)	10.13	9.02

Figure 3: (a) PHUs which are in the first cluster and located in rural parts of the country (b) PHUs which are in the second cluster and located in urban parts of the country.

try are in the second cluster. PHUs in the first cluster are; Erzincan, Uşak, Aksaray, Muş, Elazığ, Sivas, Çanakkale, Mardin, Bitlis, Şırnak, Bilecik, Sinop, Kırklareli, Batman, Hakkari, Karabük, Kastamonu, Siirt, Bartın, Kilis, Ardahan, Iğdır, Yalova, Artvin, Bingöl, Kars, Niğde, Düzce, Gümüşhane, Çankırı, Amasya, Kırıkkale, Kırşehir, Bayburt, Tunceli, Karaman, Nevşehir, Giresun, Isparta, Afyonkarahisar, Edirne, Osmaniye, Burdur, Ağrı, Rize, Ordu, Tekirdağ, Tokat, Kütahya, Denizli, Sakarya, Çorum, Kayseri, Zonguldak, Adıyaman, Van, Bolu, Malatya, Eskişehir, Yozgat. PHUs in the second cluster are; Diyarbakır, Erzurum, Adana, Kahramanmaraş, Muğla, Balıkesir, Hatay, Aydın, Gaziantep, İstanbul (Çekmeköy), İstanbul (Bakırköy), Şanlıurfa, Trabzon, Ankara (2. Bölge), Konya, Ankara (1. Bölge), İstanbul (Anadolu-Kuzey), İstanbul (Anadolu-Güney), İstanbul (Fatih), İzmir (Güney), Manisa, Mersin, Kocaeli, Samsun, Antalya, Ankara (3. Bölge), Bursa, İstanbul (Beyoğlu), İzmir (Kuzey).

Figure 1 shows the spatial distribution of PHU clusters on a map of Turkey. In this map, yellow color represents the first cluster and orange represents the second cluster. This map confirms that PHUs in the first cluster are representing rural parts of the country with low population densities and PHUs in the second cluster represent urban parts of the country with high population densities. Statistical test results about the differences between two clusters in terms of total number of medical devices confirm that the 2 clusters are different according to the total number of MR (t=-14.10, p<0,01), CT (t=-15.75, p<0.01), MAM (t=-11.40, p<0.01), USG (t=-14.62, p<0.01) and ECG (t=-12.29, p<0.01).

DISCUSSION

Health technologies and medical devices have the potential to transform and improve health care systems.[23] Turkey's health system has experienced major transformations since 2003. One of the main aims of MoH in Turkey is the reorganizing of medical technology and medical devices with the Health Transformation Program.[15] Despite transformations in the general health care system, inequalities between developed and underdeveloped parts of the country remain.[24] Closing the gap between rural and urban parts of the country is one of the main aims to improve health in Turkey.[25]

Older literature refers to the difference between rural and urban Turkey according to the access to main health care services.[26] The traditional approaches indicate that there is a difference between rural and urban health in terms of utilization, spending, and geographic distribution of service providers.[27] Apart from access to main health care services, health technology usage between rural and urban parts of the country still remains a problem. Studies emphasizing the differences between rural and urban Turkey have stated that health professionals' adaptation of technology is one of the major reasons for health technology usage differences between rural and urban parts of the country. Menachemi *et al.* (2007)[28] defends the view that rural physicians are less likely to use health technologies and need assistance. These findings show that there is a need for further efforts to overcome the barriers of health technology usage and the adaptation problems of health technologies between rural and urban parts of the country. The existing literature states that there is a big difference in access to medical technologies between rural and urban parts of Turkey; however, Singh *et al.* (2011)[29] have found that technology adaptation and usage in rural areas do not appear to be lower than in urban areas. Another study concludes that improving innovative wireless health technologies can be a good alternative for overcoming barriers in rural health care.[30] Moreover, literature suggests that from an inequality perspective, differences in access to new health technologies between rural and urban parts of the country causes an inequality problem. This has the potential to affect global health care system performance in general.[31]

Health technologies, including medical devices, are important for the good functioning of health systems. Technology plays a key role in current clinical practices.[32] Poorly-designed health technologies prevent patients from accessing good care[33] and medical devices play a major role in preventing, diagnosing and treating illnesses and diseases.[34,35] MR, CT, MAM, USG, and ECG are the most commonly-used types of health technologies. There are studies in the literature about comparing the usage of different types of medical devices. Chalela *et al.* (2007)[36] state that MR is better than CI for the detection of acute ischemia. Another study done by Subak *et al.* (1995)[37] considers that MR is better than CT for the evaluation of tumor size, such as the stromal invasion for cervical cancer.

Health Technology Assessment (HTA) is a useful tool to estimate the clinical effectiveness and cost effectiveness of medical devices. HTA products may help health policy makers with the determination process for medical devices.[32] Moreover, medical device usage and distribution is one of the main concerns of international health care organizations like the World Health Organization and the World Trade Organization. The reason for this interest is that unequal distribution of medical devices and inappropriate usage can cause adverse effects, negatively influencing a population's health.[38] HTA is a critical tool in the process of getting a medical device successfully into the market.[39] According to the economic, cultural, management, and technological policy differences between different countries, there exist 2 different perspectives in HTA: the European and USA perspectives. If these 2 perspectives are instilled across the technology assessment organizations in health, they help to improve the existing methodological framework of HTA. Drummond *et al.* (2013)[40] suggest reconciling these different perspectives in HTA and advise giving importance to a patient's participation in this process.

The medical device industry has different regulation rules in other countries because differences exist concerning population density, access to health services, and medical technologies. One example is the difference between China and the United States. Study results state that there are different regulatory policies and agencies in the United States and Chi-

na.[41] Apart from regulation policy differences between countries, there still exist inequalities within countries between their rural and urban areas. Experimental study results state that the unequal distribution of medical devices leads to major public health problems. These problems are valid for both developed and developing countries. Literature suggests that the geographic distribution of health and medical technologies is affected by market force. This is the basis of spatial competition. Spatial competition is a kind of an economic model in which the quantity of a service's resources determines their distribution. In this competition model, when few services or resources exist, the distribution is concentrated in large cities with large populations. This can cause large competition in big cities and an unequal distribution of health care services.[25] This problem is more common in countries where population density is high, such as China or Japan.[31,11] One example study was conducted by He *et al.* (2013)[31] it analyzed the equity of CT and MR distribution in China. The results state that the distribution of medical devices improved from 2006 to 2009, but considerable inequalities remained. Another study done by Matsumoto *et al.* (2015)[11] studied the geographic distribution of medical devices in Japan. The results state that the distribution of advance medical devices is unequal and support the view that educating health professionals, especially physicians, about the usage of health technologies is one of the ways of ensuring equality in the health technology market. Perhaps that is why health personnel and physicians are one of the main stakeholders of the health care industry, leading decision makers, and have the potential to increase health technology usage and energize the medical device market.[42] In brief, one way to improve the medical device market is to encourage physicians to collaborate with stakeholders in the medical device industry, share ideas with them, give them a feedback, and share their knowledge through participation in medical education programs.[43] There is a clear need for detailed analysis of the health technology markets for developing countries like Turkey in order to make policy suggestions for health policy makers. According to our knowledge, there are few studies examining rural and urban health differences in Turkey. Studies about general health services accessibility state that there are considerable differences between rural and urban parts of the country. These studies concentrate on differences in terms of self-reported health,[17] consultation times,[16] and infectious diseases.[44] Unfortunately, none of these studies illustrate the difference between rural and urban Turkey according to the distribution of health technologies and medical devices.

The results of this study fill the gap in the literature and show that there is a big difference between PHUs interms of the total number of medical devices located in urban and rural Turkey. PHUs located in cities that have a high population density are in the first cluster; all others in the second cluster. To conclude, the spatial distribution of PHU medical devices is consistent with the current population dynamics of Turkey.

CONCLUSION

Ensuring access to health care services and new health technologies among the general population is one of the main aims of health care systems in general.[45,46] Unfortunately, there are important problems in achieving this aim. Many people in developing countries have limited access to health technologies and medical devices,[46] and unequal access to basic health services and health technologies negatively affects health outcomes.[47] An awareness of health technologies and medical devices usage throughout the country from a spatial perspective will enhance our understanding of the differences between rural and urban Turkey. This will help us understand the health technology needs of people who are living in rural and urban parts of the country. This study's results highlighted that, in Turkey, PHUs can be grouped into 2 clusters according to the total number of medical devices. These 2 clusters represents the rural and urban parts of the country and are consistent with the spatial distribution of general population density. We hope that the results of this study will lead to a reevaluation of resource allocation decisions of health technology managers in Turkey. Further research is needed to assess the distribution and usage of other health technologies. We hope that these study results will improve health policymakers' efforts in fostering safe, cost effective, and accessible health technologies.

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CONFLICT OF INTEREST

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

ABBREVIATION USED

CT: Computed Tomography; ECO: Electrocardiography; EU: European Union; HTA: Health Technology Assessment; MAM: Mammography; MoH: Ministry of Health; MR: Magnetic Resonance; OECD: Organization for Economic Co-operation and Development; PHUs: Public Hospital Unions; TPI: Turkish Patent Institute; USG: Ultrasonography.

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