KLİNİK ÇALIŞMA / *CLINICAL RESEARCH*

Diabetes Mellitus Tanısında Kullanılan Tanı Stratejilerinin Karar Ağacı İle Maliyet Analizi

Cost Analysis of The Diagnostic Strategies Used For Diabetes Mellitus With Decision Tree

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ABSTRACT

Introduction: As the prevalence and incidence of diabetes mellitus (DM) continue to rise, the costs of the diagnostic strategies used to detect it have gained importance. The aim of this study was to analyze the cost of DM diagnostic strategies in a hospital setting.

Materials and Methods: This cross-sectional study included people over 18 years old with no previous DM diagnosis that presented to the internal medicine outpatient clinic for any reason and underwent serum glucose testing between December 1, 2012 and February 28, 2013. Decision tree analysis was used to calculate weighted costs of the various diagnostic methods.

Results: The study included 520 people. The prevalence of DM and pre-DM was 16.3% and 15.0%, respectively. During the study period, the total cost of all tests used was 2164.40 USD, the average cost per person was 4.14 USD, and the average cost per diagnosis was 25.46 USD. The most cost-effective strategy for the diagnosis of DM was fasting plasma glucose (FPG) and HbA1c tests requested together, while strategies using FPG testing were most cost-effective for the diagnosis of non-DM.

Conclusion: The diagnostic strategies recommended in national and international guidelines are considerably less costly than many of the strategies used in our hospital. Costs could be lowered by ensuring physicians are aware of and implementing more cost-effective diagnostic strategies.

Key Words: Cost, cost-effectiveness, decision tree, diabetes mellitus, diagnosis

ÖZET

Amaç: Diyabet mellitusun (DM) prevalansı ve artış hızı göz önünde bulundurulduğunda tanı konulması için uygulanan tanı stratejilerinin maliyetleri de günümüzde büyük önem kazanmıştır. Bu çalışmanın amacı bir hastanede DM tanısı koymak için kullanılan tanı yöntemlerinin maliyet analizlerinin yapılmasıdır.

Gereç ve Yöntem: Bu kesitsel çalışmanın katılımcılarını, dahiliye polikliniğine 1 Aralık 2012 – 28 Şubat 2013 tarihleri arasında, tanısı konulmuş diyabet hastalığı olmayıp herhangi bir nedenle polikliniğe başvuran, kişi için kan glikoz düzeyini belirten laboratuvar testlerinden herhangi birinin istemi yapılmış olan, araştırmaya katılmayı kabul eden 18 yaş ve üstü kişiler oluşturmaktadır. Ağırlıklı maliyetlerin hesaplanması için Karar Ağacı analizi uygulanmıştır.

Bulgular: Araştırma kapsamında 520 kişiye ulaşılmıştır. DM prevalansı %16,3 ve pre-diyabet prevalansı ise %15,0 olarak bulunmuştur. Çalışma süresince, DM araştırması için kullanılan testlerin toplam maliyeti 2164,4 USD, kişi başı ortalama maliyeti 4,14 USD ve DM tanısı başına ortalama maliyeti ise 25,46 USD olarak hesaplanmıştır. Karar Ağacı analizi ile elde edilen ağırlık maliyetler incelendiğinde; DM tanısı için açlık plazma glukozu (APG) ve glikolize hemoglobin (HbA$_{1c}$) testlerinin beraber istendiği ve DM değil tanısı için ise APG testinin uygulandığı stratejilerinin en maliyet-etkin tanı stratejileri olduğu anlaşılmıştır.

Sonuç: Ulusal ve uluslararası kılavuzlarda önerilen tanı stratejilerinin maliyetleri, hastanemiz polikliniklerinde uygulanan stratejilere göre daha ucuzdur. Bu nedenle poliklinikte görevli hekimlere yönelik tanı kılavuzlarının hazırlanıp, sürekli başvurabilecekleri bir yerde bulundurulmasının ya da en azından çalışmamızda da en maliyet-etkin bulunan stratejilerin takip edilmesinin sağlanması gerektiği düşünülmüştür.

Anahtar Kelimeler: Diabetes mellitus, karar ağacı, maliyet, maliyet etkinlik, tanı

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Introduction

The main goal of health economics is to enable the most efficient use of resources allocated for the provision of all kinds of health services. As resources are limited in the health field, it is essential to utilize available resources to maximize their output, which involves giving priority to practices that provide the most benefit per unit of resource (1). A major issue in the field of health economics is developing appropriate management plans for common, crippling, and fatal diseases.

With its high prevalence and incidence rates, diabetes mellitus (DM) is among the diseases that health economics primarily deals with. According to the International Diabetes Federation, the number of diabetics worldwide was 425 million (8.8%) in 2017 and will reach 629 million (9.9%) by 2045 (2). Based on data from the Turkish Diabetes, Hypertension, Obesity, and Endocrinological Diseases Prevalence Study II, the prevalence of diabetes among Turkish adults is 13.7% (3).

Contemporary health policies provide budgets for diagnosis (4). In order to use these budgets more efficiently, the Turkish Ministry of Health and professional associations and organizations publish guidelines for diagnosis and treatment.

Considering diabetes prevalence and incidence rates, the costs of diagnostic strategies used have gained substantial importance. Our literature search yielded no publications on the cost of diabetes diagnostic strategies in hospitals. The aim of this study was to conduct a cost analysis of diagnostic test methods used to diagnose DM in a university hospital.

Material and Methods

This cross-sectional study included individuals aged 18 years and older with no previous diabetes diagnosis that presented for any reason to the Internal Medicine outpatient clinic of a training and research hospital in Ankara, Turkey between December 1, 2012 and February 28, 2013, underwent any laboratory test of blood glucose level, and agreed to participate in the research. A total of 2835 patients were seen in the outpatient clinic during the study period, 520 of whom met the inclusion criteria.

Diagnostic tests recommended in the American Diabetes Association (ADA) DM diagnosis and classification guidelines are glycated hemoglobin (HbA1$_c$ ≥ 6.5%), fasting plasma glucose (FPG ≥ 126 mg/dL), 2-hour plasma glucose (2-h PG ≥ 200 mg/dL) during oral glucose tolerance test (OGTT), or for individuals with symptoms of hyperglycemia, random plasma glucose (PG ≥ 200 mg/dL). In cases without unequivocal hyperglycemia, assays for HbA1$_c$, FPG, and OGTT should be repeated for confirmation (5).

The Turkish Endocrinology and Metabolism Association's (TEMD) 2011 Guidelines for the Diagnosis, Treatment, and Surveillance of Diabetes Mellitus and Its Complications and the National Diabetes Congress Consensus Group's Guidelines for the Diagnosis and Treatment of Diabetes endorse the methods specified in the ADA guidelines and specify that HbA1$_c$ must be measured using standardized techniques. In addition, these guidelines state that for individuals without severe symptoms of diabetes, diagnosis should be confirmed using a different method on another day, and the diagnostic use of HbA1$_c$ assay is not recommended for Turkey due to the fact that A1c testing is costly, cannot be performed routinely in every center, is prone to technical problems, and is not standardized (6, 7).

Statistical Analysis: Data were analyzed using SPSS 15.0 statistics software package and presented as descriptive findings. The costs of the diagnostic methods recommended in guidelines were shown first. For those included later in the study, per-person and per-diagnosis costs of the strategies were calculated. Weighted costs were calculated by performing a Decision Tree Analysis in the Stata 13 statistics software. The analytical method used to solve a problem shown in a Decision Tree is called *backward induction* or *folding back*. This method assumes that in order to evaluate the initial decision node, all subsequent decision and chance nodes must also be taken into account. Therefore, analysis begins at the terminal decision and chance nodes and proceeds backwards until reaching the initial node (8). Once these calculations are completed, the decision with the best expected value (the highest value in profit-based problems and lowest value in cost-based problems) is adopted as the optimal decision.

The Turkish Social Security Institution pays 29.16 United State dollars (USD) as a package price per patient for outpatient visits to university hospitals (4). Therefore, test prices obtained on April 6, 2013 from the hospital billing unit were used in cost calculations. For international comparisons, costs were converted to foreign currencies based on indicative exchange rates determined by the

Table 1. Descriptive characteristics of the study participants

	Number (n=520)	%*
Gender		
Female	335	64.4
Male	185	35.6
Marital status		
Single	154	29.6
Married	366	70.4
Current employment status		
Not employed	277	53.3
Employed	243	46.7
Smoking status		
Smoker	379	72.9
Non-smoker	141	27.1
Alcohol use		
Yes	480	92.3
No	40	7.7
Diagnosed chronic diseases		
No	291	56.0
Yes	229	44.0

*Percentage of column

Table 2. Age and body mass index of the study participants

	Mean ± SD	Median (minimum - maximum)
Age (years) (n=520)	45.15 ± 14.22	47 (18 - 84)
Body mass index (kg/m2) (n=66)	28.61 ± 6.17	27.59 (17.19 – 48.05)

Central Bank of the Republic of Turkey at 15:30 on June 28, 2013 (9).

This study was approved by the Ethics Committee and all the participants signed the Informed Consent Form. This article was produced from a dissertation entitled "Cost Analyses of Diagnostic Test Methods Used to Diagnose Diabetes Mellitus at a University Hospital".

Results

The descriptive characteristics of the 520 study participants are presented in Tables 1 and 2, and their laboratory test results are presented in Table 3.

Based on their laboratory tests results, 85 (16.3%) of the participants were diagnosed with DM, 63 (12.1%) had impaired fasting glucose, 7 (1.3%) had impaired postprandial glucose (PPG), and 8 (1.5%) had combined impairment.

Findings Related to Average Costs: Of the strategies recommended by national and international guidelines, checking FPG or PPG level twice was found to be the most cost-effective method (Table 4).

The total weighted cost of this diagnostic strategy for the 19 individuals diagnosed based on FPG and HbA1$_c$ testing was 191.25 USD and the weighted cost per DM diagnosis was 9.79 USD. Requesting both FPG and HbA1$_c$ assay for DM diagnosis emerged as the most cost-effective diagnostic strategy (Table 5).

The weighted total cost and cost per patient of diagnosing DM with FPG, PPG, and HbA1$_c$ assays followed by OGTT and HbA1$_c$ assay was 274.47 USD. This was the most expensive strategy in our study. FPG testing was the most cost-effective method for a diagnosis of non-DM (Table 5).

The diagnostic strategies used to identify DM in the study participants are presented in Figure 1. A total of 518 individuals were included in the decision tree analysis. Diagnostic methods applied at initial visit included FPG and HbA1$_c$ testing in 45 patients; FPG, PPG, and HbA1$_c$ testing in 39 patients; FPG and PPG in 10 patients; and FPG,

Table 3. Distribution of study participants' laboratory test results

	Initial visit		Second visit	
	Number	%	Number	%
FPG				
High	157	30.2	11	78.6
PPG				
High	26	50.0	2	28.6
0-hr OGTT				
High	5	55.6	29	44.6
2-hr OGTT				
High	6	66.7	39	60.9
HbA1c				
High	41	46.1	10	20.0

FPG: Fasting plasma glucose, PPG: Postprandial plasma glucose, OGTT: Oral glucose tolerance test, HbA_{1c}: Glycated hemoglobin

Table 4. Unit costs, total costs, costs per person, and costs per DM diagnosis

Test	Total Number of Tests	Unit Cost* (USD)	Total Cost (USD)	Average Cost per Person (USD) (n=520)	Average Cost per DM Diagnosis (USD) (n=85)
FPG	534	0.52	278.12	0.53	3.27
PPG	59	0.52	30.72	0.05	0.35
OGTT	74	8.48	628.22	1.20	7.39
HbA1c	139	8.85	1230.72	2.36	14.47
Total	806	18.38	2167.81	4.15	25.50

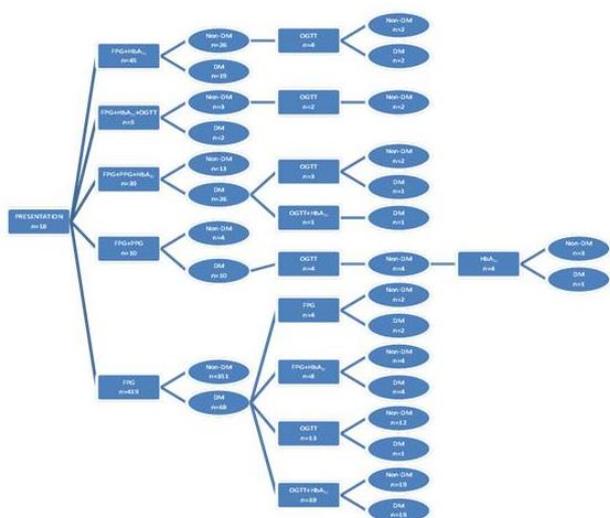*Test costs obtained on April 6, 2013 from the hospital billing unit

Fig. 1. Decision tree showing diagnostic strategies used during DM workup

HbA_{1c}, and OGTT in 5 patients. Of the remaining 419 patients who underwent only FPG testing at initial presentation, 68 had results consistent with DM. Of these, OGTT and HbA_{1c} testing were done in 38; OGTT alone in 13; repeated FPG and HbA_{1c} testing in 8; and repeated FPG alone in 4 (Figure 1).

Discussion

The prevalence and incidence of diabetes are rising steadily (3). Due to current health policies, the diagnostic process of this chronic disease must be effectively managed as well as its treatment and complications.

A nationwide DM screening and diagnosis program conducted by the Brazilian Ministry of Health in 2001 was reported to have a per-diagnosis cost of 76 USD (301 International dollars [Intl\$]) including all costs (campaign costs and direct costs) (10).

During a DM screening program conducted in the United Kingdom between 2005 and 2009 and published in 2012, all costs were evaluated with a decision tree. Of the 18 strategy simulations presented in the study, the least costly strategy consisted of risk evaluation followed by a blood test and later OGTT for confirmation (457 Great Britain Pound (GBP) per diagnosis). The most

Table 5. Decision tree showing diagnostic strategies used during DM workup

Diagnostic Strategy	Diagnosis	Number	Total Weighted Cost (USD)	Weighted Cost Per Diagnosis (USD)
FPG + HbA1c	Non-DM	0	0	0
	DM	19	186.04	9.79
FPG + HbA1c + OGTT	Non-DM	2	271.35	135.41
	DM	2	271.35	135.41
FPG + HbA1c + OGTT	Non-DM	0	0	0
	DM	2	35.72	17.86
FPG + HbA1c + OGTT + OGTT	Non-DM	2	70.57	35.26
	DM	0	0	0
FPG + PPG + HbA1c + OGTT	Non-DM	2	145.62	72.81
	DM	1	137.13	137.13
FPG + PPG + HbA1c + OGTT + HbA1c	Non-DM	0	0	0
	DM	1	274.47	274.47
FPG + PPG + OGTT + HbA1c	Non-DM	3	70.93	23.64
	DM	0	0	0
FPG	Non-DM	351	182.81	0.52
	DM	0	0	0
FPG + FPG	Non-DM	2	36.45	18.22
	DM	2	36.45	18.22
FPG + FPG + HbA1c	Non-DM	4	74.06	18.48
	DM	4	74.06	18.48
FPG + OGTT	Non-DM	12	161.30	13.43
	DM	1	67.91	67.91
FPG + OGTT + HbA1c	Non-DM	19	503.28	26.45
	DM	19	503.28	26.45

expensive strategy was two simultaneous blood tests done without risk stratification, followed by OGTT for confirmation (1487 GBP per diagnosis) (11).

In a United States' study published in 2001, a group of 201 at-risk patients underwent random PG testing followed by OGTT for those with high results, and 5 new cases of DM were diagnosed. When all costs were taken into account, the cost per diagnosis was 4064 USD (12).

In another study conducted in Germany in 2000 (KORA Study, 2000), different DM screening strategies were used with individuals 55-74 years of age, and the costs were analyzed based on the sum of both direct and indirect costs. The least expensive strategy involved risk evaluation followed by FPG test, while the most expensive strategy involved simultaneous HbA1c test and OGTT (13).

Compared with the costs reported in the aforementioned studies, the costs determined in the present study are markedly lower. However, this is because both direct and indirect costs were taken into account in those studies, and most evaluated diagnostic strategies applied in the context of a screening program.

In this study, the average cost per DM diagnosis was 25.46 USD (19.48 Euro (EUR)/16.74 GBP). The strategies recommended in diagnostic guidelines are much less costly than the average costs determined in the clinical setting. Analysis of weighted costs indicated that performing FPG and HbA1c testing as recommended was the most cost-effective diagnostic strategy (9.79 USD/7.49 EUR/6.43 GBP). It is interesting that most of the other strategies are relatively more expensive. We attribute the variation in strategies to the fact that a different resident physician is assigned to the outpatient clinic each month. The absence of a specific DM diagnostic algorithm recommended to residents while in the outpatient clinic is an important factor in this, as the residents must each rely on their own knowledge and experience. The

combination of these factors results in increased costs and waste of resources.

Due to the dearth of similar studies, the main limitations of our study are that the findings are discussed alone or with reference to the limited research conducted abroad, and are thus difficult to interpret. Multicenter studies examining DM diagnostic strategies and their costs will provide more guidance regarding efficient use of resources.

The diagnostic strategies recommended in national and international guidelines were found to be cheaper than the strategies employed in the outpatient clinics of our hospital. In fact, many of the strategies used were much more expensive. We attribute this to the fact that resident physicians doing rounds in the outpatient clinic do not have a specific diagnostic algorithm for DM. In addition, they may not have seen the patient at their initial visit due to the rotation system, and thus request additional tests at their second visit. Therefore, we believe that diagnostic guidelines should be prepared for physicians on duty in the outpatient clinic and placed where they can be consulted frequently, or it should at least be ensured that they employ the strategies shown in this study to be the most cost-effective.

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