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EFFECTS OF USING CLINICAL DECISION SUPPORT TOOLS ON VITAMIN D COST EFFECTIVENESS

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ABSTRACT

Background: In medical practices worldwide, vitamin D testing is widely requested. However, the cost-effectiveness of vitamin D testing is a major concern. Many laboratories are turning to the use of clinical decision support systems (CDSS) to reduce unnecessary demand and thus the cost burden on the system. In this study, we investigated the impact of the implementation of CDSS on costs and changes in test demand before and after rationalisation of test demand.
Methods: We analysed testing requests 90 days before (8 December 2018 - 8 March 2019) and 90 days after (9 March 2019 - 9 June 2019) the implementation of the CDSS in the hospital's software system. This system generates an on-screen warning indicating whether the patient has had a vitamin D test in the last 90 days. It completely blocks test requests from some clinics, except intensive care and inpatients, and allows diagnostic test requests in others. Test requests were analysed using a Microsoft Excel pivot table tool. Test costs were compared before and after implementation of the clinical decision support system.
Results: There were 31,066 requests for 25(OH) vitamin D in the first period compared to 18,830 requests for the same analyte in the second period. This resulted in an approximately 39 percent reduction in testing requests (12,236 tests) ($p<0.0001$). Savings of $37,350 in three months, or an estimated annual savings of approximately $150,000.
Conclusions: Incorporating CDSS into the hospital's software system resulted in a significant reduction in requests for 25(OH) vitamin D testing. The development and use of new clinical software systems in laboratories is important in terms of both resource and human workforce efficiency.
Keywords: Vitamin D testing, clinical decision support, cost

KLİNİK KARAR DESTEK ARAÇLARININ KULLANILMASININ D VİTAMİNİ MALİYET ETKİNLİĞİNE ETKİSİ

ÖZET

Amaç: D vitamini testleri tıbbi uygulamada tüm dünyada yaygın olarak talep edilmektedir. Birçok laboratuvar, sistem üzerindeki gereksiz talep yükünü ve dolayısıyla maliyet yükünü azaltmak için klinik karar destek sistemlerinin kullanımına yönelmektedir. Bu çalışmada D vitamini test isteği öncesi ve sonrasında uygulanan klinik karar destek sistemlerinin maliyete ve test isteğindeki değişime etkisi incelenmiştir.
Gereç ve Yöntem: Klinik karar destek sistemlerinin hastane yazılım sistemine girmesinden önceki (8/12/2018-8/03/2019) ve sonrası (9/03/2019-9/06/2019) 90 gün boyunca test isteklerini analiz ettik. Bu sistem, hastanın son 90 gün içinde D vitamini testi yaptırıp yaptırmadığını belirten bir ekran uyarısı oluşturur. Yoğun bakım ve yatan hastalar hariç bazı kliniklerden gelen test isteklerini tamamen engellerken, diğerlerinde tanıya bağlı test istemine izin vermektedir. Test istemlerini analiz etmek için Microsoft Excel'in Pivot Tablo aracı kullanıldı. Klinik karar destek sistemlerinin tanıtılmasından önceki ve sonraki test maliyetleri karşılaştırıldı.
Bulgular: İlk dönemde 31,066 25(OH) D vitamini talebi oldu. İkinci dönemde aynı analit için 18,830 talep geldi. Dolayısıyla test isteminde yaklaşık %39'luk (12,236 test) bir azalma gerçekleşti ($p<0.0001$). Bu da, üç ayda 37.350 ABD Doları veya tahmini yıllık yaklaşık 150,000 ABD Doları tasarruf olarak hesaplanmıştır.
Sonuç: Hastanenin yazılım sistemine klinik karar destek sistemlerinin eklenmesi, 25(OH) D vitamini testi talebinde ve maliyette önemli bir azalma ile sonuçlanmıştır. Laboratuvarlarda yeni klinik yazılım sistemlerinin geliştirilmesi ve kullanılması hem kaynak hem de insan işgücü verimliliği açısından önemlidir.
Anahtar Kelimeler: D vitamini, klinik karar destek, maliyet

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Impact Statement

The aim of this study was to investigate the effect of a clinical decision support system applied to the software system of our hospital on the number of vitamin D test orders and the cost of vitamin D testing. Incorporating CDSS into the hospital's software system resulted in a significant reduction in 25(OH) vitamin D testing orders. The implementation of new clinical software systems in laboratories is important in terms of both resources and staff.

Introduction

In recent years, the number and variety of biochemical laboratory tests that have become available has increased. Simultaneously, the turnaround time for these tests has tended to decrease. At the same time, life expectancy and the incidence of chronic diseases have increased (1). With the increase in laboratory test diversity and number of tests, unnecessary test requesting has also increased which has led to a significant increase in laboratory workload and an increase in avoidable laboratory expenditure (2). Many laboratories are turning to the use of CDSS, part rational laboratory practice, in order to reduce the unnecessary demand burden and therefore the cost burden on the system. CDSS has more potential to support physicians when deciding about ordering a test or interpreting the results. It can also contribute to reducing the cost burden of laboratories (3).

Studies focused on reducing the laboratory test order rate have also reported positive effects of CDSS on cost (4). Bridges et al. have defined a computerized alert (pop-up window) to the system to reduce repeated test prompts. In this study, the decrease in the request for repeated tests was also reflected in the cost (5). In another study, Gottheil et al. designed a study in which they aimed to reduce the Erythrocyte Sedimentation Rate (ESR) orders by 50% with the CDSS system. A forcing function is included in the system, in which an ESR order could not be entered without the clinician choosing an appropriate indication. They found a reduction in both the number of tests and the cost (6).

These studies are generally timed and experimental/semi-experimental studies. The design of the CDSS application in our study was determined by the Ministry of Health. A guideline for the prevention of unnecessary vitamin D test requests has been published and officially announced by the Ministry of Health. It has started to be implemented in all laboratories. According to this guideline, primary health care institutions cannot demand vitamin D. The system allows some clinics, inpatients and intensive care units of secondary and tertiary healthcare institutions to request tests. The test request period for vitamin D has been identified as 90 days. In addition, clinics that can request tests are authorized to request tests in the presence of certain diagnoses. Our hospital started to implement this guideline on March 9, 2019 (7).

The vitamin D is a steroid compound with many metabolic functions. Vitamin plays a major role in calcium homeostasis and thus bone metabolism (8,9). While the adequacy of dietary vitamin D and endogenous synthesis can be evaluated with 25(OH) vitamin D measurement, 1,25(OH)2D is generally used to evaluate the adequacy of kidney function for calcium homeostasis (10). Vitamin D deficiency or insufficiency is common in all age groups worldwide. Vitamin D deficiency is also associated with many diseases, such as cancer, autoimmune and neurological diseases, hypertension, diabetes, and obesity, as well as negatively affecting bone health (11). In addition, many positive effects of vitamin D on health have been shown in scientific studies (12,13). Increasing clinical interest in vitamin D has led to an increased demand for testing in medical practice but has also resulted in a marked increase in the cost of vitamin D testing. For these reasons, we aimed to evaluate the test order rates 90 days before (December 8, 2018 - March 8, 2019) and 90 days after (March 9 - June 9, 2019) the start of the CDSS application and its effect on the cost.

Materials and Methods

Setting/Participants

All patient records of requests made for a vitamin D test between 8 December 2018 and 9 June 2019 were retrospectively evaluated. The variation of test request frequency according to clinics before and after CDSS application was analyzed. Age and gender dependent vitamin D demand frequency was evaluated. Patients were divided into three groups based on age at time of request: 0-18, 19-65, ≥ 65 years old.

Intervention

The Turkish Ministry of Health has issued an announcement regarding the application of CDSS to all health institutions until 31 August 2018(14). The clinical decision support tool was implemented based on our country's

test guide. The CDSS operates on three levels. The first level is the restriction of the request for vitamin D testing to certain clinics and specialities. Children's clinics and sub-branches, internal medicine clinics and sub-branches, gynecology and obstetrics clinics, physical therapy and rehabilitation, orthopedics and traumatology and neurology clinics can make vitamin D test requests in 2nd and 3rd level health institutions. In addition, inpatients in all clinics and intensive care patients can be requested for vitamin D. Primary care institutions and clinics with limited test requests were prevented from requesting a vitamin D test. The second level is the warning that comes to the screen of the services that can request a test. Test request period for vitamin D was determined as 90 days. Thus, if a test is requested in a shorter time, the message "Test request time warning! The patient's past vitamin D test results are available. Are you sure you want to continue the request? Yes/No" message appears. The third level is diagnosis-related restrictions. Clinics can only request tests in cases accompanied by rickets, osteoporosis, vitamin D deficiency, hypoparathyroidism, hyperparathyroidism, osteomalacia, calcium metabolism disorders, phosphorus metabolism disorders, pathological fractures, pregnancy and breastfeeding period. In the presence of a different diagnosis, "Warning in restriction due to diagnosis: It may be requested in cases accompanied by rickets, osteoporosis, vitamin D deficiency, hypoparathyroidism, hyperparathyroidism, osteomalacia, calcium metabolism disorders, metabolism disorders, pathological fractures, pregnancy and lactation period." warning appears (Figure 1).

Data Analysis

Requested vitamin D test numbers were compared with the Pearson Chi-square test between the three age groups and genders and before and after the implementation of the CDSS. Analysis of the difference between the total numbers of requested tests was assessed by Wilcoxon test. Statistical significance was assumed if $p<0.05$. Microsoft Excel's Pivot Table tool was used to analyze which departments had requested the test the most, and the percentage difference in average test volumes post-implementation was compared with pre-implementation.

The cost of the 25(OH) vitamin D3 kit was calculated in US dollars, based on the cost of the kit and the exchange rate up to June 9, 2019.

Biochemical Measurements

25(OH)D3 analysis was performed by a chemiluminescent immunoassay method on a Beckman DXI 800 (Beckman Coulter, USA). The reference intervals used for the test were: deficiency: <20 ug/L; insufficiency: 21-29 ug/L; sufficiency: >30 ug/L; and toxicity: >100 ug/L.

Ethics committee approval and informed consent form were not obtained for this study since the data is available to researchers and does not contain descriptive patient results.

Results

The number of 25(OH) vitamin D tests and the cost analysis for the three calendar months before the implementation of the CDSS (8 December 2018 - 8 March 2019) and the three calendar months after the implementation (9 March - 9 June 2019) are shown in Table 1. In the pre-CDSS period 31,066 25(OH)D tests were requested while in the following three months after first implementation of the CDSS 18,830 tests were requested. This constituted a 39.4% decline in requests. When the cost saving to the laboratory was calculated and the price per test in the Health Practice Communiqué (SUT) was 3 US dollars (USD), the reduction in expenditure for the three month period was 36,708 [(31066-18830)x3] and this is estimated to generate an annual saving of 146,832 USD. While there were 1,398 patients in whom a vitamin D test was requested two or more times before in the three months before CDSS implementation, this number decreased to 673 patients after CDSS application, a reduction of almost 52%. When the orders from the period before the introduction of the CDSS are analyzed, it is seen that the orders from restricted clinics constitute 21.8% of the total vitamin D orders. We considered the possibility that there might be seasonal variations in the number of vitamin D tests performed, and we expected that more tests would be needed in the winter. To do this, we also extracted data from a year earlier for the same period. Between 8 December 2017 and 8 March 2018, the number of test requests was 30,888, and between 9 March 2018 and 9 June 2018, the number of test requests was 33,175. According to this data, the number of tests in the spring months was 2287 more than a year ago. The change in request frequency pre- and post-CDSS for 25(OH)D test by medical speciality is shown in Table 2. A decrease in test request frequency was observed in all clinics that remained exempt from test request restriction, with the exceptions of Cardiology (in patient), Internal medicine (in patient), and Oncology (outpatient clinic).

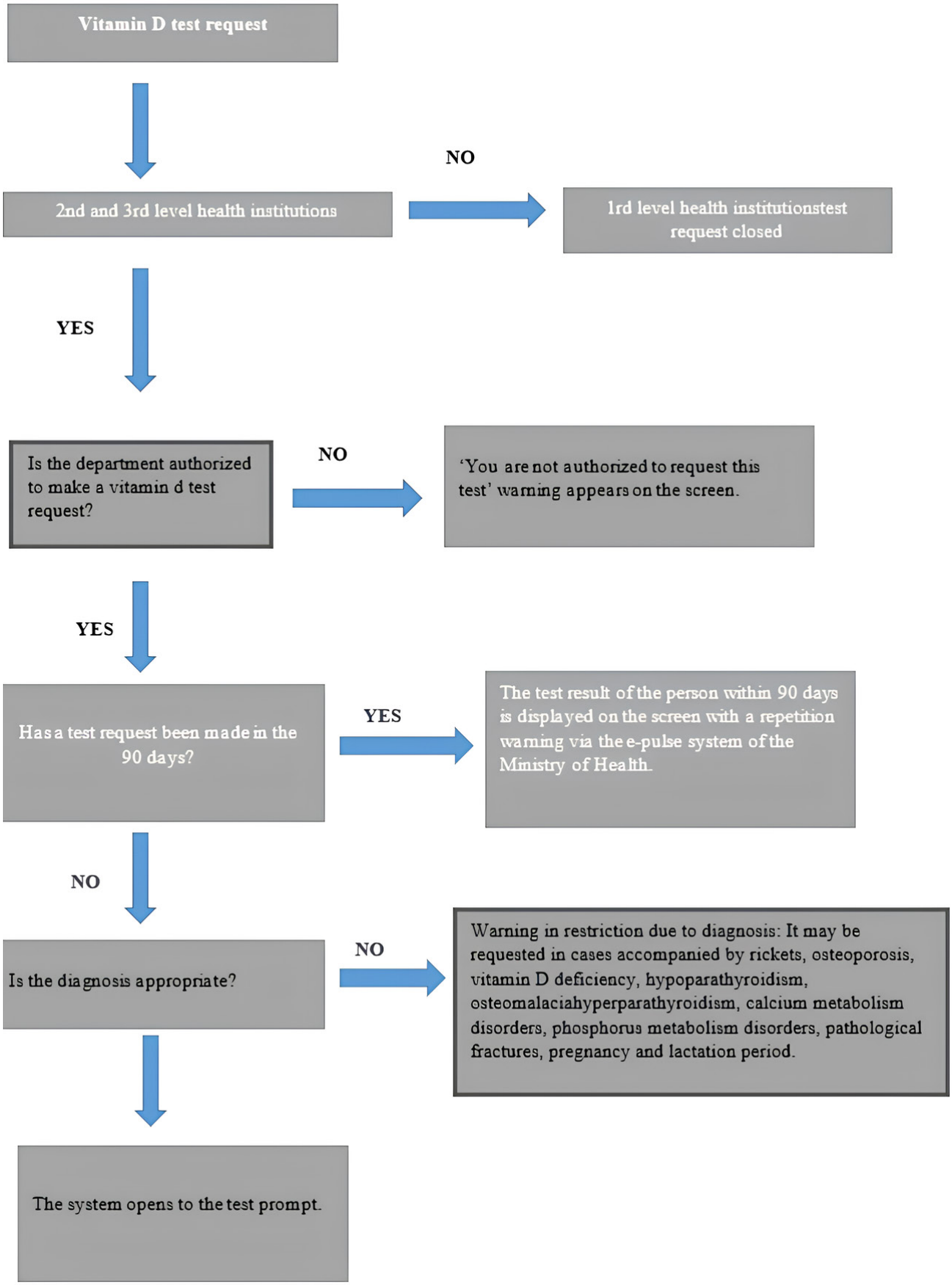

Figure 1. Schematic diagram of the study of vitamin D in health institutions

Table 1. Pre-CDSS and Post-CDSS number of tests and total cost			
	Pre-CDSS	**Post-CDSS**	**Amount saving**
Test (n)	31,066	18,830	12,236
Cost (USD)	93,198	56,490	36,708

**Pre-CDSS (clinical decision support systems before implementation), Post-CDSS (clinical decision support systems after implementation)*

Table 2. Change of test request frequency according to clinics before and after CDSS implementation							
Clinic (Department)	**Pre CDSS(n)**	**Post CDSS(n)**	**% Variation**	**Clinic (Outpatient clinic)**	**Pre CDSS(n)**	**Post CDSS(n)**	**% Variation**
Cardiology	2	6*	66.6	**Endocrinology**	1380	1023	25.9
Cardiovascular surgery	55	0	100	**Gastroenterology**	443	67	84.9
Dermatology	40	4	90	**Gynecology and obstetrics**	294	106	63.9
Endocrinology	143	106	25.9	**Internal medicine**	11960	7774	35
Gastroenterology	68	46	32.4	**Nephrology**	862	658	23.7
Gynecology and obstetrics	84	77	8.3	**Neurology**	821	248	69.8
Intensive care unit	106	64	39.6	**Oncology**	378	448*	15.6
Internal medicine	1490	2103*	29.1*	**Orthopedics**	230	140	39.1
Nephrology	115	75	34.8	**Pediatric**	2056	1246	39.4
Neurology	125	7	94.4	**Pediatric endocrinology**	44	27	38.6
Ophthalmology	13	2	84.6	**Pediatric gastroenterology**	191	91	52.4
Orthopedics	61	0	100	**Pediatric hematology**	72	28	61.1
Pediatric	45	8	82.2	**Pediatric infection disease**	10	9	10
Pediatric surgery	5	2	60	**Pediatric metabolism**	124	84	32.3
Physical therapy and rehabilitation	104	75	27.9	**Pediatric nephrology**	91	35	61.5
Radiation oncology	6	1	83.3	**Pediatric neurology**	34	7	79.4
Surgery	110	0	100	**Pediatric oncology**	62	48	22.6
Psychiatry	76	1	98.7	**Physical therapy and rehabilitation**	2565	1758	31.5

** Clinics with increasing frequency of test requests*
** Pre-CDSS (clinical decision support systems before implementation), Post-CDSS (clinical decision support systems after implementation)*

The number of patients in the three different age groups and both genders before and after CDSS application and the changes are given in Table 3 and Table 4. In terms of age grouping both the overall decrease in request numbers and the the decrease in each age group were significant ($p<0.001$ for all). Interestingly, women were asked for more tests than men before (69 per cent of the total) and after (71 per cent of the total) the introduction of the CDSS (Table 4). This suggests that female patients were more likely to come to hospital with complaints. The numbers of requests from male patients fell by 44.4% from 9,677 to 5,381 ($p<0.001$) while in females a decrease in request numbers of 37% from 21,359 to 13,449 ($p<0.001$) was observed.

Table 3. Number of patients in three different age groups, before and after CDSS					
Pre – CDSS			Post – CDSS		
Age group	n	% test requests	n	% test requests	p
0-18	3,590	11.6	1,909	10.1	<0.001
19-65	21,390	68.9	12,992	69.0	<0.001
≥ 65	6,056	19.5	3,929	20.9	<0.001
All ages	31,036	100	18,830	100	<0.001
Pre-CDSS (clinical decision support systems before implementation), Post-CDSS (clinical decision support systems after implementation)					

Table 4. Distribution of test request frequency before and after CDSS by gender					
Pre - CDSS			Post - CDSS		
Gender	n	% test requests	n	% test requests	p
Male	9,677	31.2	5,381	28.6	<0.001
Female	21,359	68.8	13,449	71.4	<0.001
Total	31,036	100	18,830	100	<0.001
Pre-CDSS (clinical decision support systems before implementation), Post-CDSS (clinical decision support systems after implementation)					

Discussion

The aim of this study was to investigate the effect of the implementation of the CDSS on vitamin D test numbers and cost, and the effectiveness of the warning message in clinics without test restrictions. Test requests decreased by 12,236 tests in the first three calendar months after implementation, with an estimated 39% reduction in test costs within three months. In addition, the alert triggered by a request to repeat the previous test within 90 days led to a reduction in vitamin D test requests in all areas except inpatient cardiology, inpatient internal medicine and outpatient oncology. It should also be noted that the numbers of requests coming from cardiology in-patients was very small in both periods. We could not identify any factor that would affect the test order in clinics where there was no decrease in vitamin D test request. Furthermore, the proportion of vitamin D requests was much higher in female patients (68.8%) than in male patients. When age group analysis was performed, the age group in which the test was requested the most was the 19-65 agerange (68.9%), but this accounts for the majority of the population.

One of the most important reasons for the increase in the frequency of vitamin D test requests is the global prevalence of vitamin D deficiency in recent years (10). The prevalence of vitamin D deficiency in Turkey was reported to be 63% in the whole population (15). When the whole Turkish population was divided into demographic groups the prevalence of vitamin D deficiency varied widely; 86.6% in infants, 76% in pregnant women, 39.8% in children, and 63.5% in adults (64.7% in women, 39.5% in men). In the United States, it has been reported that the rate of outpatient visits associated with vitamin D deficiency tripled from 2008 to 2010, and serum 25(OH) D vitamin tests increased by at least 50% between 2008 and 2009 (16). Another reason for the increase in the frequency of vitamin D test requests may be the increase in patient demand rates due to increased awareness in the general population about vitamin D and its effects. In a study conducted in Australia, it was reported that the test rate, which was 40.6 tests/100 000 persons in 2000, increased to 3472.2 tests/100 000 persons in 2011, resulting in a 59% increase in the annual average cost (17, 18). In the USA, it has been reported that 25(OH) D test rates increased six times between 2007 and 2011 (19). Nowadays, the increase in the number of patients and the reduction in the amount of time spent with patients are leading doctors to practice defensive

medicine. This may be another reason for the increase in the number and frequency of test requests.

The use of CDSS in a comprehensive electronic health record system has already been trialled by many organisations and laboratories with the aim of improving the quality of healthcare and reducing the amount of clinically unnecessary medical test orders. (10, 16, 20). Turkey has decided to use a CDSS for vitamin D testing nationally in an attempt to contain the increasing costs of these requests. The starting date of CDSS in our hospital is March 9, 2019. Felcher et al. evaluated the effect of a CDSS on the vitamin D test for a six month period before and after the implementation and reported a decrease of 67.8% and an estimated annual cost savings of 1.4 million USD (16). Tai et al. also created a CDSS that required the selection of one of five acceptable test indications for Vitamin D. After implementation the mean±SD monthly test volume for 25-OH vitamin D decreased from 504±62 tests to 370±33 per month, a decrease of 27%. This was estimated to representa cost saving of approximately 29,555 USD per year for the 25(OH)D test (10). The present study is the first from Turkey to estimate the impact of requests for vitamin D testing on diagnostic expenditure. In a single tertiary care hospital the estimated annual saving after implementation of the CDSS was just under 150k USD. If this effect was replicated in all public hospitals in the country the overall cost saving would be substantial.

Ko et al. A database of 115,971 patients and 275,565 tests was evaluated and it was reported that 5.2% of all tests were retested at intervals shorter than the minimum retest interval. The estimated cost burden was reported to be $222,096 per year. In this study, 9.3% of 25(OH) D tests were repeated at intervals that would shorten the recommended minimum retest interval (21). In our database, 1,398 patients had 2 or more vitamin D tests requested within 3 months before CDSS application and 673 patients after CDSS application. After CDSS implementation, the rate of 2 or more requests decreased by 52%. In total, 4.1% of vitamin D tests were repeated 2 or more times within 6 months for the same patient. It is noteworthy that the demand for vitamin D testing is concentrated under the age of 60. A study conducted in the United Kingdom reported that 38.5% of vitamin D tests were performed in the 30-59.9 age range, 9.9% under the age of 30, and 22.4% of the tests were performed because of fatigue. It was stated that 70-80% of the tests were performed inappropriately in terms of indication (22). In our study, approximately 69% of the patients were under the age of 65, but we did not analyze the indication for vitamin D test because clinical details given on requests may have been inaccurate and requesting may have been in response simply to individual patient demand. Patient demand is one of the main reasons for unsuitable test orders. In this regard, appropriate test order should be highlighted and correct indications for vitamin D testing should be more widely available to clinicians.

Some studies have suggested raising awareness of vitamin D deficiency and providing vitamin D supplements to people at risk of deficiency without testing them (23,24). In May 2011, the Turkish Ministry of Health issued a circular on vitamin D supplementation for pregnant and breastfeeding mothers, regardless of blood levels. It has been shown to be safe to start vitamin D supplementation without testing in low-risk groups for vitamin D toxicity (25). This type of development will contribute to further education on inappropriate testing requests. It has been suggested that quality of care and the number of clinically unnecessary requests for medical tests can be improved by combining the use of CDSS with electronic health record systems (10). We suggest that our results support this conclusion and that clinical alerting tools integrated in software systems can increase the efficiency of healthcare facilities and the cost-effectiveness of vitamin D testing. The substantial reduction in vitamin D testing across almost all specialities and patient age groups has reduced the laboratory workload and allowed the redirection of diagnostic testing budget to other, potentially more informative, tests. The development and use of new clinical software systems in laboratories in the light of current scientific data and considering economic resources is important in terms of both resource and human labor efficiency. We evaluated period of 3 months before and after the implementation of our study, examining longer time periods such as one year will provide more information in terms of the effectiveness of the application. At the same time, the fact that we did not receive feedback from clinicians about the application was another limitation of our study.

As a result, reducing the costs of improperly requested testing can provide the laboratory with a testing budget for other tests that add more value. Besides cost savings, it can also help avoid additional diagnostic testing and inappropriate treatment decisions. We anticipate that future research may provide more detailed information on testing efficacy and efficiency with longer time periods and the use of more advanced clinical alerting tools.

Conflict of Interest / Financial Support Statement

None of the authors in this article have any conflict of interest or financial support.

Author Contributions

Kara M and Ojalvo D designed the study, Ojalvo D and Serin E acquired the data, Kara M, and Öztas B analyzed the data, interpreted the results, and wrote the manuscript. All authors read and approved the final manuscript.

Ethical Approval Declaration

Ethics committee approval and informed consent form were not obtained for this study since the data is available to researchers and does not contain descriptive patient results.

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