Is screening of Staghorn Stones cost-effective?

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Background: Staghorn stones can cause damage to the kidneys and are considered as the one of the main cause of renal failure. If they are identified during the initial stages of diagnosis, kidney damage can be prevented. Screening can lead to a better diagnosis. Before the screening, it is necessary to calculate the cost-effectiveness of screening.

Methods: Using the possibility calculations of staghorn stones in the society and different age groups as well as a decision tree model, the screening costs and effectiveness were calculated against no screening. Effectiveness was determined based on the number of prevented cases of renal failure. Ultimately, the incremental cost-effectiveness ration (ICER) was calculated and compared with the World Health Organization (WHO) method based on the gross domestic product (GDP) per capita and subgroup analysis was done for different age groups. In addition, the robustness of results was examined by sensitivity analysis.

Results: The results of decision tree showed that in the screening group, the expected cost was 8815997 USD and the expected effectiveness was 358 and in the no-screening group, the expected cost was 3954214 USD and the expected effectiveness was 258. Based on the results of the study, screening compared with no screening would increase the cost by 4861783 USD and effectiveness would increase by 100 people. The incremental cost-effectiveness ratio (ICER) showed that for each unit of increase in effectiveness of screening compared with no screening, would lead to an increase the cost by 48618 USD. The results also indicated that screening 30-70-year-old people compared with other age groups (20-70 and 25-70) if done every two years, could reduce the mean costs per preventing each case of renal failure.

Conclusion: If screening staghorn stones are done every two years for 30-70-year-old individuals, it would be cost effective considering WHO method and 3026 USD could be saved in the health care system per each person.

Keywords: Staghorn stones; screening; cost effectiveness; kidney stone

INTRODUCTION

Urolithiasis is the third most common cause of urinary system disorders, after prostate pathological diseases, and urinary tract infections and is a common systemic disease, significantly associated with human health status and socio–economic consequences[1- 3].
Renal involvement is unilateral in some patients and bilateral in others. Patients who have kidney stones can have a wide range of symptoms; some patients have no symptoms and some present with episodes of symptoms, such as pain, hematuria, urinary obstruction, fever, nausea and vomiting[1].
Urolithiasis can cause complications, such as urinary tract infections, urinary obstruction, and even renal failure and some studies have attributed kidney, prostate, and bladder cancer to urolithiasis[3–7].
One of the most important types of urinary stones are kidney staghorn stones that involve a large part of the renal collecting system, pelvis, and calyx. Staghorn stones are usually made of struvite stones and are associated with high urine PH and urinary tract infections [8,9]. These stones do not usually obstruct the kidney and hence the patients feel little pain, and the stones are usually found by radiological studies, and can cause renal infection, septicemia and damage renal tissue[8].
The overall annual incidence of urolithiasis was estimated 136:100,000[11].The prevalence of staghorn kidney stones is various in different parts of the world. In one study, the prevalence of these stones was27.5% in patients with kidney stones[10].
Although urolithiasisis a rare cause of renal failure, some types of stones, including struvite and infectious types of stones, can cause renal failure[12]. In one study 3.2% of all patients suffering from renal failure had urolithiasis as the cause of their renal failure, among which 42.2% were infectious and struvite stones[13]. This type of stone can decay and destroy the kidney and the extent of kidney decay is calculated to be 28%, based on all relevant risk factors in staghorn kidney stones[5].
The mean age of onset of kidney stones is 41.5 years (SD = 16. 3Y) in patients and delay in diagnosis and treatment of these stones can lead to renal decay.[11]
Urolithiasis is usually diagnosed when a person has symptoms that are confirmed by methods, such as radi-

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Table 1. The costs of items in screening method and no screening method for staghorn stones.

The costs of items	The unit cost IRR	USD
The costs of physician's visit	92000	2.8
The costs of Ultrasound	140800	4.34
The costs of laboratory tests	390500	12
The costs of dialysis	1496000	46.2
The costs of renal transplant surgery	88000000	2717

ography, ultrasound, and CT scan. The tests of choice for diagnosis of kidney stones are CT scan and ultrasonography; CT scan has a higher sensitivity, but has disadvantages of being expensive, exposing the patient to radiation, and limited access[14], while the sensitivity of ultrasound to diagnose urolithiasis is 81–96% with a specificity of 100% [11].

In order to prevent the formation, diagnosis, and treatment of kidney stones, like other diseases, different levels of prevention can be applied. In the first level, in order to avoid the creation and formation of kidney stones, various steps can be taken, including dietary and medical prevention. In the second level, screening, early diagnosis, and appropriate treatment aimed at preventing further damage can be applied.

Since health care and methods of diagnosis and treatment are growing and expanding around the world, the costs are growing and the financial burden on the health system is increasing[15]. One of these measures include screening for diseases that meet the ten criteria of Wilson and Jungner. Certainly, one of the principles of screening programs is principal evaluation of the costs and benefits of screening and one of the important methods of economic evaluation is evaluation of cost–effectiveness that plays an important role in the assessment and evaluation of health systems[16].

Cost–effective analysis is the most common form of economic evaluation in health sector and if the consequences of various options are measured with natural units and have different effects, the cost–effective analysis would be the most appropriate method for economic evaluation that can be used[17].Considering the high prevalence of urolithiasis and significant rise in its prevalence in both sexes, as well as the financial burden imposed on patients and health care system, investigating low–cost strategies for on–time diagnosis and treatment of stones, particularly staghorn stones that may require widespread and costly treatment interventions and even cause renal failure are essential. The present study aimed to calculate the cost–effectiveness of screening programs for staghorn kidney stones in adults living in Shiraz, in order to implement the project in the community, in case of its cost–effectiveness.

MATERIALS AND METHODS

This study was a cost-effectiveness analysis done as a cross-sectional study in Shiraz, in the south of Iran. In this study, sampling was not done and all the population

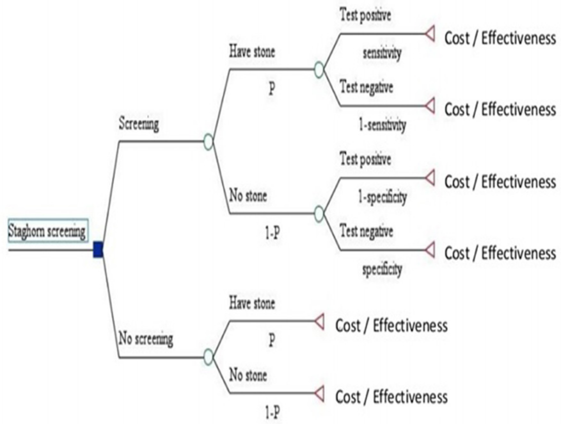

Figure 1. Decision tree model of staghorn stone screening versus no screening.
Screening initially divides people into two groups, according to the result of the test (positive or negative). Subsequent tests would divide the population into true- and false-positive cases.
P= probability of have stone= 3.8% Sensitivity= 96% Specificity=100% (11)
Effectiveness= the number of prevented cases of renal failure
Source: research finding

of Shiraz city, aged between 20 and 70 years (1,226,590 people) were included in the study. First, considering the incidence of kidney stones and staghorn stones, the number of patients with staghorn stones was estimated (Appendix 1). In the present study, using a decision tree model the cost-effectiveness of screening staghorn stone was estimated versus no screening (**Figure 1**). The Decision tree demonstrates a graphical representation of the route of diagnosis and treatment of various diseases, the costs, consequences, and probabilities[18]. The final indicator of effectiveness in this study was the number of prevented cases of renal failure. Also, in this study the costs were identified and measured from patients' viewpoint; according to the perspective of the study, only direct medical costs, including the cost of general practitioner's visits, the cost of kidneys ultrasonography, the cost of laboratory tests, the cost of dialysis, and kidney transplant were considered. In order to calculate the total cost of screening, the population aged 20–70 years (1,226,590 people) was multiplied by the total cost of the doctor and the kidneys ultrasonography. In order to estimate the cost of no screening, taking into account the incidence of kidney stones, staghorn stones, and renal failure, the number of patients with renal failure as a result of staghorn stones was calculated and then, taking into account the cost of laboratory tests, the cost of dialysis, and kidney transplant surgery costs, the total cost for no screening was calculated for the population aged between 20 and 70. For demographic subgroups, including age groups 25–70 and 30–70 years, similar methods were used to estimate the costs of screening and no screening programs (Calculations

Table 2. Cost–effectiveness analysis of screening for staghorn stone, compared with no screening in 2015(USD).

Strategy	Cost (USD)	Incremental cost (ΔC)	Effect	Incremental effect (Δ E)	C / E	ICER
screening	8815997	4861783	358	100	24626	48618
No screenings	3954214		258			

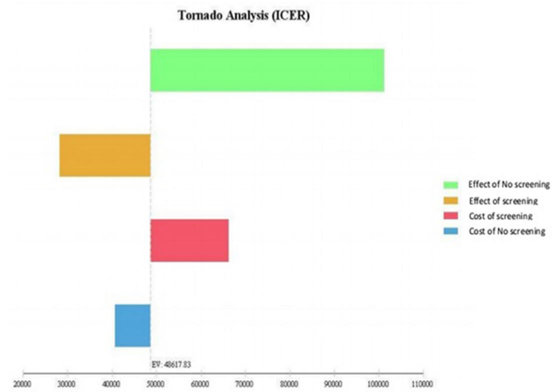

Figure 2. Results of one-way sensitivity analysis (Tornado graph). Source: research finding

are given in Appendix 2). Data were analyzed using TreeAge pro2011 software (Treeage Software, Inc., Williamstown, MA, USA). Using the decision tree, the expected costs and effectiveness were calculated and the incremental cost-effectiveness ratio (ICER) was calculated according to the formula that included the change in the cost of two programs or interventions than change their consequences. In other words, this ratio shows how much the costs change by the one-unit increase in the effectiveness[17]. After calculation of ICER, for the decision, this ratio was compared with the threshold limit. In order to calculate the threshold, the method of the World Health Organization was used, in which, if ICER index is lower than three times the GDP per capita, the program is cost-effective[19] and since each economic evaluation study has some uncertainty, in this study it was tried to test the generalizability of the results, using sensitivity analysis(20). As such, one–way sensitivity analysis was performed and the amount of each variable increased 20% and Tornado graph was prepared accordingly (**Figure 2**).

RESULTS

The results of the collected cost items are shown in **Table 1**, which shows the costs of kidney transplant surgery as the highest and physician's visit as the lowest. The results of the decision tree, according to different age groups are shown in **Table 2**, which shows that screening method, compared with no screening, increases the cost at 157,473,174,510 IRR (4,861,783 USD) and increases the effectiveness (prevented cases of renal failure) at 100 persons. In order to make a decision, ICER should be calculated and then compared with the threshold.

ICER = the difference in cost of screening compared with no screening/ the difference in effectiveness of screening compared with no screening
Incremental cost–effectiveness ratio (ICER) = $\Delta C/(\Delta E)$
ICER= (8815997- 3954214)/(358-258) = 48618
Cost of screening = 8815997 Dollar
Cost of no screening= 3954214 Dollar,
Effectiveness of screening =358
Effectiveness of no screening= 258

The calculated Incremental cost-effectiveness ratio indicates that for each unit increase in effectiveness, a screening method compared with no screening increases the costs at 1,574,731,745 IRR (48618 USD). In order to calculate the threshold level, the World Health Organization method was used, based on which, the program is cost-effective if ICER index is lower than three times the GDP per capita[19]. According to the World Bank's report, the GDP per capita of Iran and based on purchasing power parity (PPP) that equals 16507 $[21] is 32,390 IRR according to the Central Bank of Iran and the exchange rate[22]; the GDP per capita is 534,661,730 IRR(16507 USD) and the threshold is three times this amount 1,603,985,190 IRR (49521USD); considering the ICER index at 1,574,731,745 IRR (48618USD), which is lower than the threshold value 1,603,985,190 IRR (49521USD), screening method is cost-effective in the age group 20 to 70 years, compared with no screening.

Subgroup analysis

In order to determine the age and screening intervals, the cost-effective analysis was performed for the age groups 20 to 70 years, 25 to 70, and 30 to 70years with screening intervals of 1, 2, 3, and 5 years. The results of this analysis are shown in **Table 3**, which shows that screening is more cost-effective for the age group 30–70 years, compared to other age groups and if screening is conducted group every two years for this age, the mean costs will drop to 398,094,522 IRR (12290 USD) for each case of prevention of renal failure that would be 496,096,456 IRR (15316USD) in case of no screening. So, it can be said that screening is cost-effective, when performed every two years in the age group 30–70 years old and saves costs at 98,001,934 IRR (3025USD) per person. Based on the results of **Table 3**, for age groups 20 to 70 and 25 to 70 years, the mean cost per case of prevention of renal failure was 398,813,061IRR (12313USD), and 398,203,619 IRR, (12294USD) respectively, which are higher compared with mean cost of the age group 30 to 70 year (398,094,522 IRR), (12290USD) so screening is not cost-effective for age

Table 3. Cost–effectiveness analysis of screening for staghorn stone, compared with no screening in 2015 (USD), according to age and screening intervals.

Program	Groups	Effect (prevention of renal failure)	Cost per prevention of renal failure Interval			
			1 year	2 years	3 years	5 years
Screening	20-70	358	24626	12313	8208	4925
No screening	20-70	258	15326			
Screening	25-70	298	24588	12294	8196	4918
No screening	25-70	215	15272			
Screening	30-70	232	24581	12291	8194	4916
No screening	30-70	167	15316			

Table 4. Results of one–way sensitivity analysis.

Parameter's name	The main value	20% increase	The new ICER value	The initial ICER value
Effectiveness of no screening	258	310	100450	48618
Effectiveness of screening	358	430	28332	
The cost of screening	8815997	10579197	66250	
The cost of no screening	3954213	4745056	40709	

groups 20 to 70, and 25 to 70 years.

Sensitivity Analysis

Since each type of economic evaluation study is associated with some uncertainty, in this study the generalizability of the results was tested using sensitivity analyses[20]. Therefore, one–way sensitivity analysis was performed and the amount of change by 20% increase in each of the variables was calculated and Tornado diagram was prepared accordingly. The steps of the one–way sensitivity analysis were as follows: In the first step, ICER was calculated. As previously explained, ICER is calculated as the difference in the cost of screening compared with no screening to the differences in their effectiveness. ICER, in the present study, was calculated using the data of **Table 2** as follows:

ICER= (285550152000 -128076977490)/(358-258) = 1574731745 IRR
ICER= (8815997 -3954213)/(358-258) = 48618USD

In the second step, we changed the amount of each of the model parameters (for example, by 20% increase). In the third step, ICER values were computed for each parameter change. For example, the effectiveness of no screening increased from 4 to 310 by 20%, according to **Table 4**. This increase in the effectiveness of no screening also changed ICER as follows:

ICER= (285550152000 -128076977490)/(358-310) = 3253577986 IRR
ICER= (8815997 -3954213)/(358-310) = 101287 USD

For all other parameters, the amount of ICER changed in the same way. The results for each of the parameters are listed in **Table 4**. As the results of this table show, 20% increase in two parameters of the effectiveness of no screening and the costs of screening, increased the amount of initial ICER and increased the two parameters of the effectiveness of screening and the costs of no screening reduced the amount of initial ICER.

In the next step, the initial ICER (1574731745IRR (48618USD) and the amount of each of the new ICER, calculated in Table 4, was plotted in a graph that is called Tornado graph (**Figure 2**). The numbers on the horizontal axis of the graph represent the new ICER and the value 1574731745IRR (48618USD) represents initial ICER values.

One-way sensitive analysis using Tornado diagram indicated that changes in most of the input parameters had few effects on the outcome. Moreover, ICER had the highest and lowest sensitivities to the increases in the effectiveness and costs of no screening, respectively (**Figure 2**)

DISCUSSION

A review of studies on the cost-effectiveness of screening and preventing kidney stones indicated the main focus of studies on economic evaluation of the first level prevention, ie comparison between diets, drinking proper water and fluids, and metabolic and metaphylaxis studies[22–24] or focus on the second level prevention of comparing different drug treatment and surgical treatment methods[25–27]. There was no study focusing on the cost-effectiveness of screening and early diagnosis of kidney stones, by checking databases, including PubMed, science direct, and Scopus. Nevertheless, there are multiple studies on the cost-effectiveness of screening for early diagnosis of other diseases such as colon cancer, breast cancer, cervical cancer, addiction, and diabetes in adults[28–32] that all confirmed the cost-effectiveness of screening. Since our study is the first study on the cost-effectiveness of the screening for staghorn stones, compared with no screening (the current situation) using a decision tree model, it was not possible to compare the results with other studies. The results revealed that the screening for staghorn stones was more cost-effective than no screening. The results of this study also showed that screening is more cost-effective every two years for the age group 30–70 years, compared to other age groups. One reason for this can be the higher incidence of kidney stones, as well as lower costs of prevention of each case of renal failure in this age group, compared with the age groups 20 to 70, and 25 to 70 years. In other words, it can be said that screening, every two years, for age group 30 to 70 years, saves the costs at 98001934 IRR (3026USD) per person, compared to doing it on an annual basis. In addition, the results of the one-way sensitivity analysis powerfully confirmed the finding of the present study and increased the generalizability of the results. To generalize the findings of this study, we can generalize these results to other provinces of the country, but certainly, these results cannot be generalized to other countries, because of differences in the costs of insurance coverage, affordability of patients, the prevalence of the disease, payment system, and relative prices. Also, the results of this study can be used in the development of clinical guidelines for prevention of staghorn stones in Iran by the Department of Health, Ministry of Health and Medical Education, Medical Universities, Department of Health Economics, and Department of Assessing Health Technology at Ministry of Health. As mentioned, a review of previous articles resulted in no similar articles on determining the effectiveness of screening staghorn kidney stones and perhaps this study is the first study focusing on this subject. Also, compared with other screening methods on other diseases, it can be said that screening staghorn kidney stones with kidneys ultrasonography is cost–effective in the age group 30 to 70 years, when performed each two years and the mean costs (IRR)(USD) for each case of prevention of renal failure was 398,094,522 IRR (12291USD) that increased to 496,096,450 IRR (15316USD) in case of no screening. Therefore, as to the results of the present study, it can be said that screening is cost-effective every two years in the 30-70-year-old age group and saves the cost at 98001934 IRR (3026USD) per person. In this study, in order to calculate the threshold level, the World Health Organization method was used. Although this recommendation of WHO about threshold is mostly used for "cost per QALY gained" or "cost per DALY averted" as the outcome, because there is not any threshold calculated or accepted for Iran, we used it as our threshold.

CONCLUSIONS

The World Health Organization defines the threshold of cost–effectiveness of various projects and interventions that is calculated based on GDP per capita and if, in any country, the health care interventions and programs are less than three times the GDP per capita, the cost will be cost–effective(25) and in this study, considering the save in the costs at 98001934 IRR (3026USD) per person and according to the threshold of the World Health Organization, screening every two years will be cost–effective for patients aged 30 to 70 years by the conditions listed on this study.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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