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Use of the National Health and Nutrition Examination Survey to Calculate the Impact of Obesity and Diabetes on Cost and Prevalence of Urolithiasis in 2030

Jodi A. Antonelli, M.D., Naim M Maalouf, M.D., Margaret S. Pearle, M.D., Ph.D., and Yair Lotan, M.D.

UT Southwestern Medical Center, Dallas, TX

Abstract

Background—The prevalence of urolithiasis and its risk factors such as obesity and diabetes have increased over time.

Objective—Determine the future cost and prevalence of kidney stones using current and projected estimates for stones, obesity, diabetes, gender, and population rates.

Design, Setting, and participants—The Stone prevalence in 2000 was estimated from National Health and Nutrition Examination Survey (NHANES) 1988–1994 and 2007–2010. The cost per percent prevalence of stone disease in 2000, calculated using Urologic Diseases in America Project data, was used to estimate the annual cost of stones in 2030, adjusting for inflation and increases in population, stone prevalence, obesity, and diabetes rates.

Outcome measurements and statistical analysis—The primary outcome was prevalence and cost of stones in 2030. The secondary outcomes were the impact of obesity and diabetes on these values, calculated using ratios for stones by body mass index and diabetes status.

Results and limitations—The annual cost of stone disease in 2000, adjusted for inflation to 2014 US dollars, was approximately \$2.81 billion. After accounting for increased in population and stone prevalence from 2000, the estimated cost of stones in 2007 in 2014 US dollars was \$3.79 billion. Future population growth alone would increase the cost of stone disease by \$780 million in 2030. Based on projected estimates for 2030, obesity will independently increase stone prevalence by 0.36%, with an annual cost increase of \$157 million. Diabetes will independently increase stone prevalence by 0.72, associated with a cost increase of \$308 million annually by 2030. NHANES data, however, capture patient self-assessment rather than medical diagnosis, which is a potential bias.

Conclusions—The rising prevalence of obesity and diabetes, together with population growth, is projected to contribute to dramatic increases in the cost of urolithiasis, with an additional \$1.24 billion/yr estimated by 2030.

Patient Summary—Obesity, diabetes, and population rates will contribute to an estimated \$1.24 billion/yr increases in the cost of kidney stones by 2030.

Keywords

urolithiasis; cost; obesity; diabetes

1. Introduction

An assessment of the National Health and Nutrition Examination Survey (NHANES) II and III datasets revealed that the prevalence of kidney stones in US adults rose significantly, from 3.2% in 1976–1980 to 5.2% in 1988–1994¹. This trend has persisted with the latest NHANES data revealing an estimated 8.8% prevalence of stone disease².

The concomitant rise in comorbid conditions associated with stone disease, including obesity and type 2 diabetes mellitus, has been proposed as a possible explanation for the rise in stone prevalence. In US adults, the prevalence of obesity increased from 30.5% in 2000 to 35.7% in 2010³, and the age-adjusted prevalence of diabetes rose from 4.5% in 1995 to 8.2% in 2010⁴. Both conditions have been linked to an increased risk of uric acid and calcium oxalate stone formation by a variety of proposed pathophysiologic mechanisms^{5–11}.

Several studies have verified the positive association between body size and risk of stone formation^{2,12–15}. In addition, obese first-time stone formers have been shown to have an increased incidence of stone recurrence and a decreased time to recurrence compared to nonobese first-time stone formers¹⁶.

The associations between obesity, diabetes and nephrolithiasis have been well established and the pathophysiologic mechanisms are currently being studied, but the impact of these comorbid conditions on cost and prevalence of stone disease has yet to be explored. In 2000 the total annual expenditure for urolithiasis was estimated at \$2.1 billion, representing a 50% increase from estimates in 1994¹⁷. The effect of obesity and diabetes on nephrolithiasis is likely to escalate the financial burden of this increasingly common condition. The aim of the present study was to calculate the effects of population, obesity, and diabetes on future costs of nephrolithiasis, specifically in the year 2030, using current and projected prevalence estimates of obesity, diabetes, population, and stone disease.

2. Methods

This study was exempt from review by our institutional review board because it does not include patient data.

2.1 Prevalence of stone disease in 2000

Because cost estimates for urolithiasis in the US have been reported for the year 2000, cost and estimated prevalence of stone disease from that year were used to derive the cost per unit percentage prevalence that could then be applied to a year for which we had prevalence but no cost data. Since no available national prevalence data spanned the year 2000, the prevalence of stones for that year was estimated by calculating the mean stone prevalence for the 1988–1994¹ and the 2007–2010² NHANES datasets. NHANES is a nationally representative, multistage probability survey assessing the health and nutritional status of the

noninstitutionalized US population. Since there are more women than men in the United States, the stone prevalence was corrected for gender distribution (Table 1)¹⁸.

2.2 Cost per percent prevalence of stone disease in 2014 US dollars

The estimated cost for the diagnosis and management of nephrolithiasis for the year 2000 was obtained using data from the Urologic Diseases in America Project¹⁷. This cost was divided by the estimated lifetime prevalence for stone disease in 2000 to determine the cost per unit percentage prevalence of stones for that year. Year 2000 costs were then converted to 2014 dollars using an inflation calculator based on the US government Consumer Products Index to provide contemporaneous values (Table 1).

2.3 Population Estimates

Using the US Census Bureau's Population Estimates Program, which estimates yearly population in the United States from current data on births, deaths and migration to update the most recent decennial census, the total US population, as well as the percentage of men and women, was determined for 2007¹⁸, a year for which the most current stone prevalence has been published². An estimate of cost increase based on the increase in population was then determined using prevalence of stone disease from 2007–2010 NHANES data², adjusting for gender distribution¹⁸ (Table 1). Population projections for 2030 were obtained from the US Census Bureau¹⁹.

2.4 Impact of obesity on cost

The standard categories of body mass index (BMI) in kilograms per square meter, as defined by the Centers for Disease Control and Prevention (CDC), are normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥ 30.0 kg/m²)²⁰. The distribution of normal, overweight, and obese individuals in 2007 was obtained from NHANES data. These distributions were applied to the prevalence of stone disease from 2007–2010 NHANES data and the odds ratios for stone prevalence by weight category (1=normal BMI, 1.29=overweight, and 1.55=obese)² to calculate the percentage prevalence of stone disease based on anticipated 10% shift from normal to overweight BMI and overweight to obese BMI in the US population. This method was chosen because the CDC projects that >44% of US adults (approximately a 10% increase from current prevalence) will be obese by 2030²¹. The CDC's analysis is based on a model that projects that around 50% (95% confidence interval [CI], 45–55) of US adults will be obese by 2030 (Table 2).

2.5 Diabetes Prevalence

The percentage of diagnosed and undiagnosed diabetes rates among individuals ≥ 20 yr in the United States in 2007 was obtained from the CDC's National Diabetes Mellitus Fact Sheets²². These estimates were derived from the 2003–2006 NHANES, the 2004–2006 National Health Survey, 2005 Indian Health Service data, and 2007 resident population estimates. The odds ratio for a history of stone disease associated with a diagnosis of diabetes, independent of BMI and gender was previously reported as 1.59². This value was used to calculate the percentage prevalence of stone disease in 2030 applying extrapolated

estimates from previously published projections of diabetes prevalence by gender for 2030 (Table 3)²³.

3. Results

The average lifetime prevalence of stone disease in 2000 was calculated as 7.0% (8.5% in men and 5.6% in women). Assuming an annual expenditure for stone disease in 2000 of approximately \$2.1 billion¹⁷, the cost per percentage prevalence of stone disease in 2000 was approximately \$295 million. After adjusting for 35.8% inflation from 2000 to 2014, the cost per percent prevalence of stone disease in 2014 US dollars was \$401 million, and the total cost of stone disease in 2000 in 2014 US dollars was approximately \$2.81 billion (Table 1).

The US population in 2000 was 281,421,906²⁴. In 2007, the population grew to 301,621,157 and was composed of 50.7% women and 49.3% men¹⁸. The calculated cost of stone disease, accounting for the 1.07-fold increase in the population from 2000 to 2007 and a 1.26-fold increase in stone prevalence from the calculated estimate in 2000 to the NHANES estimate for 2007–2010², resulted in an annual cost of \$3.79 billion for stone disease in 2007, a year included in the most current available stone prevalence for US adults. The US Census Bureau estimate for the 2030 US population is 363,584,435, representing a 1.29 increase from 2000, which would be associated with an annual cost of stone disease of \$4.57 billion in the unlikely event that stone prevalence remained constant from 2007 to 2030. Therefore, population growth alone is expected to increase the annual cost of stone disease by \$776 million from current estimates by the year 2030 (Figure 1).

After adjusting for gender distribution, the prevalence of stone disease in 2007 was 8.8%². As shown in Table 2, we project a total lifetime prevalence of stone disease of 9.2% (95% CI, 8.3–10.1) if there is a 10% shift in normal weight to overweight and overweight to obese in men and women in the United States, as expected by 2030²⁵.

This change in obesity prevalence alone would result in a 0.36% absolute increase in stone prevalence by 2030. As such, for every 10% increase in obesity, the annual cost of stone disease is expected to be \$3.95 billion (95% CI, 3.55 billion to 4.34 billion) representing a \$157 million increase from 2007 to 2030 (Figure 1).

Table 3 shows that in 2007, the total reported prevalence of diagnosed and undiagnosed diabetes in adults 20 yr was estimated at 11.2% for US men and 10.2% for US women²². A 1.59-fold higher prevalence of urolithiasis has been reported among individuals with diabetes compared to nondiabetic individuals². Using this odds ratio, we estimate that if the prevalence of diabetes increases as projected²³, this factor alone will independently increase stone prevalence to 9.5% (95% CI, 3.62–4.58), representing an increase of \$308 million by 2030 (Figure 1).

Taking into account the projected increase in population, diabetes and obesity, the increase in the total cost of stone disease from 2007 to 2030 will be \$1.24 billion in 2014 US dollars, without taking into account other factors that influence stone prevalence.

4. Discussion

This analysis represents the first published attempt to quantify the effects of population growth and rising rates obesity, and diabetes on the prevalence and cost of stone disease. In addition, projected future costs that might be incurred as a result of population growth and increasing prevalence of these comorbid conditions are described in this paper. We chose to project estimates for 2030, a year in the near future for which high-quality estimates of obesity and diabetes exist. We showed that population growth alone will have the most profound impact on increasing the annual cost of stone disease. The cost of stone disease in 2000 was approximately \$2.1 billion annually¹⁷. After accounting for increases in population and stone prevalence from 2000, the estimated cost of stone disease in 2007 in 2014 US dollars was \$3.79 billion. We calculated that in the unlikely event that stone prevalence remains unchanged from the last national published estimate², the population growth expected by 2030 will independently increase the annual cost of stone disease by a staggering \$ 780 million. Population growth is largely a nonmodifiable factor, but we showed that potentially modifiable factors such as obesity and diabetes are related to escalations in stone disease prevalence that contribute, though not as significantly as does population growth, to substantial increase in the cost associated with urolithiasis.

The data for much of our investigation are derived from the 2007 NHANES by Scales et al², which represents the most recent assessment of kidney stone prevalence since Stamatelou and colleagues analyzed 1976–1994 NHANES data¹¹. Because of established associations among obesity, diabetes, and stone disease, Scales and colleagues created multivariable models to quantify the independent relationship of these factors to stone disease and subsequently generated odds ratios, which we used in our analysis.

The CDC released rates of current and future obesity in August 2012²⁵. Twelve states have an adult obesity rate exceeding >30%. If obesity continues at the current rate, the CDC projects that >44% of US adults (a 10% increase from current rates) will be obese by 2030. A 10% increase from normal to overweight and overweight to obese would independently account for an additional \$157 million in annual cost of stone disease, based on our calculations.

We acknowledge that obesity and diabetes are interrelated entities, and therefore an increase in one will produce a concomitant increase in the other. However, the two conditions were independently associated with a greater prevalence of urolithiasis in the latest NHANES data set². Therefore, the independent impact of diabetes on stone prevalence will likely still be realized, as a dramatic rise in the prevalence of diabetes – to nearly 1 in 10 US adults – is anticipated by 2030. We estimate that the independent effect of this projected rise in diabetes will increase the cost of stone disease by \$73million by 2030.

Using projected estimates of population, obesity, and diabetes, we predict that the annual cost of stone disease will increase by 33% in the year 2030 totaling an additional \$1.24 billion/yr annually, without taking into account other factors that influence stone prevalence. In any case, these figures are likely underestimated, since the cost of health care has outpaced inflation²⁶.

The epidemiological literature supports the metabolic associations that have been demonstrated among obesity, diabetes, and stone formation. Curhan and coworkers showed that the prevalence and incidence of stone disease were positively associated with body weight and BMI¹². Weight gain, a process that likely involves the addition of proportionally more adipose tissue compared with lean muscle, was associated with an increased rate of incident stone formation¹⁵. Semins and associates also examined the relationship between BMI and stones using claims data and found an increasing risk of kidney stones with increasing BMI up to a BMI of 30 kg/m², after which the risk stabilized¹⁴.

Our estimates of the effects of obesity and diabetes on the prevalence and cost of stone disease would be incomplete without including the impact of population growth. When attempting to consolidate the individual contribution of obesity, diabetes, and population change on stone disease, the magnitude of each has to be weighted. Although the published odds ratios for diabetes and obesity provided this information for the analysis of current prevalence and cost estimates², any projected future estimates must take into account the rate of change of each factor. In addition, the incidence of stones peaks in the fourth to sixth decade of life²⁷. As such, the direct and indirect costs of stone disease in this working age group are substantial²⁸. While an age-stratified analysis could provide insight into cost contributions of certain subgroups of the population, this level of data granularity for specific age groups was lacking and precluded this type of analysis. The majority of population gains in the future will be in older segments of the population.

Although this analysis represents the first estimate of the impact of population growth, obesity and diabetes on current and future costs of stone disease, our results must be tempered by some inherent limitations. First the NHANES instrument from which we derived much of our data is a cross-sectional design that uses patient self-assessment of stone disease and not confirmed medical diagnoses. Scales et al also recognized this limitation in their analysis and additionally considered a secondary outcome of self-reported stone passage that reflected symptomatic stones and found similar results regarding stone prevalence². Any prevalence data are limited by the inability to diagnose asymptomatic stones. In addition to NHANES, we used data derived from several other large databases, which leads to inherent bias. Finally, our analysis failed to take into account other important demographic factors, such as race/ethnicity, geography, and socioeconomic status, that may change unpredictably over time and effect stone prevalence independently, as well as rates of diabetes and obesity. The incorporation of these variables into future analyses will provide a more fine-tuned estimate of current and future costs.

5. Conclusions

In this paper we present a sound analysis of the most current data regarding stone prevalence, obesity, diabetes, and population changes and their effects on cost both today and in the future. Obesity and diabetes are somewhat modifiable diseases that affect stone prevalence, and as demonstrated in this paper, their rising incidence, in conjunction with population growth, will lead to substantial increases in future stone-related health care costs.

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Figure 1.
Cost of stone disease in 2007 and the future based on obesity, diabetes, and population growth

Table 1

Lifetime stone prevalence and total annual cost of stone disease adjusting for population rates and gender distribution

	Percent prevalence of stone disease		
	Men	Women	Total Population
NHANES 1988–1994 ¹	6.3	4.1	5.2
NHANES 2007–2010 ²	10.6	7.1	8.8
Year 2000 (estimated)	8.5	5.6	7.0 [*]
Calculated Values	Total Annual Cost		
Cost of stone disease in the US in 2000 (UDA data ¹⁷)	\$2,067,400,000		
Estimated cost per 1% stone prevalence in 2000	\$2,067,400,000/0.0700505 = \$295,129,942		
Estimated cost per 1% stone prevalence in 2013 dollars ^{**}	\$295,129,942 × 1.3535 = \$399,458,377		
Estimated cost of stone disease in 2000 in the US in 2013 dollars ^{**}	\$2,067,400,000 × 1.3535 = \$2,798,225,900		
Estimated cost of stone disease in 2007 in the US [^] in 2013 dollars ^{**}	[\$2798225900 × 1.0718] × 1.25988 \$3,778,459,341		
Estimated cost of stone disease in 2030 in the US ^{^^} in 2013 dollars ^{**}	[\$2798225900 × 1.2920] × 1.25988 \$4,554,683,824		

* Average, adjusted for gender distribution of US population in 2007: 49.30% men and 50.70% women¹⁸

** Adjusted for 35.35% inflation from 2000 to 2013

[^] Adjusted for the increases in population¹⁸ and stone prevalence² between 2000 and 2007

^{^^} Adjusted for the increase in population from 2000 to 2030¹⁹

Table 2

Prevalence and cost of stone disease by BMI category in the adult US population in 2007 and projected estimates for 2030

BMI	Men			Women			Stone prevalence (%)	Annual Stone Cost (billion \$)
	Normal	Overwt	Obese	Normal	Overwt	Obese		
2007 (%)	23.5 [*]	40.1 [*]	36.4 [*]	28.7 [*]	28.6 [*]	42.7 [*]	8.8	3,791 billion
2030 ^{**} (%)	13.5	40.1	46.4	18.7	28.6	52.7	9.2	3,948 billion
Change from 2007 to 2030								increase of 157 million

^{*} Percent of men and women by BMI category in 2007²¹

^{**} Projected prevalence of obesity in 2030²⁵

[^] 95% CI is reported for obese²⁵, and other values are extrapolated using 10% variance.

Table 3
Prevalence and cost of stone diseases by diabetes rates in the adult US population in 2007 and projected estimates for 2030.

	Diabetic Men (%)	Stone Prevalence in Men (%)	Diabetic Women (%)	Stone Prevalence in Women (%)	Stone Prevalence Total (%)	Annual Stone Cost (billion \$)
2007	11.2 *	10.6	10.2 *	7.1	8.8	3,791,000,000
2030	19.1 **	10.8	18.0 **	7.3	9.5	4,099,000,000
Change from 2007 to 2030						Increase of 308,000,000

* Prevalence of diabetes in 2007²²
^ 95% CIs reported for total diabetes prevalence in 2030²³; other values extrapolated from this 11% estimate.
** Projected prevalence of diabetes in 2030 with 95% CIs²³