

A population-based retrospective cohort study analyzing contemporary trends in the surgical management of urinary stone disease in adults

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Abstract

Introduction: We aimed to review the trends and incidence of surgical intervention for adults with upper urinary tract stones in Ontario, Canada, and to hypothesize potential causes for the observed changes.

Methods: We carried out a retrospective, population-based cohort study using administrative databases held at the Institute of Clinical Evaluative Sciences (IC/ES) to identify all adults (≥ 18 years) who underwent surgical treatment for urolithiasis, defined by records using a combination of both hospital and physician billing from 2002–2019. Descriptive statistics were used to summarize baseline patient demographics, and surgical trends were analyzed using the Cochrane-Armitage test for trend.

Results: From 2002–2019, 140 263 patients were treated surgically for urolithiasis. During this time period, the total number of surgically treated stone disease increased by 80.5%. By type of

procedure, percutaneous nephrolithotomy (PCNL) increased by 187% and ureteroscopy (URS) increased by 158%, while the number of shockwave lithotripsy (SWL) declined by 31.4%. The adult population in Ontario in the years evaluated grew by 24.4%. The number of surgical procedures per 100 000 people over this time grew by 45.3%. For every 1% increase in the population, there was a 2.6% rise in stone-related surgical procedures.

Conclusions: The number of stone-related surgical procedures performed rose significantly and cannot be accounted for by population growth alone. This rise was proportionally larger in the female population, further supporting a narrowing of the gender gap in urinary stone disease. The reasons for the increase are likely multifactorial and may imply an increasing incidence of surgically treated stone disease. The change in the proportion of URS and SWL performed may demonstrate a continued shift in surgical preference or may be reflective of resource limitations and availability. The increase in PCNL volumes may also suggest a greater complexity of cases. These findings should be considered for future resource planning and require further study.

Introduction

Urolithiasis is a prevalent disease, affecting 10% of the population worldwide¹. The prevalence and incidence of urinary stones has increased over the last three decades^{2,3}. Technological refinements have resulted in miniaturization of the endoscopes used in these procedures. With these advancements, URS and laser lithotripsy has become increasingly popular.

A study looking into surgical trends between 1990-1998 reported that the number of PCNL's remained stable, URS's increased by 53%, while the number of SWL's, decreased by 15%⁴. Ordon et al.⁵, reported that between the years 1991–2010, in Ontario, Canada, the utilization of URS increased significantly from 25% to 59% of all procedures, whereas PCNL remained unchanged in its' utilization and SWL decreased significantly from 69% to 34% of all procedures. We felt it was important to revisit the issue using a more contemporary cohort, and to explore possible reasons for any trends that might be observed.

In this study we reviewed the trends in surgical intervention for urolithiasis of the upper urinary tract in patients living in the province of Ontario, Canada. The aims of our study were to determine if the total number of surgical procedures was increasing relatively to the general population. We were also interested in determining if the previously noted surgical modality trends were persistent and hypothesize potential epidemiological reasons for the observed changes.

Methods

This retrospective population-based cohort study included all adult patients (≥ 18 years of age) who underwent a minimally invasive surgical treatment for urolithiasis (calculi located within the kidney or ureter) in the province of Ontario, Canada, from April 1st, 2002 to March 31st,

2019. Although urinary stone disease has a high recurrence rate, we chose to exclude patients with prior surgical procedures in the last 10 years and aimed to capture those who had their initial presentation during the study period and exclude patients who underwent secondary procedures for residual fragments. We excluded non-Ontario residents, patients with missing or invalid age, sex, or date of death information, open cases and those who had undergone previous surgical management of urolithiasis within the last 10-years. Figure S1 in Appendix describes the cohort selection process. Hospital and same day surgery services are recorded in the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database and Same Day Surgery databases, whereas physician billing records are maintained in the Ontario Health Insurance Plan (OHIP) database. The Registered Persons Database was also used to obtain baseline patient characteristics. These datasets were linked using unique encoded identifiers (Table S1) and analyzed at ICES Western. Reporting of this study follows the RECORD statement⁶ (Table S2).

Variable definitions

Surgical management of urolithiasis was identified using inclusion in either the OHIP or CIHI databases. Duplicate records were reconciled by keeping one record and only the first procedure per patient was included in the analysis. Since this is primarily a trends study, a combination of either/or OHIP and CIHI codes were used as inclusion criteria to ensure we captured the largest possible population. The CIHI codes were more definitive in determining the index modality and were used as the primary inclusion code. The OHIP codes utilized were a combination of S-codes with either simultaneous E codes or independent Z codes (Table S1). A large degree of agreement was noted between the two databases. Eligible patients were categorized into three groups based on their index surgical modality: URS, SWL and PCNL. Patients who underwent multiple surgical treatment modalities on the same date were assigned to a group according to the following hierarchy: PCNL, SWL, and URS. This hierarchy was based on the fact that if PCNL and SWL was performed, it is likely that URS was probably a secondary surgical modality. Patient baseline characteristics captured included: age, sex, rural/urban residence (population above/under 10,000), calculus location (ureter or kidney), and first imaging modality used for assessment of stone disease in the 90 days before the surgical procedure. If both CT and US occurred on the same date, the first imaging modality was categorized as CT.

Statistical analysis

Data is reported as means and standard deviations. The linear trend in the overall number of cases per year was assessed using a linear regression model. Trends across the study period in terms of patient sex and surgical intervention were evaluated using the Cochran-Armitage test for trend. For all analyses, reported p-values are from 2-tailed tests where a value of <0.05 was considered statistically significant. The main assumptions of this model include that the dependent variable and errors of the linear regression model are normally distributed. All analyses were performed using SAS EG version 7.15 (SAS Institute, Cary, NC, USA).

Results

Over the 17-year study period, 140,263 adult patients underwent a minimally invasive surgical procedure for management of urolithiasis in Ontario. The mean age of patients undergoing surgical management for urolithiasis was 54 years of age and 60.5% of patients were male. Detailed demographic and preoperative data are given in Table 1.

CT scans were predominantly used as the first imaging modality (66%), compared to US scans which were only used as the first imaging modality in 29% of the cases overall. Throughout the study period the number of patients undergoing CT scans preoperatively and the proportion of patients undergoing CTs scan as their first imaging modality increased significantly ($p < 0.0001$). Specifically, for PCNL, the first imaging modality used was CT for 44.2% of patients, US for 22.7% and 2.6% had both modalities on the same day. An additional 14% of patients underwent CT imaging after their first imaging investigation so that overall, 58.2% underwent CT at some time preoperatively.

The proportion of females undergoing surgery for urolithiasis increased from 39.5% in 2002 to 42% in 2018 ($p < 0.0001$). This corresponded to a percentage increase of 112% in females undergoing surgical management for stone disease, compared to an increase of only 60% in the male population (Figure 1). The overall increase in the population of females and males during that same time period was 22.5% and 23.8% respectively.

During the studied period, the adult population in Ontario grew by 24.4%, from 9,294,774 to 11,564,360. The total number of surgical procedures presented a steady increase, rising by 80.4%, from 5,946 cases in 2002 to 10,732 cases in 2018, resulting in an average yearly rise of 3.7%. In 2002, the annual stone related surgical intervention rate in Ontario was 64 per 100,000 population while in 2018 it was 93 per 100,000 population, a 45.3% rise (Figure 2). When considering the adult population in Ontario relative to the number of stone related surgical procedures, it was observed that for every 1% increase in the population, there was a 2.6% increment in stone related surgical procedures.

The number of URS and PCNL procedures per 100,000 population grew from 29.6 to 61.5 and 6.97 up to 16.1 respectively. The number of SWL procedures per 100,000 population decreased from 27.4 in 2002, down to 15.1 in 2018 (Figure 3). There was a steady yearly increase in the number of PCNLs performed, from 648 to 1,864 cases, corresponding to a 7% annual increase and a 185% rise over the study duration. URS increased at an average annual rate of 6%, resulting in a total increase of 158% over the study period, from 2,751 cases in 2002 to 7,121 cases in 2018. Conversely, SWL procedures were observed to steadily decline, with a yearly decrease of 2%, an overall decrease of 31.4%, from 2,547 down to 1,747 procedures (Figure 3). Linear regression analysis demonstrated a significant increase in both URS and PCNL and a decrease in SWL over the study period ($p < 0.005$ overall for all 3 modalities).

Discussion

The incidence and prevalence of urolithiasis has increased over the years. This rise in prevalence has been reported in studies from Europe⁷, North America⁸ and Asia⁹. Increases in the number of patients diagnosed with stones may subsequently result in a rise in the number of stone-related surgical procedures. Previous studies reported on the rising number of stone related surgical procedures over the years^{10,11}. Ordon et al.⁵ reported that the number of URS increased significantly, while the number of PCNL procedures remained unchanged and the number of SWL decreased from 69% to 34% of all procedures. We report on a continued increase in the number of URSs performed, but in contrary to Ordons' report, we noted a rise in the number of PCNLs. Similar to their study, we noted a continued decrease in the utilization of SWL. The rise in number of PCNLs performed may be indicative of a greater stone complexity as well as a growing number of practicing urologists in Ontario trained in PCNL. Although we could not calculate stone disease incidence or prevalence figures with the dataset we used, we observed a steady rise in stone related surgery, with a total increase of 80.5% in the 12 years assessed. We also report on a significant percentage increase in females undergoing stone related procedures compared to the male population (Figure 1).

The reasons for the observed increase in the surgical intervention of stone disease and the change in surgical modalities are likely multifactorial and are most probably not just strictly related to the increase in the number of patients afflicted with stones observed in recent worldwide trends^{7,8,9}. In the remainder of this report, we explore the possible explanations for the increase in interventions.

Population size and age

It is also well-known that the prevalence of urolithiasis increases with age⁸. In Ontario, the adult population aged 18 years and above, increased by 24.1%, in the years assessed. Moreover, the age group of 40-69 years old increased significantly by 29%, from 4,336,116 up to 5,597,172⁸ (Figure 4). The surgical intervention rate in the adult population in Ontario in the year 2002 was 64 per 100,000 population, rising to 93 in 2018. The number of stone related surgical procedures per 100,000 people grew in those years by 45.3% (Figure 3). In our data we noted that for every increase by 1% in the population size, there was a 2.6% rise in stone related surgical procedures. We were surprised to find that as the population rose by 24.4% in the years investigated, the number of stone related procedures outpaced the population, and had risen by 80.5%. By extrapolating the yearly average increase in population with the yearly increase in the number of surgical procedures, we predict that if the population continues to grow at the same rate and the rate of stone disease remains constant, the total number of stone related surgeries will increase to almost 14,000 by the year 2025. We hypothesize that both the increase in the overall adult population and specifically the age group of 40-69 years-old, may be correlated with the increased number of surgical procedures. If our prediction is correct, this will have a significant impact on patient care and resource management.

Obesity and diet

There are two main dietary factors that may play a major role in the upsurge in the prevalence of urolithiasis: quantity and quality of food. Studies have shown a direct correlation between the prevalence of urolithiasis and an elevated body mass index (BMI)^{12–15}. The prevalence of obesity in Ontario has increased significantly over the past three decades¹⁶, growing by 31% between 2004–2015. According to a 2015 Canadian Community Health Survey, 32% (3,444,100) of Canadians were considered overweight (BMI 25–29.9) and 26% (2,768,100) were found to be obese (BMI \geq 30)¹⁷ (Figure 5). The percentage increase in obesity was 21.3% and 45% in females and males respectively. Unfortunately, we were unable to capture BMI data for our study cohort; however, the rising rates of obesity within the province of Ontario have likely contributed to the increase in surgically managed urinary stone disease observed.

The quality of the diet, mainly low urinary volumes due to insufficient fluid intake, combined with a high sodium and protein consumption, may also play a role in stone formation¹⁸. A recent study by the Canadian government reported that Canadians consume a staggering amount of 3,400 mg of sodium daily¹⁹. We hypothesize therefore that both the quality and quantity of the diet consumed may have contributed to the rising numbers of urolithiasis related surgical procedures.

Number of practicing urologists

According to the Canadian Urological Association (CUA), the number of practicing urologists in Ontario has risen by 70.6%, from 200 in 2002 up to 283 in 2018²⁰. Moreover, the number of fellowship trained endourologists also increased. Welk et al.²¹ reported that among urology graduates, 39% proceeded to fellowship in minimally invasive urology/endourology. Presumably, these urologists feel more comfortable performing PCNLs and URSSs.

Improved diagnostics

According to the Canadian Medical Imaging Inventory, in 2017 there were 561 CT units in Canada, up from 419 in 2007. It was estimated that a total of 5.61 million CT examinations were performed in 2017, up from 3.38 million in 2007²². With improved diagnostics and shorter waiting time, the number of patients diagnosed with renal stones would probably rise, leading to more patients seeking medical attention and treatment. This was also reflected in our data, where we observed a significant increase in the number of patients undergoing preoperative CT scans and having a CT scan as their initial imaging modality.

Decreasing number of SWL procedures

Our study has demonstrated that the number of SWL procedures being performed in Ontario has decreased during the years of our evaluation. We believe that the cause for this is multifactorial. Most importantly, there are only three shock wave lithotripsy units in Ontario, which results in limited access to this technology. 11.3% of patients in our cohort live in a rural area, which may have led them to travel a great distance in order to undergo treatment. This may have resulted in

patients preferring a different treatment modality, such as URS, performed in a local community medical center. This is reflected in our data as a smaller proportion of patients living in rural areas underwent SWL (8.3%) compared with either URS (12.6%) or PCNL (11.7%). Additionally, the reported lower stone free rate of SWL compared to URS²³ may lead urologists and patients to choose one modality over another. This data should be taken into consideration for future resource planning regarding the surgical management of urolithiasis.

In our study we were able to access a large contemporary patient cohort treated in a universal care, single-payer health care system over a long study period. There are several limitations to our study include the retrospective study design with all its inherent biases. The administrative databases we utilized were unable to provide certain clinical data such as patient dietary habits, stone composition and metabolic evaluation results. Unfortunately, we did not capture the rates of other imaging modalities, like X-ray KUB, as one of the goals of this study was to capture the trends in CT imaging usage versus Ultrasound for stone treatment. We are therefore, unable to determine the overall rate of preoperative imaging in our study cohort. We acknowledge an additional limitation, only capturing imaging completed 90-days before surgery, which may have resulted in missing some imaging that took place earlier than that. This is a trends study and therefore aimed to capture all patients who underwent a surgical procedure for urolithiasis. Therefore, when including both OHIP and CIHI coding data we acknowledge that there is a potential for misclassification of these patients according to their primary surgical modality (SWL, URS, PCNL). We attempted to minimize this with using the CCI codes as the primary source to classify the stone treatment modality. Our study only included the first surgical procedure captured during the study period; therefore, patients who underwent multiple procedures for treatment of the same stone or residual fragments, as well as patients with recurrent stones were excluded from the analysis. Consequently, our data will not reflect the total number of surgical stone procedures in the Ontario population and overall urinary stone disease incidence and prevalence data cannot be extracted from this cohort.

Conclusions

The number of surgical procedures performed on patients with upper tract urinary stones in Ontario, Canada has significantly risen during the years assessed. Endoscopic procedures have increased while the utilization of SWL has decreased. The overall increase in surgical intervention is most likely multi-factorial. There was a higher percentage increase in females undergoing stone related surgical procedures that was independent of changes in population growth and increasing BMI levels, which further supports the narrowing of the gender gap in urinary stone disease. We believe that health care providers should be aware of the upward trend in the number of stone-related surgical procedures and plan appropriately with funding, personnel and equipment. Further study is required to determine which factors are driving the increasing number of surgical procedures and if they reflect a true increase in stone incidence. We have hypothesized a number of potential causes for the suspected increase in incidence and

additional work is required to better understand which parameters are most important and to determine if any are modifiable.

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Figures and Tables

Fig. 1. Percentage increase in surgical intervention in males and females from 2002–2019.

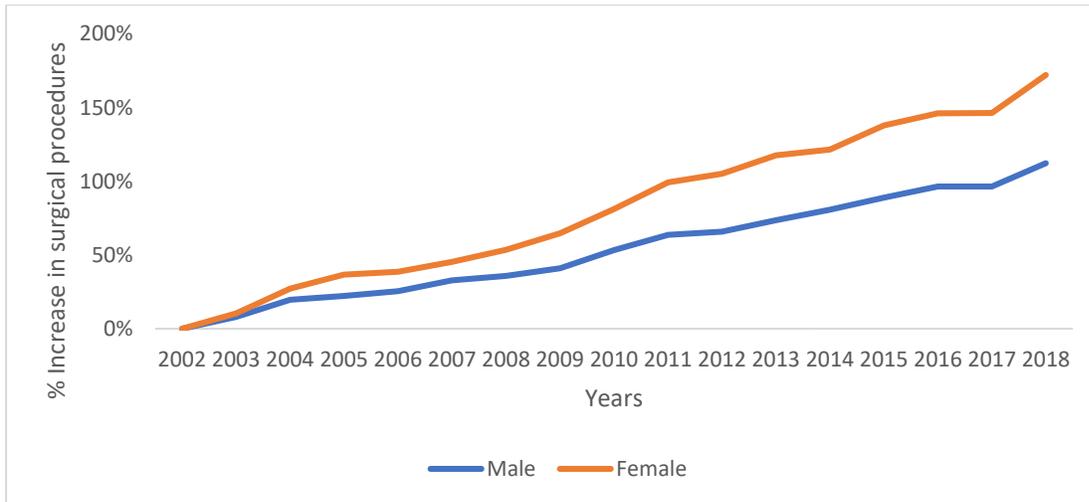


Fig. 2. Adult population in Ontario and number of stones related surgical procedures from 2002–2019.

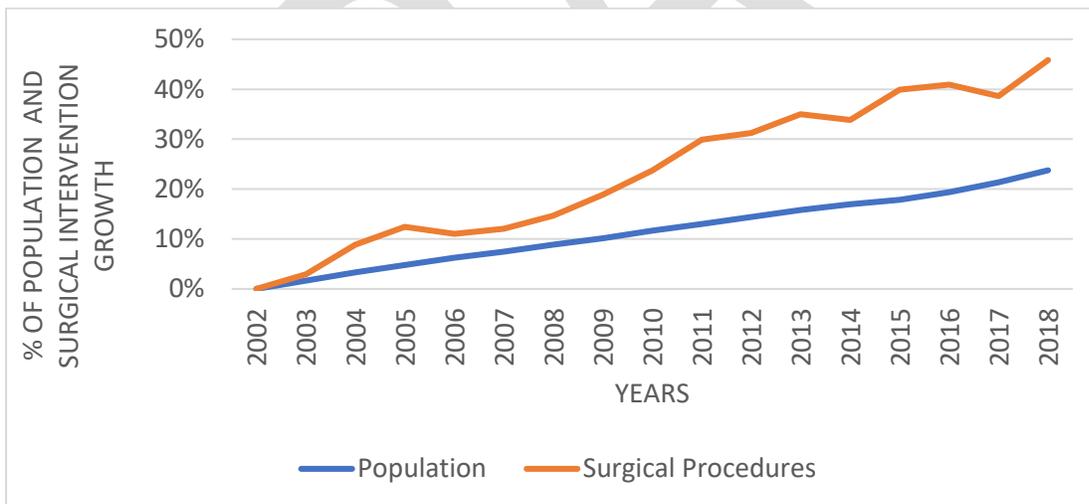


Fig. 3. Surgical intervention rate with percutaneous nephrolithotomy (PCNL), ureteroscopy (URS), and shockwave lithotripsy (SWL) from 2002–2019.

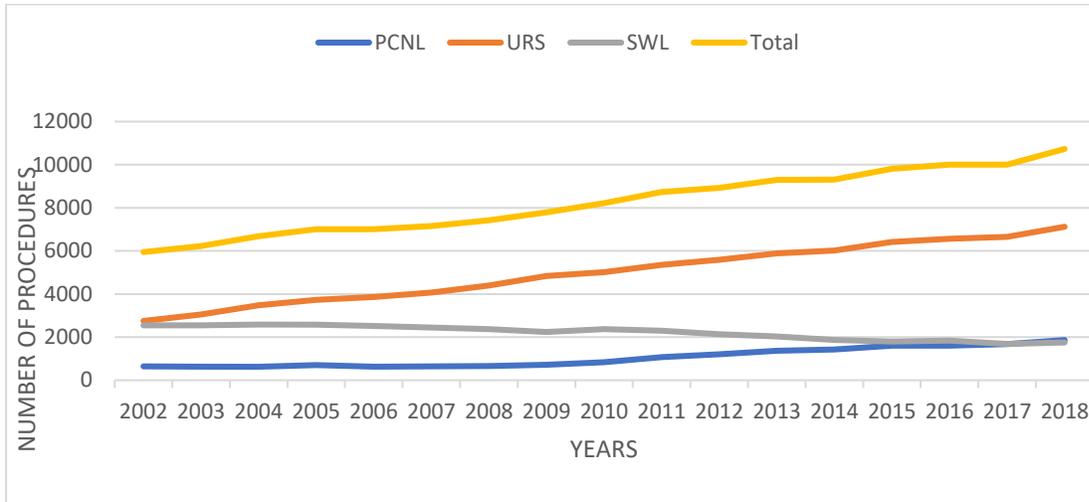


Fig. 4. Adult population in Ontario stratified by age from 2002–2019.²⁴

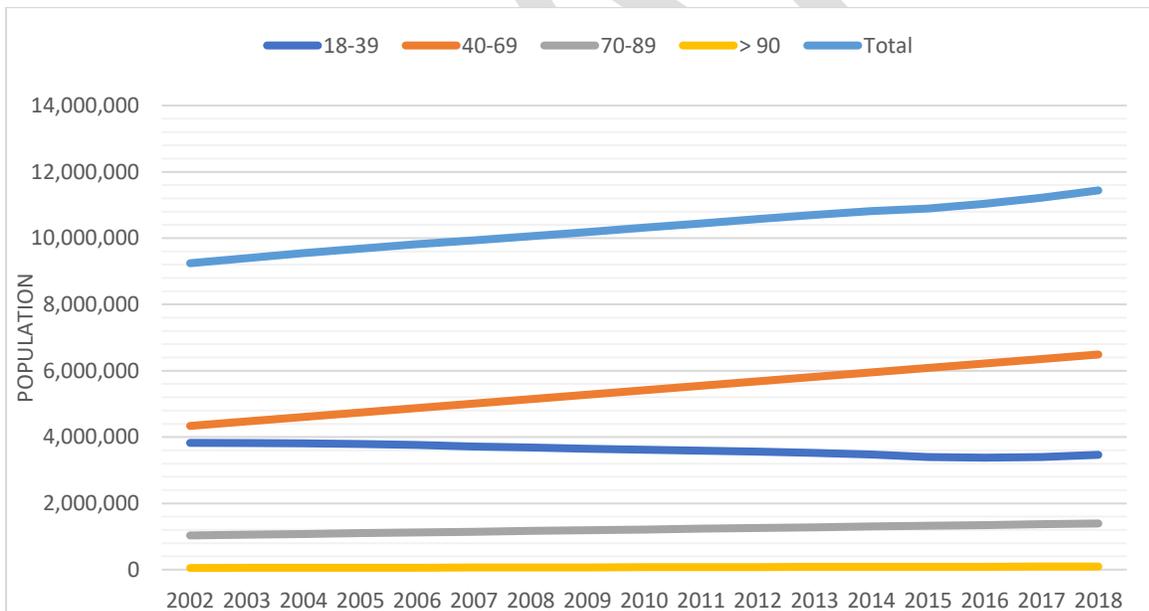
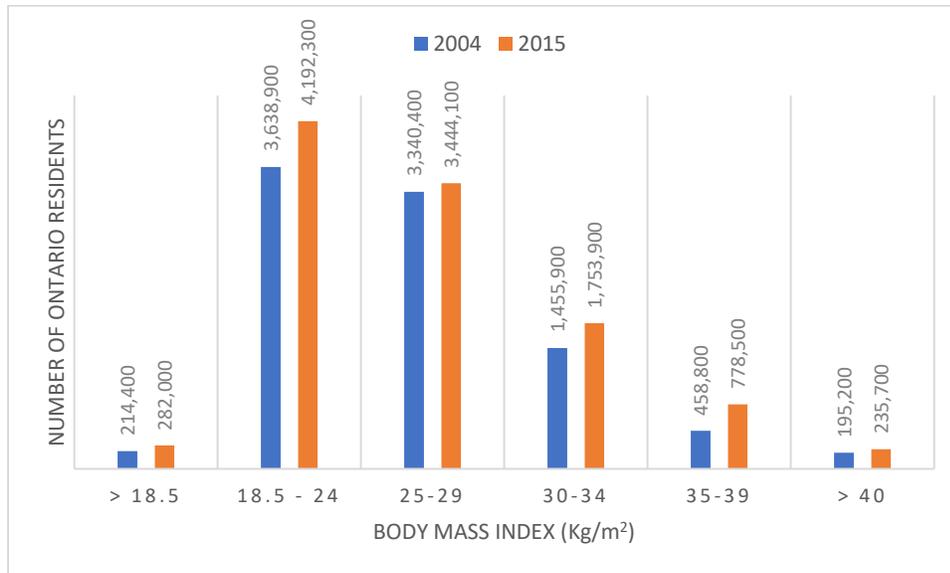


Fig. 5. Measured adult body mass index (BMI) in Ontario in 2004 and 2015.¹⁶

	PCNL (n=17 892)	URS (n=87 784)	SWL (n=37 587)
Age (mean ± SD)	56.09±15.05	54.35±15.76	52.9±14.27
Males, n (%)	10 029 (56.1)	50 813 (59.9)	23 771 (63.2)
Rural residence, n (%)	2082 (11.6)	10 736 (12.7)	3085 (8.2)
First imaging modality used, n (%)			
CT	7917 (44)	48 809 (58)	17 860 (48)
US	4066 (23)	20 983 (25)	8337 (22)
Preoperative CT scan obtained, n (%)	10 462 (58)	64 153 (75)	22 144 (59)
Stone location, n (%)			
Ureter	3774 (21)	53 541 (63)	7477 (20)
Kidney	12 814 (72)	23 308 (28)	17 043 (45)
Missing data	1304 (7)	10 935 (9)	13 067 (35)

CT: computed tomography; PCNL: percutaneous nephrolithotripsy; SD: standard deviation; SWL: shockwave lithotripsy; URS: ureteroscopy; US: ultrasound.