Incidence and trends in the treatment of kidney stones in Canada: A population-based cohort study

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ABSTRACT

Introduction: Our objective was to assess the incidence of kidney stones requiring acute care, trends in the surgical treatment of stones, and the demographics of stone formers in Canada.
Methods: We conducted a population-based, retrospective cohort study using administrative data from the Canadian Institute for Health Information. We included Canadian residents age >18, outside of Quebec, who presented between January 1, 2013, and December 31, 2018, with a kidney stone episode. This was defined as a kidney stone resulting in hospital admission, emergency

KEY MESSAGES

- This is the first reported population-based Canadian series on the demographics of kidney stone formers requiring intervention and treatment trends.
- The most used intervention across Canada is ureteroscopy, followed by shockwave lithotripsy; however, the rate of intervention varied widely between provinces.
- Overall, those presenting to hospital or requiring intervention for a kidney stone were more likely to be male, aged 41–65, and undergo ureteroscopy.

department visit, or stone intervention, specifically shockwave lithotripsy (SWL), ureteroscopy (URS), or percutaneous nephrolithotomy (PCNL).
Results: There were 471 824 kidney stone episodes, including 184 373 interventions. The number of kidney stone episode increased from 277/100 000 in 2013 to 290/100 000 in 2018. The median age was 53 (interquartile range 41–65) and 59.9% were male. The crude rate for stone intervention was 877/100 000. The age- and gender-standardized rate for interventions was highest in Nova Scotia and Newfoundland and Labrador and lowest in Prince Edward Island. The most common intervention in Canada was URS (73.5%), followed by SWL (19.8%) and PCNL (6.7%). The percent utilization of SWL was highest in Manitoba, whereas for URS, it was highest in Prince Edward Island and Alberta.
Conclusions: Our study provides the first population-based data on the demographics of stone formers and treatment trends across Canada. There has been a 4.7% increase in kidney stone episodes over the study period. Those presenting to hospital or requiring intervention for a kidney stone are more likely to be male, age 41–65, and undergo URS.

INTRODUCTION

Kidney stone disease is common with a lifetime prevalence estimated as high as 15%[1]. Studies from the United States and other countries around the world have demonstrated an increasing incidence and prevalence[2-7]. Unfortunately, there is little published data on the incidence of kidney stones and stone interventions across Canada.

Along with the increasing incidence and prevalence, the demographics of stone formers has also been changing over time with an increase in females[8, 9] and older adults (>65 years)[8]. Similar to the incidence of stones, little is known about the demographics of stone formers in Canada, outside of Ontario[8].

At present there is no contemporary population-based data assessing the incidence of kidney stone interventions in Canada. Considering the increasing incidence of kidney stones in other countries around the world[2-7, 10], it is important to evaluate the current treatment trends in the Canadian population, including the demographics of stone formers, to help focus prevention efforts and for resource planning. Accordingly, our objective was to conduct a population-based study to determine the incidence of kidney stones necessitating acute care across Canada, the demographics of these stone formers and treatment trends for stones, including inter-provincial variation.

METHODS

Study design and setting

We conducted a population-based retrospective cohort study using Canada's administrative healthcare databases held at the Canadian Institute for Health Information. Canada currently has

approximately 36 million residents who have universal access to hospital care and physician services that is captured in these healthcare administrative databases. Reporting of this study follows guidelines set for observational studies using routinely collected health data (RECORD)[11].

Data sources

Several administrative databases were utilized to ascertain baseline characteristics, covariate information and outcome data. The Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) has demographic, diagnostic and procedural information for all inpatient admissions to acute care institutions. It also captures outpatient surgeries at acute care or ambulatory care centres in all provinces except Prince Edward Island, (P.E.I.), Nova Scotia (NS), Ontario (ON) and Alberta (AB) (details for outpatient surgery in these provinces is detailed below). The National Ambulatory Care Reporting System (NACRS) captures information on patient visits to hospitals and community based ambulatory care centres, including outpatient clinics and emergency departments (ED). Submission of ED data to NACRS is mandated in ON, AB and Yukon; partially mandated in P.E.I., NS, Manitoba (MB), Saskatchewan (SK) and British Columbia (BC); not mandated in Newfoundland and Labrador (NL), New Brunswick (NB), the Northwest Territories and Nunavut. As a result of the above complete capture of ED visit data is only available for ON, AB and the Yukon. NACRS also captures outpatient surgeries at acute care or ambulatory care centres in P.E.I., NS, ON and AB, the provinces where it is not captured in CIHI-DAD.
Both databases have been used extensively to research health outcomes[12-16].

Study population

We included all Canadians residents (based on postal code), age ≥ 18, who had a kidney stone (KS) episode between January 1, 2013 and December 31, 2018. A KS episode was defined as a kidney stone resulting in hospital admission or ED visit (in select provinces described above) and/or a kidney stone intervention, specifically SWL, URS, PCNL, stent insertion or percutaneous nephrostomy (PCN) tube. Each KS episode could have one or more of the above events.

Hospital admission and ED visit for stones were determined using ICD-10 codes (Appendix A) within the CIHI-DAD and NACRS datasets respectively. Kidney stone interventions (SWL, URS, PCNL, stent insertion and PCN) were determined using CCI codes (Appendix B) in the CIHI-DAD and NACRS datasets depending on province, as detailed above. The province of stone treatment/hospital presentation was based on the postal code of the patient.

All residents from the province of Quebec were excluded from the study due to privacy issues and inability to access their provincial data. Non-residents of Canada were also excluded.

Data from the Northwest Territories, Nunavut and Yukon were pooled and reported as the Territories due to small number patients across each Territory.

Outcomes

Our study outcomes included the incidence of KS episodes, the demographics of stone formers and treatment trends.

The incidence of KS episodes across Canada was determined over the entire study period and by year, as well as stratified by province. One KS episode for every 90 days was included for each individual, in an effort to improve capture of incident events and avoid including repeated occurrences related to the same kidney stone. Meaning if an individual had more than one intervention or hospital admission/ED visit within 90 days this counted as a single KS episode and the first intervention (index intervention) is what we reported. However, the total number of interventions, including repeated interventions within each episode were also recorded and reported. In addition, the mean number of hospital admissions and ED visits per episode are reported.

Demographics were reported only for the first/index KS episode during the study period and were summarized for the entire cohort, as well as stratified by province and modality of treatment.

For treatment trends, the percent utilization, crude rate and age and gender standardized rate of SWL, URS and PCNL over the study period was determined across Canada, as well as stratified by province to assess inter-provincial variation. The rate for each year was standardized to the 2016 population for study provinces. This year was chosen as it was the mid-point of our study time frame

RESULTS

There were 471,824 KS episodes over the study time frame (Table 1). This included 221,884 index kidney stone interventions, comprised of 184,373 definitive index stone interventions (i.e., SWL, URS or PCNL) (Supplement 1a) and 37,511 temporizing interventions (i.e., 16,227 stent insertions and 21,284 PCN tubes). In addition, when including repeated interventions within each KS episode there were 206,802 definitive stone interventions (Supplement 1b).

The mean number of hospitalizations per KS episodes was 0.5, with 63.7% (n=300,633) of episodes having no hospitalization, 29.3% (n=138,348) having 1 hospitalization and 7% (n=32,843) having ≥2 hospitalization per KS episode. The mean number of ED visits per KS episode was 0.8, with 36.7% (n=173,042) of episodes having no ED visit, 49.7% (234,497) having 1 ED visit and 13.6% (n=64,285) having ≥2 ED visits per KS episode. Fifty-nine percent (n=279,594) of KS episodes did not include a kidney stone intervention within 90 days of hospital admission or ED visit.

The number of KS episodes per year increased from 277/100,000 in 2013 to 290/100,000 in 2018, a 4.7% increase over the study time frame. The province of ON had the highest absolute number of KS episodes each year followed by AB (Table 1), likely reflective of these two provinces having complete capture of ED visits and being the largest (ON) and third largest (AB) provincial populations. The number of index URS and SWL interventions increased over the study time frame, whereas the number of index PCNLs remained stable (Table 2).

The median age of patients presenting with an KS episode was 53 (IQR 41-65) and 59.9% were male. The median age increased from 52 in 2013 to 54 in 2018 (Table 2). The median age in males (55) was higher than in females (51). The highest median age (59) was in NL and the lowest median age (50) was in AB and the Territories (Table 1). The percentage of males/females with KS episodes remained stable over the study time frame (Table 2). The highest percentage of females (48.7%) was in NL and lowest percentage of females (39%) was in ON and AB (Table 1). Of the patients undergoing SWL 61% were male, compared with 57% for URS and 55% for PCNL

Across Canada, the crude rate for stone intervention over the 6-year study time frame was 877/100,000. This translates to an average rate of 146/100,00 per year. The age and sex standardized rate for stone intervention was highest in NS and NL, and lowest in PEI and the Territories (Table 3). Considering the individual interventions, the crude rate over the 6-year study time frame was highest for URS, followed by SWL and then PCNL (Table 3). The standardized rate for URS was highest in NS and AB, whereas for SWL it was highest in NL and MB. For PCNL the standardized rate was highest in NL and NS (Table 3)

In terms of definitive kidney stone interventions, as revealed by the standardized rates, the percent utilization for index stone interventions across Canada was highest for URS (73.5%) followed by SWL (19.8%) and PCNL (6.7%). When including index and repeated interventions within each 90-day ACKS episode the percent utilization remained consistent (URS-72%, SWL-22% and PCNL 6%).

Across provinces there was substantial variability in the utilization of each modality. The percent utilization of URS ranged from 39%-96% and was highest in PEI and AB and lowest in NL and MB (Figure 1). Similarly, the percent utilization of SWL ranged from 2%-56% and was the highest in MB, NL and lowest in PEI and AB (Figure 1). For PCNL the percent utilization was much more consistent across all provinces ranging from 2%-9% and was highest in NB and lowest in PEI (Figure 1).

DISCUSSION

Our population-based retrospective cohort study demonstrates an increasing incidence of KS episodes over the study period. The most utilized intervention across Canada (excluding Quebec) is URS, followed by SWL and then PCNL. The percent utilization of URS and SWL varied widely between some provinces. The highest rate of intervention was seen in the NS and NL. Overall, those presenting to hospital or requiring intervention for a kidney stone were more likely to be male, between the age of 41-65 and undergo URS.

According to the Urologic Diseases in America Project there has been a 40% increase in outpatient hospital visits and a 50% increase in annual expenditure for kidney stone disease from 1992–2000[17] in the United States. Several other studies have similarly demonstrated an increasing incidence and prevalence around the world[2-7]. Unfortunately, aside from two population-based studies from Ontario, Canada[18, 19] there is little published data on the incidence of kidney stones and stone interventions across Canada. The first population-based study from

Ontario did demonstrate that the standardized rate of kidney stone procedures had increased from 90/100,000 to 120/100,000 between 1992-2009[18]. In the current study, the average rate for intervention per year across Canada was 146/100,000 and in Ontario was 129/100,000, demonstrating a further increase in the rate of intervention over time.

To our knowledge, this represents the first population-based Canada wide epidemiologic study examining the incidence of definitive stone intervention, including interprovincial variation in the rate and type of interventions, as well as the demographics of Canadians undergoing stone interventions. This data is important for resource planning, targeting primary and secondary prevention efforts and providing reference epidemiologic data for future studies.

Data on the demographics of kidney stone formers in Canada is limited outside of a study examining changing age and sex trends over 20 years in Ontario[8] from 1992-2009. Our study provides essential contemporary data on the age and sex of those with kidney stones requiring acute care or intervention. Unlike recent studies from the United States[10, 20] showing a trend toward gender equivalence in kidney stone incidence, there continues to be a greater number of men presenting with KS requiring admission or intervention in Canada and this remained consistent over the study time frame.

The highest rate for definitive stone interventions (i.e., SWL, URS or PCNL) was seen in NS and NL and were notably higher than in the other provinces and territories. This could be the result of a higher incidence of stones in these provinces. NS and NL have the highest prevalence for diabetes of all the Canadian provinces[21, 22] and also have higher rates for hypertension and a higher percentage of the population with a body mass index in the obese category[22]. All three of these conditions are associated with an increased risk for stone disease[23, 24]. Increased fluid intake and dietary stone prevention along with preventative efforts targeted at addressing risk factors for hypertension, diabetes and obesity will be important to reducing stone events in both provinces and improving overall health in the future. Interestingly, NB also has higher rates for hypertension and elevated body mass index with a higher stone intervention rate than most provinces, but still much less than NS and NL. This suggests that other factors are likely also contributing to the high rate of intervention in NS and NL, which may include access to operating room time, number of practicing urologists, and financial reimbursement

The utilization of SWL was much higher in MB than other provinces and is potentially related to access. SWL is performed in Winnipeg, where approximately 56% of the province's 1.3 million residents reside, meaning there is relatively easy access to SWL for the majority of the provinces population without a need to travel. Conversely, ON which had a population of ranging from 13.5 million to 14.32 million over the study time frame has only three lithotripters (London, Toronto and Ottawa). This translates to patients having to travel further in ON, or potentially having to wait longer in the Greater Toronto Area, where one lithotripter services 6 million people, if SWL is chosen for treatment. Accordingly, in ON more patients may have opted for URS to remain closer to home or to get faster access to treatment.

The results of our study need to be interpreted within the context of our study limitations. First, given this an observational study we can only hypothesize as to the underlying reasons for some of the trends and associations observed. Furthermore, we have no ability to account for regional provider and patient treatment preferences that may impact inter-provincial variation. Second, the NACRS database only has complete capture of ED data for the provinces of ON, AB and the Yukon, which prevented us from accurately assessing the incidence of ED visits for renal colic across Canada. However, we did have complete capture of hospital admissions and stone interventions in the included provinces and this data has not been previously reported and published. Third, we did not have access to data from the province of Quebec and as such this prevented us from being able to report on treatment trends and demographics across the entire country. Fourth, this is not a true incidence study of kidney stones as we are only capturing events that required acute care or intervention. Nevertheless, the incidence data we do provide on acute care stones and specifically on intervention was lacking and most definitely needed. Lastly, we used a time frame definition for identifying index or "incident" stone events, as this cannot truly be defined with administrative data. This poses the risk for misclassification bias, potentially resulting in a slight over or underestimation of the true incidence of index/incident stone events. Despite this, we can be confident that the percent utilization of each modality would not be impacted, as this remained consistent when including repeat interventions within 90 days in addition to the index intervention.

Our study has shown stone disease and its treatment is a growing problem, but especially so in certain provinces. Future studies are needed to better understand the inter-provincial variation in treatment utilization and rate of intervention, as this will be critical to prevention and resource planning. Evaluating the number of urologists per province may help to understand the existing variation. Furthermore, exploration of provincial variation in treatment utilization could provide insight that influences policy making and guidelines for treatment.

CONCLUSIONS

Our study provides the first population-based data on the demographics of kidney stone formers requiring intervention, along with treatment trends in Canada. There has been a 4.7% increase in KS episodes over 6 years. Those presenting to hospital or requiring intervention for a kidney stone are more likely to be male, between the age of 41-65 and undergo URS. The highest rate for intervention per 100,000 was in NS and NL.

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FIGURES AND TABLES

Figure 1. Shockwave lithotripsy (SWL), ureteroscopy (URS), and percutaneous nephrolithotomy (PCNL) use by province.

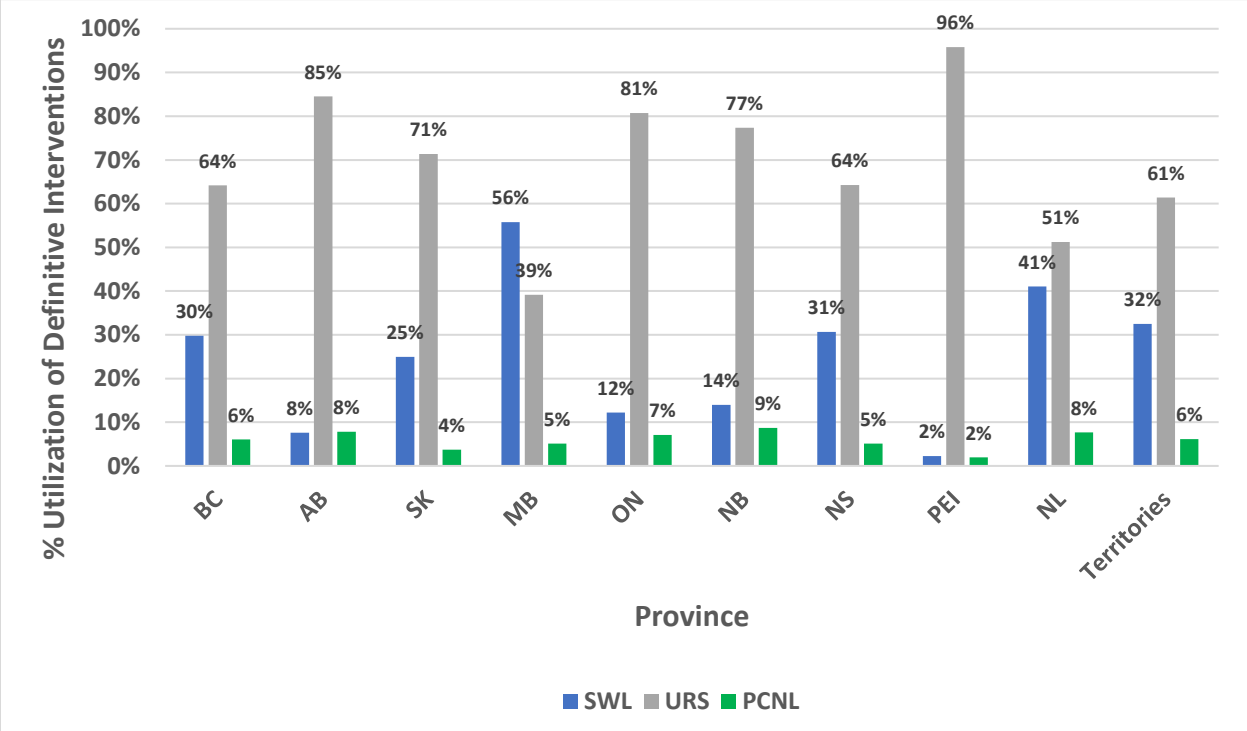

Table 1. Incidence of acute care kidney stone events stratified by year and province and demographics of study cohort stratified by province

	Overall	**Province**									
		BC	**AB**	**SK**	**MN**	**ON**	**NB**	**NS**	**PEI**	**NL**	**Territories**
Episodes, n (%)	471 824	43 291 (9.2)	84 585 (17.9)	15 409 (3.3)	11 593 (2.5)	282 298 (59.8)	7205 (1.5)	15 888 (3.4)	1604 (0.3%)	9160 (1.9)	791 (0.2)
Index year, n (%)											
2013	74 651	6868 (9.2)	13 221 (17.7)	2347 (3.1)	2178 (2.9)	44 516 (59.6)	1169 (1.6)	2554 (3.4)	277 (0.4)	1380 (1.8)	141 (0.2)
2014	74 779	6873 (9.2)	13 676 (18.3)	2415 (3.2)	1810 (2.4)	44 676 (59.7)	1037 (1.4)	2536 (3.4)	258 (0.3)	1385 (1.9)	113 (0.2)
2015	77 693	7232 (9.3)	13 957 (18)	2390 (3.1)	1882 (2.4)	46 403 (59.7)	1191 (1.5)	2635 (3.4)	264 (0.3)	1596 (2.1)	143 (0.2)
2016	80 385	7352 (9.1)	14 392 (17.9)	2533 (3.2)	1947 (2.4)	48 249 (60)	1221 (1.5)	2796 (3.5)	287 (0.4)	1485 (1.8)	123 (0.2)
2017	81 185	7308 (9)	14 633 (18)	2827 (3.5)	1877 (2.3)	48 506 (59.7)	1274 (1.6)	2729 (3.4)	277 (0.3)	1606 (2)	148 (0.2)
2018	83 131	7658 (9.2)	14 706 (17.7)	2897 (3.5)	1899 (2.3)	49 948 (60.1)	1313 (1.6)	2638 (3.2)	241 (0.3)	1708 (2.1)	123 (0.1)
Patient demographics											
Age											
Mean	52.9	57.4	49.9	51.2	55.0	52.6	56.7	56.6	55.2	57.7	49.2
SD	16.25	15.84	15.96	16.75	16.08	16.21	15.92	15.53	16.28	15.04	14.96
Median	53	58	50	52	56	53	58	58	56	59	50
IQR	41–65	47–69	37–61	38–63	44–66	41–64	46–68	47–68	43–67	48–68	37–60
Sex, n (%)											
Male	282 447 (59.9)	25 137 (58.1)	51 404 (60.8)	9185 (59.6)	6482 (55.9)	171 233 (60.7)	3951 (54.8)	9009 (56.7)	901 (56.2)	4697 (51.3)	448 (56.6)
Female	189 377 (40.1)	18 154 (41.9)	33 181 (39.2)	6224 (40.4)	5111 (44.1)	111 065 (39.3)	3254 (45.2)	6879 (43.3)	703 (43.8)	4463 (48.7)	343 (43.3)

IQR: interquartile range; SD: standard deviation.

Table 2. Study cohort demographics stratified by year							
	Overall	**Index year**					
		2013	**2014**	**2015**	**2016**	**2017**	**2018**
Patient demographics							
Age							
Median	53	52	52	53	54	54	54
IQR	41–65	40–63	40–64	41–64	41–65	41–65	42–66
Sex, n (%)							
Male	282 447 (59.9)	45 074 (60.4)	44 762 (59.9)	46 607 (60)	48 228 (60)	48 175 (59.3)	49 601 (59.7)
Female	189 377 (40.1)	29 577 (39.6)	30 017 (40.1)	31 086 (40)	32 157 (40)	33 010 (40.7)	33 530 (40.3)
ED visits and inpatient hospitalization, n							
ED visits	292 840	46 466	47 348	48 702	49 872	49 697	50 755
Inpatient hospitalization	120 633	19 698	19 190	20 157	20 297	20 493	20 798
Intervention, n (%)							
URS	135 598 (73.5)	20 454 (72.5)	20 510 (74.7)	22 540 (75.6)	23 123 (72.4)	24 158 (72.5)	24 813 (73.7)
SWL	36 416 (19.8)	5765 (20.4)	4965 (18.1)	5202 (17.4)	6646 (20.8)	6992 (21)	6846 (20.3)
PCNL	12 359 (6.7)	2002 (7.1)	1982 (7.2)	2079 (7)	2152 (6.7)	2154 (6.5)	1990 (5.9)
Diagnosis at index, n (%)							
N13.2 - Hydronephrosis with renal and ureteral calculous obstruction	61 014 (12.9)	7803 (10.5)	8436 (11.3)	9703 (12.5)	10 669 (13.3)	11 694 (14.4)	12 709 (15.3)
N13.6 - Pyonephrosis	10 937 (2.3)	1478 (2.0)	1652 (2.2)	1690 (2.2)	1852 (2.3)	2105 (2.6)	2160 (2.6)

N20.0 - Calculus of kidney	135 891 (28.8)	20 764 (27.8)	20 754 (27.8)	21 732 (28)	23 093 (28.7)	24 379 (30)	25 169 (30.3)
N20.1 - Calculus of ureter	80 061 (17)	12 995 (17.4)	12 561 (16.8)	13 096 (16.9)	13 398 (16.7)	13 562 (16.7)	14 449 (17.4)
N20.2 - Calculus of kidney with calculus of ureter	12 814 (2.7)	1929 (2.6)	2001 (2.7)	2132 (2.7)	2174 (2.7)	2290 (2.8)	2288 (2.8)
N20.9 - Urinary calculus, unspecified	6459 (1.4)	1047 (1.4)	988 (1.3)	1028 (1.3)	1095 (1.4)	1121 (1.4)	1180 (1.4)
N23* - Unspecified renal colic	156 139 (33.1)	27 644 (37)	27 240 (36.4)	27 047 (34.8)	26 634 (33.1)	24 379 (30)	23 195 (27.9)

ED: emergency department; IQR: interquartile range; PCNL: percutaneous nephrolithotomy; SWL: shockwave lithotripsy; URS: ureteroscopy.

Table 3. Crude and standardized rates (per 100 000) for resource use by province over 6 years (2013–2018)

Region	**Any intervention**		**URS**		**SWL**		**PCNL**	
	Crude[1]	**Standardized[2]**	**Crude[1]**	**Standardized[2]**	**Crude[1]**	**Standardized[2]**	**Crude[1]**	**Standardized[2]**
Overall[3]	**876.9**		**561.4**		**169.6**		**47.8**	
BC	925.3	882.4	545.2	520.2	253.3	243.7	47.8	45.3
AB	841.0	921.8	631.8	683.0	61.3	65.9	54.4	60.2
SK	727.5	767.5	445.8	470.1	183.2	193.6	22.0	23.3
MB	887.8	938.5	281.0	297.1	527.8	557.6	35.7	37.8
ON	771.2	769.7	540.0	539.4	89.1	89.2	44.1	44.0

NB	927.4	852.9	641.2	593.5	144.5	131.4	67.5	62.0
NS	1755.9	1620.6	988.1	915.5	594.4	550.4	73.4	67.4
PEI	584.4	549.4	535.6	504.6	11.3	10.8	9.9	9.7
NL	2164.6	1931.2	758.4	677.0	756.7	678.1	109.8	98.2

[1]2016 provincial population (age 18+) used as denominator. [2]Total 2016 population for study provinces (age 18+) used as standard population. [3]Total 2016 population for study provinces (age 18+) used as denominator. PCNL: percutaneous nephrolithotomy; SWL: shockwave lithotripsy; URS: ureteroscopy.