Is computed tomography-defined obstruction a predictor of urological intervention in emergency department patients presenting with renal colic?

Peter Alexander Massaro, MD, MASc, FRCSC[1]; Avinash Kanji[2,3]; Paul Atkinson, MD, FRCPC[4]; Ryan Pawsey, MD[5]; Tom Whelan, MD, FRCSC[1]

[1]Department of Urology, Dalhousie University, Halifax, NS, Canada; [2]Faculty of Medicine, University College Cork National University of Ireland, Cork, Ireland; [3]Department of Emergency Medicine, Horizon Health Network, Saint John, NB, Canada; [4]Department of Emergency Medicine, Dalhousie University, Halifax, NS, Canada; [5]Faculty of Medicine, Dalhousie University, Halifax, NS, Canada

Cite as: *Can Urol Assoc J* 2017;11(3-4):88-92. http://dx.doi.org/10.5489/cuaj.4143

See related commentary on page 93.

Abstract

Introduction: Our objective was to determine whether unilateral calculus-induced ureteric obstruction on computed tomography (CT) was independently associated with the need for urological intervention and 30-day return to the emergency department (ED).
Methods: We performed a retrospective cohort study of patients with symptomatic urinary calculi diagnosed by unenhanced helical CT. Stepwise regression analysis was used to determine the predictors of urological intervention and 30-day return to the ED. Potential predictors assessed included: patient demographics, calculus size, calculus location, degree of obstruction, analgesic doses, signs and symptoms of infection, serum creatinine, cumulative intravenous fluid administered, and the prescription of medical expulsive therapy.
Results: Of 195 patients, 81 (41.5%) underwent urological intervention. The size of the calculus, its location, and the cumulative opioid dose were all independent predictors for urological intervention. Every 1 mm increase in calculus size increased the likelihood of intervention 2.2 times (odds ratio [OR] 2.17; 95% confidence interval [CI] 1.67–2.85). Proximal stones were 4.7 times more likely to require intervention than distal calculi (OR 0.21; 95% CI 0.09–0.49). Every 10 mg increase in morphine was associated with a 30% increase in the odds of intervention (OR 1.30; 95% CI 1.07–1.58). Degree of obstruction was not associated with the need for urological intervention. Finally, none of the variables were predictors for 30-day return to the ED.
Conclusions: Although stone size, proximal location, and severe pain, as indicated by higher opioid doses, were associated with the need for intervention, the degree of obstruction did not influence the management of patients with CT-defined urinary calculi.

Introduction

Renal colic secondary to urinary calculi is a common presentation to the emergency department (ED), with increasing prevalence in the developed world.[1,2] Calculi can be managed either conservatively through a trial of stone passage, or by active urological intervention, such as with shockwave lithotripsy (SWL), ureteroscopy (URS), percutaneous nephrolithotomy (PCNL), or decompression by means of ureteric stenting or nephrostomy tube placement. Although there are relatively clear guidelines for the treatment of urinary calculi on the basis of stone size, it is unclear if other criteria, such as the presence of ureteric obstruction, qualify for more active intervention.[2,3] Knowledge of the predictors for intervention in urinary calculi may further guide the timing and nature of urological management, ED patient disposition, allow for a more efficient allocation of healthcare resources, and reduce patient discomfort.

Upper urinary tract obstruction (UTO) secondary to urinary calculi is often cited as a consideration in the management of ureteral calculi by both ED physicians and urologists. UTO has been associated with kidney parenchymal injury and may compromise renal function if there is bilateral obstruction or if the contralateral kidney is unable to compensate for the obstructed renal unit.[4,5] In addition, UTO may increase the risk of urosepsis, an indication for urgent decompression.[2] Lastly, obstructing stones may be associated with a longer duration of pain.[6] In the absence of absolute indications for acute intervention, such as signs of urinary tract infection (UTI), renal failure, or unrelenting pain, there remains uncertainty as to whether patients presenting with unilateral obstructing calculi can be treated conservatively or warrant more prompt urological management. Our study aimed to determine whether unilateral, obstructing ureteric calculi identified on computed tomography (CT) at the time of renal colic presentation in the ED, independent of other factors, was associated with an increased likelihood of urological intervention.

Methods

After approval by our institutional research ethics board, we performed a retrospective cohort study of consecutive patients who presented to the ED of a Canadian tertiary hospital with renal colic between 2011 and 2013. Our cases were restricted to patients with a CT-diagnosed unilateral ureteric calculus. Subjects with bilateral ureteric stones, a congenital kidney malformation (such as horseshoe kidney), prior renal transplantation, or anatomic or radiographically proven functional solitary kidney were excluded. Cases in which the patient was diagnosed with a concurrent pathology that would account for the colic symptoms, such as acute cholelithiasis, were also excluded, even if calculi were present on CT.

CT scans were retrospectively reviewed by a single radiologist who classified the calculus as non-obstructing, partially obstructing, or completely obstructing according to pre-determined criteria that included the degree of hydronephrosis, hydroureter, nephromegaly, and perinephric stranding present on the CT. In addition, the radiologist specified the size of the impacted calculus according to its largest diameter and located the stone as being in either the proximal, mid, or distal ureter. Proximal stones were located between the ureteropelvic junction and proximal end of the sacroiliac joint, midureteral stones within the boundaries of the sacroiliac joint, and distal calculi between the distal end of the sacroiliac joint and the ureterovesical junction.

An independent urologist reviewed a consecutive selection of the CTs for the degree of obstruction to provide an estimate of interobserver reliability. Both the radiologist and urologist were blind to all other patient clinical parameters.

The ED visit at which time the patient underwent the CT scan was used as the reference for recording patient characteristics, which included: age, gender, serum creatinine, leukocyte count, cumulative intravenous fluid, cumulative equianalgesic oral morphine dose, total non-steroidal anti-inflammatory drug (NSAID) dose (ketorolac), fever (temperature above 38ºC), as well as treatment with medical expulsive therapy and antibiotics. In addition, patient comorbidities were quantified with the Charleston Comorbidity Index. Concurrent UTI was defined as signs and symptoms of infection with a positive urinalysis (presence of bacteria, and pyuria- or nitrite-positive) or a positive urine culture. Lastly, the number of ED visits both 30 days prior to and after the reference ED visit were recorded to assess the impact of additional ED visits on proceeding to intervention.

The primary outcome of our analysis was the need for intervention within 30 days of presentation, defined as treatment with SWL, URS, PCNL, open ureterolithotomy, or decompression of the urinary system by ureteric stenting or nephrostomy tube placement. In situations where a radiographically visualized stone was not identified at the time of planned intervention (i.e., interval stone passage), cystoscopy and retrograde pyelogram with or without stent placement was also considered an intervention. The secondary outcome was the return to the ED within 30 days. Based on the assumption that approximately 50% of renal colic patients presenting with a unilateral ureteric calculus demonstrate signs of obstruction, a minimum of 150 patients were needed in order to determine whether obstruction increased the odds of intervention by at least 40% at a power of β=0.8.

Urological intervention was categorized as either acute or elective. Acute intervention was defined as within 24 hours of patient presentation or during the same stay in hospital if admission was required for symptom control while awaiting surgery. Patients re-presenting to the ED after initial

Table 1. Characteristics of patients with CT-diagnosed ureteric calculi

	Intervention	Non-intervention
Number of subjects (n)	81	114
Age, years (IQR)	51 (39–60.75)	49 (39–59)
Male gender, n (%)	48 (58.5)	64 (56.6)
Stone size, mm (IQR)	6 (4–8)	3 (3–4)
Stone location, n (%)		
Proximal ureter	45 (54.9)	18 (15.9)
Midureter	5 (6.1)	2 (1.8)
Distal ureter	32 (39.0)	93 (82.3)
Charlson Comorbidity Index, mean (SD)	0.35 (0.69)	0.41 (0.97)
Febrile, n (%)	0 (0)	0(0)
Bloodwork at presentation		
Leukocyte count	9 (7–12) x 10^9/L	9 (7–11) x 10^9/L
Serum creatinine, μmol/L (IQR)	86 (72–103)	84 (70–96)
Urine tests at presentation, n (%)		
Negative urinalysis or culture	50 (61.0)	95 (84.1)
Positive urinalysis or culture*	4 (4.9)	3 (2.7)
No urinalysis or culture performed	28 (34.1)	15 (13.1)
IV cystalloid, ml (IQR)	1000 (500–1500)	1000 (500–1000)
Analgesics (cumulative)		
Opioids, mg (IQR)§	20 (0–43.75)	10 (5–25)
Ketorolac, mg (IQR)	30 (30–30)	30 (30–30)
Antibiotics prescribed, n (%)	10 (12.2)	7 (6.2)
MET prescribed (%)	17 (20.7)	26 (23)
ED visits		
Within 30 days pre-CT-diagnosed calculus (IQR)	0 (0–1)	0 (0–0)
Obstruction, n (%)		
Non-obstructed	26 (31.7)	41 (36.3)
Partial	17 (20.7)	37 (32.7)
Complete	39 (47.6)	35 (31.0)

*Defined as either presence of bacteria on culture or bacteria with pyuria and/or nitrates on urinalysis with signs and symptoms of infection; §opioid values normalized to equianalgesic dose of oral morphine. CT: computed tomography; ED: emergency department; IQR: interquartile range; MET: medical expulsive therapy; SD: standard deviation.

discharge requiring operative intervention within 24 hours were also categorized as acute. Elective intervention was defined as surgery carried out on a non-urgent basis greater than 24 hours after discharge from the ED.

A stepwise logistic regression analysis was used to identify independent predictors for the primary and secondary outcomes. Potential predictors were identified by significance on univariate analysis, and using the Aikake and Bayesian Information Criterion. Potential interaction terms were evaluated. The predictive accuracy of the final model was measured with the concordance statistic (c-statistic).[7]

Results

Table 1 summarizes the characteristics of patients diagnosed on CT with a ureteric calculus managed with or without active urological intervention. Of the 195 cases that were included in our study, 81 (41.5%) underwent urological intervention, while 114 (58.5%) received medical management only (Fig. 1). Patients who underwent urological intervention were first treated acutely in 51% of cases or electively in 49%. Table 2 summarizes the type of primary intervention required, as well as any subsequent therapies for the target stone of interest. Of patients requiring intervention, 68.3% had obstructing calculi on CT (47.6% complete, 20.7% partial obstruction). Of patients not requiring intervention, 63.7% were obstructed (31.0% complete, 32.7% partial obstruction).

The results from the initial univariate analysis are presented in Table 3, while the predictors from the final multivariate model are presented in Table 4. The size of the calculus and its location were both independent predictors for urological intervention. Every 1 mm increase in the size of the calculus increased the likelihood of intervention 2.2 times (odds ratio [OR] 2.18; 95% confidence interval [CI] 1.67–2.85). With stone size as a continuous variable, the OR for predicting urological intervention is plotted in Fig. 2. The stone size over which the OR exceeds unity is 4.5 mm. Discrete stone sizes of 5, 6, 7, and 8 mm result in ORs for intervention of 1.49, 3.24, 7.05, and 15.35, respectively.

In addition, proximal stones were 4.7 times more likely to require intervention than distal calculi (OR 0.21; 95% CI 0.09–0.49). Finally, every 10 mg increase in morphine was associated with a 30% increase in the odds of intervention (OR 1.30; 95% CI 1.07–1.58). There were no significant differences in timing (acute vs. elective) or type of initial intervention (Table 2) between obstructing or non-obstructing calculi (data not shown).

The final multivariate model (Table 4) was strongly predictive of urological intervention, as indicated by a c-statistic of 0.886. The degree of obstruction was not an independent predictor of intervention (Table 3). None of the variables examined from Table 1 were predictors for 30-day return to the ED with renal colic.

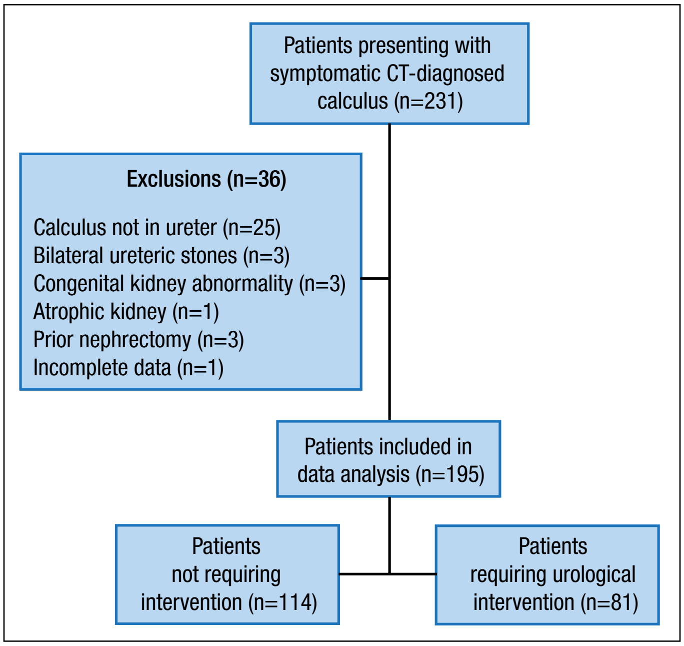

Fig.1. Patient inclusion and exclusion process.

Lastly, the agreement rate between radiologist and urologist when assessing degree of obstruction on CT was 79.3%, with a kappa value of 0.574 (standard error [SE] 0.155) indicating moderate agreement.

Discussion

Current literature is inconclusive with respect to the association between obstructing ureteric stones and intervention. However, the presence or absence of obstruction is often a consideration when ED physicians and urologists formulate management plans for renal colic patients. Several studies have compared the secondary signs of obstruction on CT of patients who required intervention with those that passed stones spontaneously. Takahashi et al found that perinephric stranding and perinephric edema were greater in the group that experienced

Table 2. Type of primary and subsequent interventions for target ureteric calculi

Primary intervention	Number of patients, n=81 (%)	Subsequent elective therapies after primary intervention*		
		SWL	URS	SWL & URS
Ureteric stent, n (%)	20 (25)	15 (75)	15 (75)	10 (50)
SWL, n (%)	13 (16)	5 (38)	3 (23)	2 (15)
URS, m (%)	44 (54)	7 (16)	7 (16)	2 (5)
Cystoscopy and retrograde pyelogram, n (%)	4 (5)	0 (0)	0 (0)	0 (0)

*Some patients underwent multiple subsequent elective therapies after primary intervention. SWL: shockwave lithotripsy; URS: ureteroscopy.

spontaneous stone passage;[8] however, this association was not found by other studies.[9,10] Moreover, their study did not examine the signs of obstruction independent from other relevant factors, such as calculus size. Studies that used a multivariate analysis of potential predictors of obstruction noted an association between spontaneous stone passage and degree of hydronephrosis, although this association was not present for other secondary signs of obstruction.[11-13] Therefore, few studies have examined the impact of calculus-induced UTO independent from individual secondary CT signs in a manner clinically relevant to urologists and emergency physicians.

Consistent with current literature, we found that large calculi, severe pain (as measured by the cumulative opioid dose), and proximally impacted stones were associated with an increased likelihood for urological intervention.[14] However, most importantly, we found that obstruction was not an independent criterion for intervention, which is inconsistent with previous studies reporting an association between intervention and degree of hydronephrosis.[11-13] Taylor et al, for example, recently reported a + likelihood ratio (LR) of 1.45 for mild hydronephrosis and 3.05 for moderate to severe hydronephrosis.[13] One explanation for this apparent inconsistency is that since hydronephrosis may not be present if obstruction is detected early, it may be an indicator of a more severely decompensated collecting system.[4] Moreover, severe hydronephrosis may favour initial decompression, which accounted for less than a quarter of all interventions within our population. Lastly, the presentation of LRs, unlike logistic regression as used in our study, does not account for potential confounders and assumes a normal distribution of the data.

Although obstruction was not a predictor for intervention, we had hypothesized that obstruction, in addition to signs of infection or renal failure, would be associated with intervention. That these interaction effects were not significant in our final model can be attributed to the fact that serum creatinine is not a sensitive indicator of kidney function within the affected kidney due to compensation by the unaffected kidney. With respect to infection, our study was not powered to detect an association: of the four cases with a positive urinalysis, three were fully obstructed and sent for immediate intervention. None of the cases met our criteria for fever.

There are a number of factors that could account for the fact that obstruction was not a significant predictor of intervention. First, our study may have overestimated the rate of obstruction in patients presenting with renal colic or the effect size of obstructed calculi on urological intervention. However, even if our analysis was underpowered, we can still infer that, within our study population, the degree of obstruction had a much lower effect size on intervention when compared to calculus size, location, and degree of pain.

Second, the decision to intervene in a urinary calculus may be influenced by many factors, including the objective characteristics of the patient, the preferences and clinical judgment of the individual urologist, institutional norms, and professionally specified treatment protocols. As there are no absolute indications for the acute treatment of unilateral obstructing stones in the absence of UTI, renal failure, or intractable pain, individual preference and institutional norms may have played a significant role in the eventual decision to intervene in the treatment of the urinary calculi.

Third, given that the degree of obstruction was determined by a single radiologist in our study, the determination of obstruction may have been subject to bias. Our study design required the subjective identification of the secondary signs of obstruction, including hydronephrosis, perinephric stranding, and nephromegaly, followed by the subjective determination of the stone as being either obstructed, partially obstructed, or non-obstructed. Although this process mimics the clinical setting, it is susceptible to bias. In a selection of cases in which an independent urologist reviewed the results, the agreement rate was 79.3%, with a kappa of 0.574, which indicates moderate agreement. This level of agreement is consistent with previously reported kappa

Table 3. Univariate analysis of potential predictors for urological intervention

	OR	95% CI	p
Age	1.004	0.985–1.023	0.693
Antibiotics	2.103	0.765–5.781	0.150
Charleston Comorbidity Index	0.929	0.662–1.303	0.669
Creatinine	**1.009**	**1.001–1.018**	**0.028**
Gender: male vs. female	1.081	0.608–1.922	0.791
30 day pre-CT ED visits	**2.306**	**1.209–4.398**	**0.011**
Intravenous fluid	1.000	1.000–1.001	0.251
Location: mid vs. proximal	1.000	0.178–5.632	1.000
Location: distal vs. proximal	**0.138**	**0.070–0.271**	**<0.001**
MET vs. no MET	0.875	0.439–1.746	0.705
NSAID (ketorolac)	0.992	0.975–1.009	0.338
Partial obstruction vs. no obstruction	0.725	0.340–1.543	0.403
Complete obstruction vs. no obstruction	1.757	0.899–3.436	0.100
Opioids	**1.016**	**1.002–1.030**	**0.024**
Size	**2.268**	**1.769–2.910**	**<0.001**
Urinalysis: positive vs. negative	2.533	0.545–11.765	0.235
Leukocyte count	1.056	0.990–1.125	0.098

CI: confidence interval; CT: computed tomography; ED: emergency department; MET: medical expulsive therapy; NSAID: non-steroidal anti-inflammatory drug; OR: odds ratio.

Table 4. Final multivariate model for predictors of urological intervention

	OR	95% CI	p
Stone location: distal vs. proximal	0.212	0.092–0.489	<0.001
Stone size (per mm increase)	2.178	1.666–2.846	<0.001
Opioids 1 mg[§]	1.027	1.007–1.047	<0.001
Opioids 10 mg[§]	1.301	1.074–1.576	<0.001

[§]Interval opioid values normalized to equianalgesic dose of oral morphine. CI: confidence interval; OR: odds ratio.

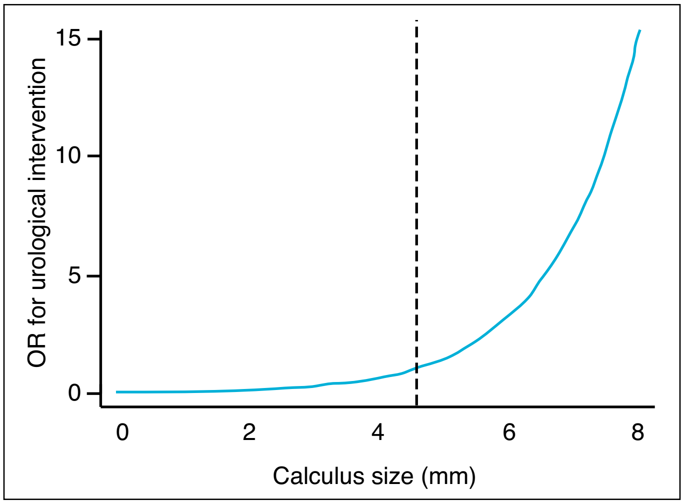

Fig. 2. Logistic regression model for calculus size. The dashed line represents the 4.5 mm stone size cut-point (OR >1) above which operative intervention is increasingly predicted. OR: odds ratio.

values between urologists and radiologists when assessing the degree of obstruction of urinary calculi from CT.[15]

Lastly, certain populations may have been systematically excluded from our study by our decision to include only patients with CT-defined calculi. Recent studies have shifted practice away from the use of CT in the diagnosis of urolithiasis.[16] Moreover, our institution has an established culture of point-of-care ultrasound use in the ED, thus patients with a high clinical suspicion of calculi or with significant hydronephrosis may have been excluded from our study. Nevertheless, urological intervention at our centre is rarely pursued in the absence of CT-diagnosed urolithiasis.

Conclusion

Ureteric obstruction was not an independent predictor for invention in patients presenting to the ED with unilateral renal colic. Larger, proximally impacted calculi, and those associated with severe pain were more likely to require urological intervention. Every 1 mm increase in stone size increased the odds of operative intervention by 2.2, while proximal stones were 4.7 times more likely to require intervention than distal calculi. Further, unilateral UTO does not predict that a renal colic patient is more likely to present to the ED within 30 days of their original diagnosis. Taken together, it is unlikely that the presence of unilateral UTO has an effect on the spontaneous passage of urinary calculi and, therefore, UTO should not alter the acute management of the renal colic patient in the absence of absolute indicators for intervention, such as renal failure, unrelenting pain, or UTI. These findings are of practical clinical importance to both ED physicians and urologists who rely, in part, on CT findings to diagnose and guide the treatment of renal colic patients.

Competing interests: Dr. Whelan has participated in clinical trials for AbbVie. The remaining authors report no competing personal or financial interests.

This paper has been peer-reviewed.

References

1. Shoag J, Tasian GE, Goldfarb DS, et al. The new epidemiology of nephrolithiasis. *Adv Chronic Kidney Dis* 2015;22:273-8. https://doi.org/10.1053/j.ackd.2015.04.004
2. Turk C, Petrik A, Sarica K, et al. EAU guidelines on diagnosis and conservative management of urolithiasis. *Eur Urol* 2016;69:468-74. https://doi.org/10.1016/j.eururo.2015.07.040
3. Ordon M, Andonian S, Blew B, et al. CUA guideline: Management of ureteral calculi. *Can Urol Assoc J* 2015;9:E837-51. https://doi.org/10.5489/cuaj.3483
4. Frokiaer J, Zeidel ML. Urinary tract obstruction. 9th ed. Philadelphia: Elselvier, 2012. https://doi.org/10.1016/b978-1-4160-6193-9.10037-5
5. Zeidel ML, O'Neill WC. Clinical manifestations and diagnosis of urinary tract obstruction and hydronephrosis. UpToDate 2015. http://www.uptodate.com/contents/clinical-manifestations-and-diagnosis-of-urinary-tract-obstruction-and-hydronephrosis. Accessed February 21, 2017.
6. Varanelli MJ, Coll DM, Levine JA, et al. Relationship between duration of pain and secondary signs of obstruction of the urinary tract on unenhanced helical CT. *AJR Am J Roentgenol* 200;177: 325-30. https://doi.org/10.2214/ajr.177.2.1770325
7. Austin PC, Steyerberg EW. Interpreting the concordance statistic of a logistic regression model: Relation to the variance and odds ratio of a continuous explanatory variable. *BMC Med Res Methodol* 2012;12: 82. https://doi.org/10.1186/1471-2288-12-82
8. Takahashi N, Kawashima A, Ernst RD, et al. Ureterolithiasis: Can clinical outcome be predicted with unenhanced helical CT? *Radiology* 1998; 208: 97-102. https://doi.org/10.1148/radiology.208.1.9646798
9. Boulay I, Holtz P, Foley WD, et al. Ureteral calculi: Diagnostic efficacy of helical CT and implications for treatment of patients. *AJR Am J Roentgenol* 1999;172:1485-90. https://doi.org/10.2214/ajr.172.6.10350277
10. Fielding JR, Silverman SG, Samuel S, et al. Unenhanced helical CT of ureteral stones: A replacement for excretory urography in planning treatment. *AJR Am J Roentgenol* 1998;171: 1051-3. https://doi.org/10.2214/ajr.171.4.9762995
11. Parekattil SJ, White MD, Moran ME, et al. A computer model to predict the outcome and duration of ureteral or renal calculous passage. *J Urol* 2004;171:1436-9. https://doi.org/10.1097/01.ju.0000116327.29170.0b
12. Ozcan C, Aydogdu O, Senocak C, et al. Predictive factors for spontaneous stone passage and the potential role of serum C-reactive protein in patients with 4–10 mm distal ureteral stones: A prospective clinical study. *J Urol* 2015;94:1009-13. https://doi.org/10.1016/j.juro.2015.04.104
13. Taylor M, Woo MY, Pageau P, et al. Ultrasonography for the prediction of urological surgical intervention in patients with renal colic. *Emerg Med J* 2016; 33:118-23. https://doi.org/10.1136/emermed-2014-204524
14. Papa L, Stiell IG, Wells GA, et al. Predicting intervention in renal colic patients after emergency department evaluation. *CJEM* 2005;7:78-86. https://doi.org/10.1017/S1481803500013026
15. Freed KS, Paulson EK, Frederick MG, et al. Interobserver variability in the interpretation of unenhanced helical CT for the diagnosis of ureteral stone disease. *J Comput Assist Tomogr* 1998; 22:732-7. https://doi.org/10.1097/00004728-199809000-00013
16. Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography vs. computed tomography for suspected nephrolithiasis. *N Engl J Med* 2014;371:1100-10. https://doi.org/10.1056/NEJMoa1404446

Correspondence: Dr. Peter Alexander Massaro, Department of Urology, Dalhousie University, Halifax, NS, Canada; Peter.Massaro@medportal.ca