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ORIGINAL PAPER

The influence of ureteral stent on renal pelvic pressure in vivo

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Abstract The objective of this study was to explore the influence of ureteral stent on renal pelvic pressure by urodynamic study. 41 patients (with unilateral renal and/or ureteral calculi) after minimally invasive percutaneous nephrolithotomy (MPCNL) were placed a 4.7-Fr ureteral stent and 16-Fr nephrostomy tube. Renal pelvic pressure of these patients was measured by urodynamic study at the 5–7 days after MPCNL. Renal pelvic pressure (RPP), intraabdominal pressure (IAP), and vesical pressure (VP) during the filling and voiding phases were detected by urodynamic study with intravesical perfusion. At the baseline, intraabdominal pressure (IAP_0) was 27.52 ± 7.03 cmH_2O, renal pelvic pressure (RPP_0) was 33.07 ± 7.04 cmH_2O; at the maximum cystometric bladder capacity (MCBC) during the filling phase, vesical pressure (VP_{vol}) was 41.61 ± 10.34 cmH_2O, renal pelvic pressure (RPP_{vol}) was 39.44 ± 7.33 cmH_2O; at the maximum vesical pressure during the voiding phase, vesical pressure (VP_{max}) was 74.95 ± 12.79 cmH_2O, renal pelvic pressure (RPP_{max}) was 65.68 ± 17.03 cmH_2O. (1) There was a strong relationship between RPP_0 and IAP_0 ($P = 0.0001$); (2) There was statistical significance among RPP_0, RPP_{vol} and RPP_{max} ($P = 0.0001$); (3) RPP was higher than 40 cmH_2O during the voiding phase, and it was obviously relevant to the VP ($P = 0.0001$) but not to the MCBC ($P = 0.2696$). RPP increased mildly during the filling phase and dramatically during the voiding phase after stenting. RPP increased higher than the level required for a backflow (40 cmH_2O) during the voiding phase. So it was encouraged to remove the stent at earlier stage or decrease using the ureteral stent if possible.

Keywords Ureteral stent · Renal pelvic pressure · Urodynamic study

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Introduction

Ureteral stent is widely used in urology. The main advantage of stenting is the prevention of ureteral obstruction and renal colic, and stenting may also promote ureteral healing and prevent ureteral stricture. However, some complications associated to the ureteral stent, such as stent-related symptoms and morbidity, were often reported. Many patients with stent suffered stent-related pain in the loin/flank region, and severe pain in kidney area during voiding; some patients experienced urinary tract infections with high fever after stenting [1–3]; and some patients with hydronephrosis could not benefit from the stenting, but even worsened after stenting for more than 3 months [4, 5]. But the reason for hydronephrosis which could not benefit from the stenting was unknown. Though we are all known high renal pelvic pressure would impair renal function, little was known about the relationship between ureteral stent and renal pelvic pressure. Any association of renal pelvic pressure and intravesical pressure along with intrabdominal pressure did not provide much to our current knowledge. The urodynamic study was good to detect the real-time renal pelvic pressure during the vesical filling and voiding phases. In this work, we used urodynamic study to measure

the renal pelvic pressure of the patients after minimally invasive percutaneous nephrolithotomy (MPCNL) who were with 4.7-Fr ureteral stent and 16-Fr nephrostomy tube, and investigated the influence of corresponding factors upon renal pelvic pressure.

Patients and methods

Patients

From Oct 2005 to Feb 2007, a total of consecutive 41 patients (28 males and 13 females, from 20- to 70-year-old, their mean age was 47.3 years) with the following situations were enrolled in this study after MPCNL: (1) more than 18-year-old; (2) unilateral renal calculi and/or ureteral calculi; (3) no severe hydronephrosis by preoperative intravenous pyelogram (IVP) and ultrasound, and no hydronephrosis by postoperative ultrasound; (4) no residual crushed stone in the ureter and kidney; (5) 4.7-Fr ureteral stent (Cook Ireland Ltd.) and 16-Fr nephrostomy tube were in situ and draining smoothly. Patients with any of the following situations were excluded from the study: (1) a history of nephrolithotomy or ureterolithotomy; (2) a history of extracorporeal shock wave lithotripsy (SWL); (3) ureteral stricture, neurogenic bladder, or lower urinary obstruction; (4) patients could not urinate with holding catheter and the renal pelvic pressure could not be recorded during the voiding phase.

Measurement of renal pelvic pressure

Measurement of renal pelvic pressure was administered at the 5–7 days after MPCNL. A 8-Fr twin lumen urodynamic catheter (Laborie medical technologies, Montreal, QC, Canada) was placed into the bladder for the measurement of vesical pressure (VP); a 8-Fr twin lumen urodynamic catheter (Laborie medical technologies, Montreal, QC, Canada) was placed into the renal pelvis through the nephrostomy tube for the measurement of renal pelvic pressure (RPP); a 10-Fr latex rectal balloon urodynamic catheter (Laborie medical technologies, Montreal, QC, Canada) was placed into the rectum for the measurement of intraabdominal pressure (IAP). Then they were all connected to the urodynamics device (Laborie medical technologies, Aquarius-DORADO USA-CANADA) with a baroceptor. After zero adjustment in vitro, the basal renal pelvic pressure (RPP_0), basal vesical pressure (VP_0), basal abdominal pressure (IAP_0) were recorded. Then with intravesical perfusion, the renal pelvic pressure (RPP_{vol}), vesical pressure (VP_{vol}), abdominal pressure (IAP_{vol}) and the maximum cystometric bladder capacity (MCBC) were recorded during the filling phase. Renal pelvic pressure (RPP_{max}), vesical pressure (VP_{max}), abdominal pressure (IAP_{max}) and the maximum vesical pressure were recorded during the voiding phase.

Outcome analysis

All measurement data were presented as mean ± standard deviation (SD). The mean renal pelvic pressure (RPP) value was compared among the baseline, the filling phase and the voiding phase by using analysis of variance (ANOVA). Pearson correlation coefficient was used to measure the strength of relationship between the basal renal pelvic pressure (RPP_0) and basal abdominal pressure (IAP_0). The relationship among renal pelvic pressure (RPP), vesical pressure (VP) and the maximum cystometric bladder capacity (MCBC) was analyzed by multiple regression analysis.

The study was approved by our ethics committee and all patients provided an informed written consent.

Results

At the baseline, basal abdominal pressure (IAP_0) was 27.52 ± 7.03 cmH_2O, basal renal pelvic pressure (RPP_0) was 33.07 ± 7.04 cmH_2O; there was a strong relationship between RPP_0 and IAP_0 value ($P = 0.0001$) (Fig. 1).

With intravesical perfusion, basal renal pelvic pressure (RPP_0) was 33.07 ± 7.04 cmH_2O, renal pelvic pressure (RPP_{vol}) at the maximum cystometric bladder capacity during the filling phase was 39.44 ± 7.33 cmH_2O, renal pelvic pressure (RPP_{max}) at the maximum vesical pressure during the voiding phase was 65.68 ± 17.03 cmH_2O. Renal pelvic pressure increased mildly during the filling phase, and increased dramatically during the voiding phase. There was statistical significance among the RPP_0, RPP_{vol}, and RPP_{max} ($P = 0.0001$).

Renal pelvic pressure responds with augmented increases to increments in vesical pressure during the voiding

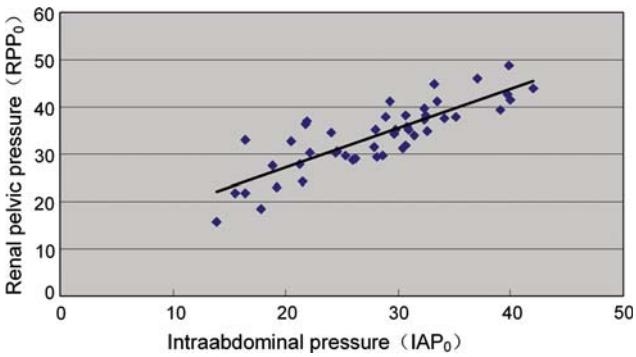

Fig. 1 The relationship between RPP_0 and IAP ($P = 0.0001$)

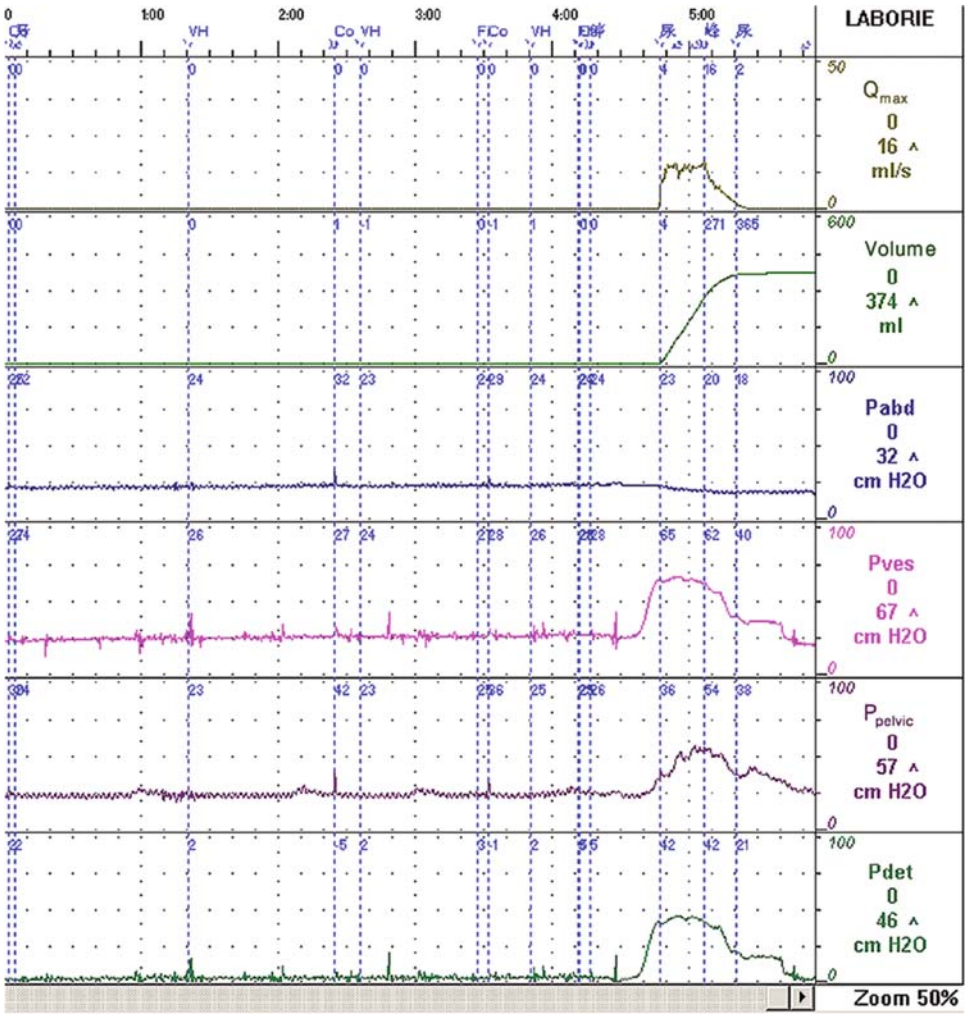

Fig. 2 Renal pelvic pressure (RPP) changed during the filling and voiding phases

phase after stenting. Vesical pressure (VP_{vol}) at the maximum cystometric bladder capacity (MCBC) during the filling phase was 41.61 ± 10.34 cmH_2O, while renal pelvic pressure (RPP_{vol}) reached 39.44 ± 7.33 cmH_2O, and the maximum cystometric bladder capacity (MCBC) was 359.68 ± 116.25 ml; vesical pressure (VP_{max}) during the voiding phase reached 74.95 ± 12.79 cmH_2O, while renal pelvic pressure (RPP_{max}) reached 65.68 ± 17.03 cmH_2O. Renal pelvic pressure was higher than 40 cmH_2O during the voiding phase (Fig. 2). The renal pelvic pressure was obviously relevant to the vesical pressure ($P = 0.0001$), but not to the maximum cystometric bladder capacity (MCBC) ($P = 0.2696$) (Figs. 3, 4).

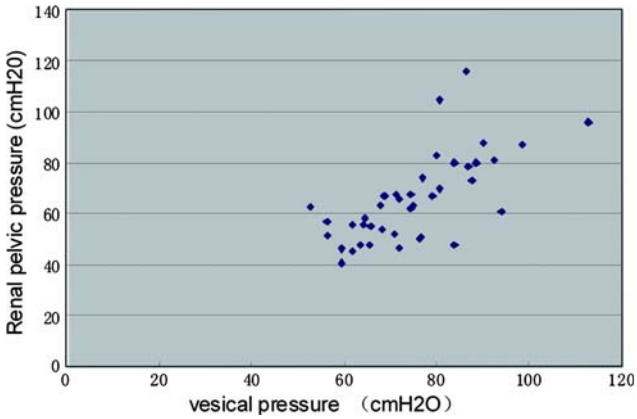

Fig. 3 Scatterplot of RPP and VP values during the voiding phase ($P = 0.0001$)

Discussion

Patients with the nephrostomy tube after MPCNL acquired the chance for the study of upper urinary tract urodynamics, by avoiding the extra percutaneous puncture stoma. Saxby reported [6] that PCNL had almost no side effect on renal function at postoperative first day. Tok reported [7] that PCNL does not worsen the renal function in the geriatric and non-geriatric patients in the early postoperative period. Moreover, geriatric patients may benefit more from PNL than non-geriatric patients. And it has been shown that

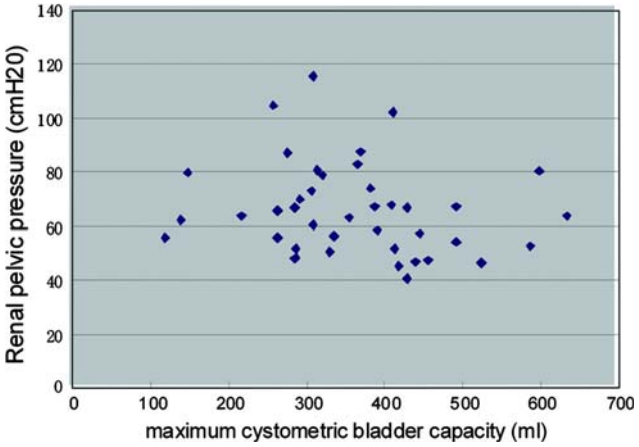

Fig. 4 Scatterplot of RPP and MCBC during the voiding phase ($P = 0.2696$)

PCNL does not result in loss of renal function even when treating complex renal calculi [8]. In this study, the upper urinary calculus was treated through the 16-Fr percutaneous working tract, instead of the conventional 30-Fr tract. Compared to the conventional PCNL, the MPCNL has the potential advantage of decreased trauma to the renal parenchyma. So the urodynamic study could be performed after MPCNL at 5–7 days, and reflect the relationship between ureteral stent and renal pelvic pressure precisely.

Guohua et al. [9] reported a cough and an increase of abdominal pressure could bring a temporary increase of renal pelvic pressure during MPCNL, which means that there was a certain relationship between RPP and IAP. Karnak et al. [10] reported renal pelvic pressure responds with augmented increases to increments in intraabominal pressure in the rabbits. Increases in IAP may simulate proximal ureteric obstruction and result in high renal pelvic pressure. But the rabbit has unipapillary, unicalyceal kidneys with partially intrarenal pelvis [11], which was different from human kidney pelvis and calices. The relationship between renal pelvic pressure and intraabominal pressure about human was still unclear. In this study, there was a strong relationship between RPP_0 and IAP_0; renal pelvic pressure responds with augmented increases to increments in intraabominal pressure at the baseline. A cough and an increase of abdominal pressure could bring a temporary increase of renal pelvic pressure during MPCNL, but that would not impair renal function. A persistent-increased IAP may cause similar increases in RPP, and then would impair renal function. It has been reported that a persistent-increased IAP caused high RPP, and then impaired renal pelvic excretion [12].

During normal function, when vesical pressure rises (e.g., when the bladder is full, or during urination) the vesical-ureter junction (the vesico-ureteric junction or VUJ) contracts and closes. After stenting, however, the VUJ is not able to close fully because of the presence of the stent which will result in reflux. Mosli et al. [13] reported reflux occurred in 19 of the 30 renal units (63%) during the filling phase of the cystourethogram after stent placement; reflux was observed in 24 of the 30 renal units (80%) during the voiding phase of the cystourethogram after stent placement. Reflux that reached only the lower ureter during vesical filling, reached up to the kidney during voiding. In this study, renal pelvic pressure was significantly associated with vesical pressure. When vesical pressure (VP_{vol}) at the maximum cystometric bladder capacity during the filling phase was 41.61 ± 10.34 cmH_2O, vesicoureteral reflux occurred at a low grade, and renal pelvic pressure increased mildly to 39.44 ± 7.33 cmH_2O. While vesical pressure (VP_{max}) during the voiding phase reaching 74.95 ± 12.79 cmH_2O, which could cause a high grade vesicoureteral reflux, and renal pelvic pressure (RPP_{max}) increased significantly up to 65.68 ± 17.03 cmH_2O. There was a strong relationship between RPP and VP, but the RPP has nothing to do with the maximum cystometric bladder capacity. It should be careful to place a stent if patient had bladder outflow obstruction. Because vesical pressure of bladder outflow obstruction was significantly higher than normal, it may result in obviously augmented increases in the renal pelvic pressure.

Ringel et al. [4] reported that, after stenting for more than 3 months, the hydronephrosis had no alleviation in 9.1% of the patients (10 cases), whereas developed or worsened in 5.4% of the patients (6 cases). Richter et al. [5] also had the similar report. These results were contrast to the conventional viewpoint that stent could help to drain. In this study we found that renal pelvic pressure increased after stenting, particularly renal pelvic pressure exceeded 40 cmH_2O during the voiding phase. Renal pelvic pressure exceeded 40 cmH_2O could result in pyelorenal backflow. When this happened the primary site of extravasation was the sinus, pyelosinous backflow. From the sinus, backflow may extend toward the hilum and hence into the retroperitoneal space as well as into the veins and lymphatics [14]. If this condition existed for a long time, the pressure of kidney tubules (especially convoluted tubule) would increase constantly with the excretion of urine, which would oppress blood vessels near tubuli contorti, then result in anoxia and atrophy of kidney tissue, and irreversible impairment of renal function. Furthermore, ureteral stent could increase the opportunities of upper urinary tract infection under impaired renal function. So, renal function might continue to be impaired by the stent-related high renal pelvic pressure.

Lingeman et al. [15] reported that mucous membrane edema of ureter would be in regression in 48 h after ureteroscopy. Following uncomplicated ureteroscopy, stent were often removed after 48 h. Now a few randomized control

trials have confirmed that routine stenting after ureteroscopic intracorporeal lithotripsy was not necessary after uncomplicated ureteroscopic lithotripsy. There were less urinary symptoms, body pain, and cost without stent [16–18]. When there is ureteral edema or polypoid change with pyuria, ureteral stents should be indwelled to avoid severe postoperative complications. Patients undergoing bilateral ureteroscopy, those with recent or recurrent urinary tract infections, those with a history of urolithiasis, those with solitary kidney, and those with ureteral perforation in which ureteral stenting is mandatory [19, 20].

In this study, we only used a 4.7-Fr ureteral stent, without using other kind of ureteral stent. It would be interesting if there was a parallel group of patients with other kind of ureteral stent to compare this result. We can do further work about the intrarenal pressure by a difference of ureteral stent in the next study.

Conclusion

Renal pelvic pressure increased mildly during the filling phase and dramatically during the voiding phase after stenting. Renal pelvic pressure increased higher than the level required for a backflow (40 cmH_2O) during the voiding phase. So it was encouraged to remove the stent at earlier stage or decrease using the ureteral stent if possible.

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