ISSN: 2469-5742

Shalabi et al. Int Arch Urol Complic 2017, 3:026
DOI: 10.23937/2469-5742/1510026
Volume 3 | Issue 2
Open Access

International Archives of
Urology and Complications

RESEARCH ARTICLE

Impact of Pneumoperitoneum on the Post-Operative Renal Function and Level of Acute Kidney Injury Markers: Comparison between Laparoscopic and Open Nephrectomy

Amjad Shalabi[1], Omri Nativ[2]*, Mustafa Sumri[3], Bishara Bishara[1], Wisam Khoury[1], Hoda Awad[2], Ofer Nativ[4] and Zaid Abassi[2]

[1]Department of General Surgery, Rambam Health Care Campus, Israel

[2]Department of Nephrology, Bruce Rappaport Faculty of Medicine, Technion, Israel

[3]Department of Anesthesiology, Bnai Zion Hospital, Haifa, Israel

[4]Department of Urology, Bnai Zion Hospital, Haifa, Israel

***Corresponding author:** *Dr. Omri Nativ, MD, Department of Nephrology, Bruce Rappaport Faculty of Medicine, Technion, 6th HaAliya HaShniya St., Haifa, Israel, Tel: 972-54-6307-147, Fax: 972-4-8295-267, E-mail: Onativ@gmail.com*

Abstract

Purpose: As laparoscopic surgery becomes more widespread, understanding the adverse effects of pneumoperitoneum becomes more important, especially in patients subjected to laparoscopic unilateral nephrectomy. The purpose of the current study was to investigate the effect of pneumoperitoneum on the remnant kidney after laparoscopic nephrectomy compared to open surgery.

Methods: The study group included 30 patients. 22 patients underwent laparoscopic nephrectomy whereas 8 patients underwent open nephrectomy. Serum and urine samples were collected before surgery, 8 and 24 hours after surgery. At these time points urine levels of NGAL and KIM-1, two novel biomarkers for Acute Kidney Injury (AKI) were also determined.

Results: Following surgery serum creatinine slightly increased in both groups but then decreased in those who had open procedure compared with the laparoscopic cases where it continued to increase. Urinary NGAL, but not urinary KIM-1, increased in both groups after 8 and 24 hours. The pattern of change of both urinary markers (NAGL and kim-1) after surgery, was not affected by the use of pneumoperitoneum compared to the open procedure. More patients in the laparoscopic group developed acute kidney injury (41% vs. 12%).

Conclusions: The present study shows a negative effect of pneumoperitoneum on the kidney function in patients undergoing laparoscopic nephrectomy compared to the open procedure. NGAL and KIM-1 urinary levels were not affected by the increased intra-abdominal pressure.

Keywords

KIM-1, Nephrectomy, NGAL, Pneumoperitoneum, Renal function

Introduction

Minimally invasive surgery continues to gain popularity and widespread acceptance due to its clear advantages. During laparoscopic surgery, pneumoperitoneum is mandatory to allow adequate exposure. It is, however, may be associated with oliguria, decreased Glomerular Filtration Rate (GFR) and renal perfusion [1,2]. The exact mechanism of renal dysfunction secondary to pneumoperitoneum is not fully understood. This may be related to direct compression of the renal parenchyma and vasculature that leads to reduced renal blood flow [3]. It should be mentioned that the possible deleterious effect of pneumoperitoneum on the post-operative kidney function may be enhanced according to base line renal function and comorbidities, operative variables and post-operative course (procedures and medications). The consequence is an increased stimulation of the Renin-Angiotensin-Aldosterone System (RAAS) and exertion of antidiuretic hormone [4]. The result is salt and water retention leading to oliguria.

We have previously reported the association be-

Citation: Shalabi A, Nativ O, Sumri M, Bishara B, Khoury W, et al. (2017) Impact of Pneumoperitoneum on the Post-Operative Renal Function and Level of Acute Kidney Injury Markers: Comparison between Laparoscopic and Open Nephrectomy. Int Arch Urol Complic 3:026. doi.org/10.23937/2469-5742/1510026

Received: April 07, 2017: **Accepted:** May 22, 2017: **Published:** May 24, 2017

tween pneumoperitoneum and kidney injury in rat model [5]. Others reported similar results in human [6,7]. These results may be of clinical significance especially in patients remaining with a single kidney after laparoscopic nephrectomy. Unfortunately, there are very small number of human studies in the literature addressing this important topic. One study investigated the effect of pneumoperitoneum after laparoscopic donor nephrectomy [8]. However, donor patients were healthy and rigorously screened for preexisting comorbidities and the patients were not compared to open procedure.

NGAL is a 25-kDa protein from the lipocalin family that is primarily secreted by activated neutrophils. NGAL is produced in the granules of activated neutrophils and also by the nephron in response to any damage to tubular epithelium; therefore, NGAL can serve as a biomarker for tubulointerstitial injury. During renal injury, NGAL is mainly produced in the ascending thick limb of the loop of Henle and renal collecting tubule, and is immediately secreted into urine, which makes it a suitable biomarker for the prediction of renal failure [9].

KIM-1, a type-1 transmembrane protein, is an emerging biomarker whose expression and release are induced in renal tubular cells, especially the proximal tubule, after injury. Previous reports involving rat models have shown that KIM-1 is an outstanding indicator of kidney injury and is a better predictor of kidney injury than serum creatinine [10,11].

The aim of the current study was to quantitatively document in patients after unilateral nephrectomy the possible deleterious effect of pneumoperitoneum on the residual kidney function by serial measurements of serum creatinine and the urinary level of two novel biomarker for early kidney injury, namely Neutrophil Gelatinase-Associated Lipocalin (NGAL) and Kidney Injury Molecule-1 (KIM-1). The results were compared between two groups of patients who underwent laparoscopic and open procedures.

Material and Methods

Patients

This is a non-randomized prospective study that was carried out after achieving the IRB approval and an informed consent was obtained from all individual participants included in the study. The study group included 30 caucasian patients who underwent nephrectomy for various causes. Indications for surgery included enhancing solid renal masses suspicious for malignancy or non-functioning kidney. 22 patients underwent laparoscopic surgery and 8 open approach. Patients with active chronic infection due to severe pyelonephritis and/or renal abscesses mainly secondary to obstruction were excluded from the study.

Pre and post-operative renal function of the studied patients was assessed either by serum creatinine level or by estimated Glomerular Filtration Rate (eGFR) using the four items MDRD equation. AKI was considered either when SCr level increased by more than 50% or by 0.3 mg/dL from baseline [12,13].

All patients have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Surgical technique

Open technique: All Open Nephrectomies (ON) were performed through a subcostal incision approximately 2.0 cm bellow the costal margin. The rectus abdominis muscle was divided as were the ipsilateral external and internal obliques and the transversus abdominis muscles. The peritoneum was entered and an Omni retractor was positioned to expose the operative field. The white line of Toldt was incised and the colon reflected medially to expose the renal vessels. The kidney was then bluntly mobilized posteriorly and laterally in the avascular plane between Gerota's fascia and quadratus lumborum and psoas muscles. At the inferior portion of the kidney the ureter was identified ligated and divided. The renal artery and vein were identified, cleaned of surrounding fibrofatty tissue, doubly ligated and divided. The superior portion of the Gerota's fascia was freed and the whole surgical specimen was removed.

Laparoscopic technique: All laparoscopic procedures were performed via a transperitoneal approach in the modified lateral decubitus position. The Veress needle was used for insufflation and the 10 mm laparoscope port was inserted in the midclavicular line 2 to 3 cm at or just above the umbilicus. A 12 mm port was inserted in the anterior axillary line 2 cm below the costal margin, and a 10 mm port was placed on the anterior axillary line at the level of the anterior iliac crest. A 5 mm port was placed in the midline for liver retraction on right-sided nephrectomies. The colon was mobilized medially after incision along Toldt's line, and the gonadal vein was located and traced to the renal vein or inferior vena cava. The hilum was dissected and the artery was secured with vascular clips and the vein was stapled with the vascular endo-GIA stapler. The intact specimen was placed in an endocatch bag and removed through an extension incision at the level of the 12 mm port site. Port sites were closed with sutures and skin clips.

Samples collection: Voided urine samples were collected for all patients before surgery, 8 and 24 hours following nephrectomy. The collected urine samples were stored at -80 °C until analysis.

Determination of urinary NGAL and KIM-1: NGAL and KIM-1 were determined from a single 10 µl specimen of urine and were measured with commercially available ELISA kits (NGAL Rapid ELISA Kit; Bio Porto Diagnostics, Gentofte, Denmark) and (Wuhan EIAab Sci-

Table 1: Clinical characteristics of patients undergoing laparoscopic and open nephrectomy.

Variable	Lap (n = 22)	Open (n = 8)
Mean age (year)	61.18 ± 2.91	68.7 ± 3.54
Gender: Male/Female	13/9	6/2
Side: Right/Left	5/17	5/3
Tumor Location Central/Peripheral	14/8	6/2
Mean Tumor Size (cm)	6.21 ± 0.44	6.97 ± 1.31*
Pre-Op Serum Creatinine (mg%)	1.08 ± 0.073	1.012 ± 0.09*
NGAL/Ucr (Pre-Op) (ng/mg Cr)	192.36 ± 51.7	85.8 ± 27.7
KIM-1/Ucr (Pre-Op) (ng/mg Cr)	2.96 ± 0.67	2.39 ± 0.84
Mean eGFR (pre-Op) (ml/min)	87.2 ± 5.6	83.8 ± 8.45
Patients with comorbidities	17 HTN; 10 DM; 3 IHD; 1 Nephrolithiasis; 9 dyslipidemia	5 HTN; 5 DM; 0 IHD; 1 Nephrolithiasis; 4 dyslipidemia

*p < 0.05.

Table 2: Post-operative changes of urinary NGAL and KIM-1 as well as serum creatinine in patients treated by laparoscopic and open nephrectomy.

	LAP	Open
Baseline NGAL (ng/mg Cr)	192.3 ± 51.7	85.8 ± 27.6
8h' NGAL (ng/mg Cr)	210.24 ± 71.9	268.9 ± 98.7
24h' NGAL (ng/mg Cr)	246.16 ± 64.4	354.6 ± 231.7
Baseline KIM-1 (ng/mg Cr)	2.96 ± 0.67	2.39 ± 0.84
8h' KIM-1 (ng/mg Cr)	1.88 ± 0.3	1.73 ± 0.87
24h' KIM-1 (ng/mg Cr)	1.64 ± 0.3	1.12 ± 0.54* (P = 0.0184)
Baseline Creatinine (mg%)	1.08 ± 0.073	1.012 ± 0.09
8h' Creatinine (mg%)	1.31 ± 0.109	1.325 ± 0.186
24h' Creatinine (mg%)	1.45 ± 0.118* (P = 0.01)	1.18 ± 0.14

(*) P < 0.05 vs. baseline.

ence Co. Wuhan, China), respectively. [KIM-1 signalling pathway, KIM-1 proximal tubule biomarker].

Statistical analysis: Data are presented as mean ± S.E.M (standard error of the mean). One-Way Analysis Of Variance (ANOVA) for repeated measures, followed by Dunnett's test, were used for comparison of values from the different post surgery time points with baseline values. P value of $p < 0.05$ was considered statistically significant.

Results

A total of 30 patients (19 males and 11 females) who underwent unilateral laparoscopic nephrectomy (n = 22) or open nephrectomy (n = 8) were included in the current study. The baseline characteristics of the laparoscopic and open groups were similar in term of age, comorbidities, tumor characteristics, preoperative baseline serum creatinine and estimated GFR. With respect to urine biomarker levels, while KIM-1 urine concentration did not differ significantly between the studied groups, the urinary NGAL level was lower in the open group (Table 1).

Table 2 summarizes the pattern of post-operative changes of the studied biomarkers as well as serum creatinine. Assessment of urinary level of NGAL 8 and 24 hours after nephrectomy demonstrated gradual elevation compared with the pre-operative values in both groups.

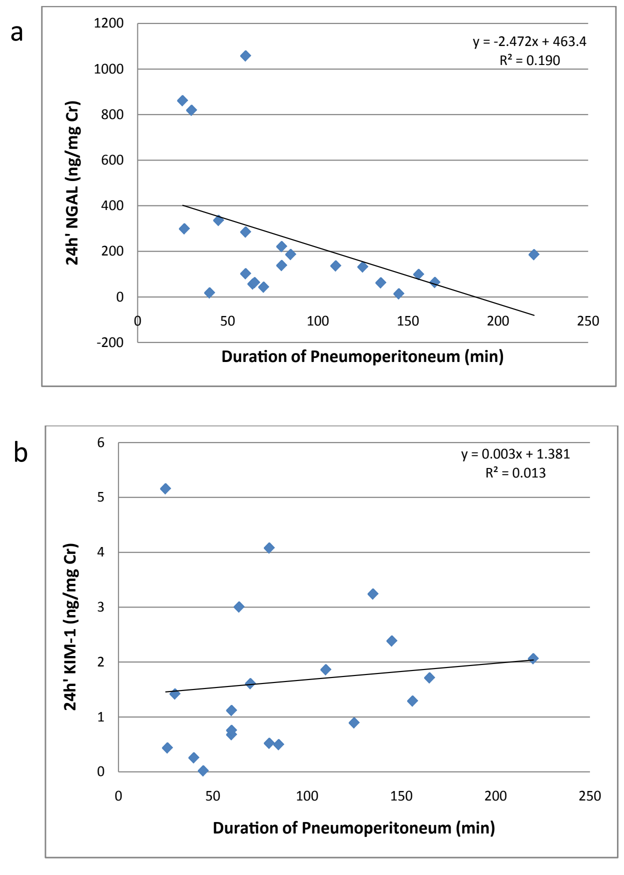

Figure 1: Correlation between the duration of pneumoperitoneum and the post-operative urinary levels (a) NGAL; (b) KIM-1.

When urinary level of KIM-1 was studied at the same time points before and after surgery a different pattern was observed, i.e. the urinary concentration of the marker gradually decreased regardless of the operative

Table 3: Relationship between urinary NGAL and KIM-1 levels in patients with and without AKI in patients treated by laparoscopic nephrectomy.

Parameter	Baseline		Post operation			
			8 Hours		24 Hours	
	Non-AKI patients	AKI-Patients	Non-AKI patients	AKI-Patients	Non-AKI patients	AKI-Patients
Urinary NGAL (ng/mg Cr)	$R^2 = 0.0009$ P value = 0.89	$R^2 = 0.46$ P value = 0.06	$R^2 = 0.06$ P value = 0.28	$R^2 = 0.47$ P value = 0.059	$R^2 = 0.13$ P value = 0.09	$R^2 = 0.47$ P value = 0.06
% change of Urinary NGAL			$R^2 = 0.018$ P value = 0.55	$R^2 = 0.12$ P value = 0.39	$R^2 = 0.106$ P value = 0.149	$R^2 = 0.07$ P value = 0.49
Absolute KIM-1 (ng/mg Cr)	$R^2 = 0.002$ P value = 0.82	$R^2 = 0.06$ P value = 0.53	$R^2 = 0.03$ P value = 0.45	$R^2 = 0.018$ P value = 0.75	$R^2 = 0.06$ P value = 0.29	$R^2 = 0.0007$ P value = 0.94
% change of Urinary KIM-1			$R^2 = 0.018$ P value = 0.56	$R^2 = 0.001$ P value = 0.93	$R^2 = 0.0006$ P value = 0.915	$R^2 = 0.04$ P value = 0.63

Table 4: Clinical variables of patients with and without AKI in the laparoscopic group.

Variable		Non-AKI (n = 13)	AKI (n = 9)
Mean age (year)		56.9 ± 3.2	67.3 ± 4.9* (P < 0.0001)
Gender: Male/Female		7/6	6/3
Side: Right/Left		3/10	2/7
Tumor location Central/Peripheral		8/5	7/2
Mean Tumor Size (cm)		6.63 ± 0.62	5.65 ± 0.61* (P = 0.0001)
Patients with comorbidities		13 (10 HPT; 5 DM; 1 IHD; 1 Nephrolithiasis; 5 dyslipidemia)	9 (7 HPT; 4 DM; 2 IHD; 4 Nephrolithiasis; 4 dyslipidemia
Mean base line eGFR (ml/min)		82.7 ± 5.1	50.43 ± 5.09* (P < 0.0001)
Mean blood loss (ml)		569 ± 239	163.3 ± 88.8* (P = 0.0001)
Mean duration of peumoperitoneum (min)		87.23 ± 15.14	99.11 ± 21.42
Serum creatinine (mg%)	Pre-op'	1.005 ± 0.05	1.205 ± 0.16* (P = 0.0004)
	Post-op' 8 H	1.13 ± 0.06	1.57 ± 0.23* (P < 0.0001)
	Post-op' 24 H	1.14 ± 0.07	1.74 ± 0.21* (P = 0.001)

(*) P < 0.05 vs. Non-AKI.

method used. The patterns of change of the studied markers were not affected by the pneumoperitoneum.

Evaluation of post nephrectomy serum creatinine demonstrated early (8 hours) similar increase in both groups of 0.23 mg% and 0.31 mg% for laparoscopic and open groups respectively (p = 0.83). Further measurements revealed continuous elevation of the creatinine in the patients managed by laparoscopy (up to 1.45 mg%) but decreased level in the open surgery cases (up to 1.18 mg%). Such pneumoperitoneum related decrease in the laparoscopic group is statistically significant (P = 0.01).

Additionally, we examined the impact of pneumoperitoneum duration in patients treated by laparoscopic procedures on the urinary levels of NGAL and KIM-1. As presented in Figure 1a and Figure 1b, there was no correlation between the duration of pneumoperitoneum and the post-operative urinary levels of the studied markers.

During the postoperative period, 10 patients (33%) developed Acute Kidney Injury (AKI). Only one (12%) among the open surgery group compared with nine cases (40%) in patients subjected to pneumoperitoneum. Table 3 presents the baseline and post operative urinary levels of NGAL and KIM-1 normalized to urine creatinine among patients with and without AKI in the laparoscopic group. As shown these biomarkers did not demonstrate a different pattern in terms of urinary concentration changes among the two sub-groups (AKI vs. Non-AKI). We further looked at clinical variables and their association with peri-operative functional outcome that define the two categories. As demonstrated in Table 4 the basal renal function was statistically significantly lower in patients who developed AKI, i.e. before surgery eGFR of 50.43 vs. 82.70 (P < 0.0001) and serum creatinine 1.205 vs. 1.005 (P = 0.0004) for AKI and Non-AKI patients respectively. Patients in the AKI group were on average 10-year-older, had slightly smaller lesions (mean size 5.65 cm vs. 6.63 cm) and their surgical procedure was associated with reduced blood loss. By contrast no difference in rate of relevant comorbidities or duration of pneumoperitoneum was observed between the two sub-groups.

Discussion

The expansion of minimally invasive laparoscopic surgery emphasizes the essential need to understand the adverse effects of pneumoperitoneum which is an essential part of this therapeutic modality. This is particularly important in cases of laparoscopic nephrectomy, because maintaining the function of the remnant kidney is critical. Increased intra-abdominal pressure associated with pneumoperitoneum leads to compression of the kidney parenchyma, reduced cardiac output and systemic hormonal effects, which result in decreased Glomerular Filtration Rate (GFR) and urinary output [1-5]. In a review of five animal studies, Shafer, et al. demonstrated a decrease in renal perfusion ranged from 12% to 14% [14]. Miki, et al. reported a decreased urine output and GFR in patients after laparoscopic cholecystectomy, whereas no significant changes in these parameters were observed when an abdominal lift device was used [15].

The present study shows a negative effect of pneumoperitoneum on the post-operative kidney function in patients undergoing laparoscopic nephrectomy. This is evident by the further decrease of serum creatinine (beyond 8 hours) after surgery which was not observed in the open nephrectomy group. Moreover, the rate of AKI after laparoscopic surgery was 3.4-fold higher compared with those treated by the open approach. Our results suggest that older age and decreased baseline renal function may contribute to the development of AKI in patients managed by laparoscopic nephrectomy. One may assume that kidneys in elderly patients and compromised renal function are more vulnerable to the deleterious effect of increased intra-abdominal pressure. In a study by Cho A, et al. who evaluated 519 patients they found that age and GFR were predictors of post nephrectomy AKI. In their report patients who experienced post-operative AKI had a 4.24-fold higher risk of new onset CKD, $P < 0.001$ [16].

The duration of pneumoperitonum during surgery by itself or amount of intra-operative blood loss were not predictors of AKI. Santos LS, et al. who studied the effects of pneumoperitoneum (15 mmHg) during two and four hours in rats, reported no histologic changes of the kidneys [17]. They used the same magnitude of intra-abdominal pressure that we have used during our laparoscopic procedures (12-14 mmHg). By contrast in a study published by Ben-Haim M, et al. who used higher pressure (20-25 mmHg) significant microscopic ischemic changes were observed. These data suggest that the magnitude of intra-abdominal pressure elevation may be important in causing renal injury [18].

We expected to find correlation between two novel biomarkers for AKI, namely NGAL and KIM-1 that were found to increase following kidney injury for various reasons [19,20]. Such elevation could serve as a marker and may indicate the need to consider different post-operative management such crystalloid support or use of nephroprotective agents. Our data indicate that pneumoperitoneum or the occurrence of AKI did not result in increased urinary level or different pattern concentration of these markers. Micali, et al. reported similar results. They compared laparoscopic and open procedure using N-acetyl-beta-D-glucosaminidase as a marker for kidney injury. No differences were noted in the urinary level of the marker between both groups. They concluded, that pneumoperitoneum is not associated with renal tubular injury [21]. Others claim, that after the release of pneumoperitoneum, renal function has recovered early and there were no signs of microscopic renal tubular damage [22]. We may speculate that the lack of correlation between pneumoperitoneum and the change in NGAL and KIM-1 is related both to the fact that the renal injury was gradual but not acute and also that the increase in intra-abdominal pressure was attenuated by the perirenal fat that protected the renal pedicle and parenchyma by absorbing the CO_2.

Our study has several limitations including: 1) Small number of patients, especially in the open surgery; 2) A non-randomized study; 3) A single center study; 4) Some patients suffers from comorbidities (Diabetes, hypertension, peripheral vascular disease ect) that cannot be quantitated adequately; 5) We focused only on two biomarkers, based on previous literature and our own experience.

Conclusion

In the current study we were able to demonstrate that pneumoperitoneum used during laparoscopic nephrectomy affects immediate post-operative serum creatinine. The increased intra-abdominal pressure may result in higher rates of AKI compared with open procedure especially in elderly patients with compromised renal function. However, one should keep in mind that other factors such as: medications, comorbidities, surgical parameters such as blood loss or duration of the procedure may also contribute to postoperative decline in renal function. NGAL and KIM-1 urinary level were not affected by the increased intra-abdominal pressure. To confirm these findings, a prospective randomized study with greater number of patients is needed.

Compliance with Ethical Standards

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest

None of the contributing authors have any conflict of interest, including specific financial interests or relationships and affiliations relevant to the subject matter or materials discussed in the manuscript.

References

1. Dunn MD, McDougall EM (2000) Renal physiology. Laparoscopic consideration. Urol Clin N Am 27: 309-314.

2. Kirsh AJ, Hensle TW, Chang DT, Kayton ML, Olsson CA, et al. (1994) Renal effects of CO2 insufflation: Oliguria and acute renal dysfunction in a rat pneumoperitoneum model. Urology 43: 453-459.

3. Vasdev N, Poon AS, Gowire-Mohan S, Lane T, Boustead G, et al. (2014) The physiologic and anesthetic consideration in elderly patients undergoing robotic renal surgery. Rev Urol 16: 1-9.

4. Wiesenthal JD, Fazio LM, Perks AE, Blew BD, Mazer D, et al. (2011) Effect of pneumoperitoneum on renal tissue oxygenation and blood flow in a rat model. Urology 77: 1508.e9-1508.e15.

5. Abassi Z, Bishara B, Karram T, Khatib S, Winaver J, et al. (2008) Adverse effects of pneumoperitoneum on renal function: involvement of the endothelin and nitric oxide systems. Am J Physio Regul Integr Comp Physiol 294: 842-850.

6. Hedican SP (2000) Laparoscopy in urology. Surg Clin North Am 80: 1465-1485.

7. Gomez Dammier BH, Karanik E, Guler S, Jesch NK, Kubler J, et al. (2005) Anuria during pneumoperitoneum in infants and children: a prospective study. J Pediatr Surg 40: 1454-1458.

8. Yap S, Park SW, Ergan B, Lee HT (2012) Cytokine elevation and transaminitis after laparoscopic donor nephrectomy. Am J Physiol Renal Physiol 302: 1104-1111.

9. Kuribayashi R, Suzumura H, Sairenchi T, Watabe Y, Tsuboi Y, et al. (2016) Urinary neutrophil gelatinase-associated lipocalin is an early predictor of acute kidney injury in premature infants. Exp Ther Med 12: 3706-3710.

10. Han WK, Bailly V, Abichandani R, Thadhani R, Bonventre JV (2002) Kidney Injury Molecule-1 (KIM-1): A novel biomarker for human renal proximal tubule injury. Kidney Int 62: 237-244.

11. Tian L, Shao X, Xie Y, Wang Q, Che X, et al. (2017) Kidney Injury Molecule-1 i Elevated in Nephropathy and Mediates Macrophage Activation via the Mapk Signalling Pathway. Cell Physiol Biochem 41: 769-783.

12. Schrier RW, Wang W, Poole B, Mitra A (2004) Acute renal failure: definitions, diagnosis, pathogenesis, and therapy. J Clin Invest 114: 5-14.

13. Lameire N, Van Biesen W, Vanholder R (2005) Acute renal failure. Lancet 365: 417-430.

14. Schäfer M, Krähenbühl L (2001) Effect of laparoscopy on intra-abdominal blood flow. Surgery 129: 385-389.

15. Miki Y, Iwase K, Kamiike W, Taniguchi E, Sakaguchi K, et al. (1997) Laparoscopic cholecystectomy and time-course changes in renal function: The effect of the retraction method on renal function. Surg Endosc 11: 838-841.

16. Cho A, Lee RE, Kwon GY, Huh W, Lee HM, et al. (2011) Post-operative acute kidney injury in patients with renal cell carcinoma is a potent risk factor for new-onset chronic kidney disease after radical nephrectomy. Nephrol Dial Transplant 26: 3496-3501.

17. Santos LS, Tambara Filho R, da Figueiredo TM, Cravo G (2005) Effects of the pneumoperitoneum in rats submitted to unilateral nephrectomy: morphologic and functional study on the remnant kidney. Acta Cir Bras 20: 195-199.

18. Ben-Haim M, Rosenthal RJ (1999) Causes of arterial hypertension and splanchnic ischemia during acute elevations in intra-abdominal pressure with CO2 pneumoperitoneum: a complex central nervous system mediated response. Int J Colorectal Dis 14: 227-236.

19. Devarajan P (2010) Neutrophil gelatinase-associated lipocalin: a troponin-like biomarker for human acute kidney injury. Nephrology 15: 419-428.

20. Vaidya VS, Ferguson MA, Bonventre JV (2008) Biomarkers of acute kidney injury. Annu Rev Pharmacol Toxicol 48: 463-493.

21. Micali S, Silver RI, Kaufman HS, Douglas VD, Marley GM, et al. (1999) Measurement of urinary N-accetyl-beta-glucosaminidase to assess renal ischemia during laparoscopic operations. Surg Endosc 13: 503-506.

22. Lee BR, Cadeddu JA, Molnar-Nadasdy G, Enriquez D, Nadasdy T, et al. (1999) Chronic effect of pneumoperitoneum on renal histology. J Endourol 13: 279-282.