Nephro-Urol Mon. 2018 January; 10(1):e60128. doi: 10.5812/numonthly.60128.

Published online 2017 December 13. **Research Article**

The Prevalence of Nocturia and Nocturnal Polyuria After Renal Transplantation and Associated Factors

Mohammadkazem Lebadi,[1] Ali Monfared,[1] Zahra Atrkar Roshan,[1] Ali Babaei Jandghi,[2] Seyedeh Narjes Mozafari Chenijani,[1,*] and Seyed Abuzar Fakhr Mousavi[3]

[1]Urology Research Center, Razi Hospital, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran
[2]Department of Radiology, Poursina Hospital, Guilan University of Medical Sciences, Rasht, Iran
[3]School of Medicine, Guilan University of Medical Sciences, Rasht, Iran

[*]*Corresponding author*: Seyedeh Narjes Mozafari Chenijani, Department of Nephrology, Razi Hospital, Sardar Jangal Street, Rasht, Iran. E-mail: nmozaffari77@yahoo.com

Received 2017 August 13; **Accepted** 2017 October 12.

Abstract

Background: Although uncontrolled systemic hypertension is associated with poor survival and allograft outcomes in patients after renal transplant, nondipping systolic blood pressure at night is not identified as an independent factor for deterioration of renal function after renal transplant. Therefore, in this study, we aimed to evaluate the prevalence of nocturia and nocturnal polyuria in renal transplant patients.

Methods: This cross sectional study included 114 renal transplant patients above 18 years, who were referred to the nephrology clinics of Rasht, Iran in 2016. The patients were asked to collect 24-hour urine samples twice at home, once during the day and once at night. Urine volume, creatinine, sodium, osmolarity, and creatinine clearance of resting and working periods were measured. Monitoring of ambulatory 24-hour blood pressure was performed simultaneously, and findings including the mean arterial pressure (MAP) were evaluated during the day and night. Moreover, dimensions of the transplanted kidney, postvoid residual (PVR) urine, and prostate size were evaluated by ultrasonography.

Results: The analyses showed that 81 (71.1%) patients had nocturia, while 77 (67.5%) patients had nocturnal polyuria. The mean age of the patients with nocturia was significantly higher than that of patients without nocturia ($P = 0.003$). MAP in patients with nocturnal polyuria was higher than that of patients without nocturnal polyuria. Blood pressure nondipping at night was significantly more common among patients with nocturia and nocturnal polyuria ($P < 0.001$). The increased level of urine sodium at resting time (night) was associated with nocturnal polyuria and nocturia ($P < 0.001$). In addition, the increase in creatinine clearance at resting time was associated with nocturnal polyuria and nocturia ($P = 0.04$ and $P < 0.001$, respectively). A higher level of creatinine clearance was reported during the day in patients without nocturnal polyuria or nocturia ($P < 0.001$).

Conclusions: Since nondipping blood pressure is associated with more tissue damage and deterioration of renal transplant outcomes, control of hypertension and changes in the time of antihypertensive drug administration (for improving blood pressure dipping at night) may prevent the adverse effects of nondipping blood pressure.

Keywords: Nocturia, Nocturnal Polyuria, Nocturnal Blood Pressure Dipping, Urine Osmolarity, Urine Sodium, Creatinine Clearance

1. Background

Renal transplant has been an effective treatment for end-stage renal disease, resulting in the improved quality of life and survival of patients (1). This treatment is more cost-effective than dialysis (2), and its prevalence is increasing among people. In patients undergoing renal transplantation, urine volume increases during the night (3). In healthy adults, nights are associated with a significant decrease in urine production and excretion of water and soluble substances (4). Nocturnal polyuria refers to the excessive excretion of urine at night. The normal range of nocturnal urine volume appears to be wide in large populations with a narrower age range. Overall, it has been established that nocturnal polyuria is a component of nocturia (5).

Normally, blood pressure shows a circadian rhythm, with higher levels during the day and lower levels at night. In healthy people, systolic and diastolic blood pressure usually reduces by approximately 10% at night (dipping). On the other hand, nondipping refers to the absence of blood pressure reduction at night. Overall, nondippers face more tissue damage, strokes, dementia, left ventricular hypertrophy, and microalbuminuria, compared to others (6-8).

Several studies have suggested that nondipping can

prompt a decline in glomerular filtration rate (GFR) among patients with or without chronic renal diseases (9, 10). Renal transplant recipients often complain of an abnormal increase in urinary output at night, leading to sleep disorders and reduced efficiency during the day (11). Some studies have shown an inverse circadian rhythm in urine production after renal transplant (12-15). Moreover, some studies have introduced bladder dysfunction, renal denervation, psychological stress (16, 17), and nocturnal nondipping blood pressure as the etiological factors. However, findings are limited and the underlying pathophysiological mechanisms are not well-defined (11). In addition, more excretion of sodium and absorption in edema have been suggested at night.

According to some studies, although uncontrolled systemic hypertension is associated with poor survival and allograft outcomes of patients after renal transplant, nondipping systolic blood pressure at night is not recognized as an independent factor for deterioration of renal function after renal transplant (18-20). Therefore, we aimed to evaluate the prevalence of nocturia and nocturnal polyuria and to determine some of the associated factors in patients undergoing renal transplantation.

2. Methods

This cross sectional study included 128 renal transplant patients above 18 years, who were referred to nephrology clinics in 2016. Recipients who had undergone renal transplant at least 1 month ago and had a creatinine level below 2 mg/dL were included in the study. On the other hand, the exclusion criteria were as follows: 1, diabetes mellitus (DM) or diabetes insipidus (DI); 2, use of diuretics; 3, urinary tract infection or obstruction; 4, urinary catheterization or nephrostomy; and 5, clean intermittent catheterization (CIC).

The patients' information, including demographics (eg, age and sex), dialysis duration before renal transplant, transplant duration, underlying cause of renal failure, immunosuppressive drugs, and peripheral edema, was collected. The patients were asked to collect 24-hour urine samples at home in 2 separate bottles at 2 intervals, ie, from wakeup time in the morning (after 1 micturition) until sleep time at night (working time; day bottle) and from sleep time at night until wakeup time in the morning (resting time; night bottle).

Since we aimed to assess the hemodynamic effects on urine volume, it was necessary to keep the circadian rhythm intact. We asked the patients to collect the urine samples in the day bottle since their wakeup time in the morning until night. They were asked to go to bed 1 hour before the usual time and collect their urine in the day bottle at the time of sleep. They were also asked to collect their urine in the night bottle; the first urine sample in the morning after waking up was considered as part of the nocturnal interval.

Urine volume, creatinine, sodium, osmolarity, and creatinine clearance were measured at resting and working time. Nocturia was defined as voiding more than twice at night, while nocturnal polyuria was defined as working-to-resting urine volume ratio below 2. Monitoring of ambulatory 24-hour blood pressure was performed simultaneously with measurements of blood pressure every 0.5 hour. The findings, including the mean arterial pressure (MAP) during the day and night, were also evaluated. Normal blood pressure dipping at night was defined as ΔMAP above 10%. ΔMAP was calculated as follows (11):

$$\Delta\text{MAP} = \frac{|\text{MAP night} - \text{MAP day}|}{\text{MAP day}} \times 100 \quad (1)$$

Patients were classified into 3 categories, based on the nocturnal decline in MAP: dippers ($\Delta\text{MAP} > 10\%$), nondippers ($0 \leq \Delta\text{MAP} \leq 10\%$), and reverse dippers (increased nocturnal MAP). The serum level of cyclosporine was also measured. Dimensions of the transplanted kidney, postvoid residual (PVR) urine, and prostate size were evaluated by a radiologist, using ultrasonography (model Aplio300; Toshiba). PVR below 50 cc (normal PVR) is suggestive of sufficient emptying of the bladder (21). Overall, the normal kidney size is 10 - 12 cm in length and 4 - 5 cm in width (22). Also, the normal size of prostate is less than 25 - 30 mL (23).

Data were entered into SPSS version 19 and analyzed using descriptive statistics (mean and ratio), Chi square test, student's t test, and logistic regression analysis.

3. Results

Overall, 14 out of 128 patients were excluded due to lack of cooperation. Among 114 patients, 66 (57.9%) were male and 48 (42.1%) were female. The mean age of the participants was 43.16 $\pm$ 12.43 years (18 - 78 years). Based on the findings, 81 (71.1%) patients had nocturia, and 77 (67.5%) patients had nocturnal polyuria. The analyses showed that patients with nocturia were significantly older than those without nocturia (46.59 $\pm$ 11.06 vs. 37.48 $\pm$ 13.20; P = 0.003, OR, 1.05). However, the difference in age between patients with and without nocturnal polyuria was not significant (45.38 $\pm$ 11.16 vs. 41.32 $\pm$ 14.42; P = 0.16).

Comparison of gender among patients with and without nocturia and nocturnal polyuria was not significant. The transplant duration and dialysis duration before renal transplant were not significantly different among patients

with and without nocturia; similar findings were reported for nocturnal polyuria, underlying diseases, and edema. As the findings revealed, 92 patients were using cyclosporine, 14 patients were using tacrolimus, and 8 patients were on noncalcineurin inhibitors. Table 1 demonstrates the background information of the patients.

As shown in Table 2, there was no significant difference in the size of the transplanted kidney, prostate size, PVR, serum cyclosporine level, and MAP (day and night) between patients with and without nocturia or nocturnal polyuria. According to the findings, 63 (55.3%) patients were nondippers, 38 (33.3%) patients were reverse dippers, and 13 (11.4%) patients were dippers. In patients with nocturia, a nondipping pattern of blood pressure, followed by reverse dipping, was more common than dipping, as in patients with nocturnal polyuria ($P < 0.001$).

Urine sodium excretion and creatinine clearance at rest were significantly higher in patients with nocturia and nocturnal polyuria, compared to patients without these conditions ($P < 0.001$). The odds ratios (OR) of urine sodium at rest for nocturia and nocturnal polyuria were 1.06 and 1.03, respectively. Moreover, ORs of creatinine clearance at rest for nocturia and nocturnal polyuria were 1.01 and 1.02, respectively, while the OR of creatinine clearance for nocturia and nocturnal polyuria were 0.97 and 0.98, respectively; however, urine osmolarity showed no significant differences. As indicated in Table 3, different immunosuppressive drugs could not affect nocturnal blood pressure dipping.

4. Discussion

Nocturia and nocturnal polyuria are symptoms of a variety of pathological conditions, including DM (24), cardiovascular diseases (25), renal diseases (26, 27), and enuresis (28). It seems that different pathological mechanisms are responsible for abnormal circadian rhythm in diuresis (11). In children with enuresis, lack of a nocturnal increase in arginine vasopressin (AVP) level, disorders in hormones regulating renal sodium (aldosterone and angiotensin II), and overproduction of prostaglandin E2 (PGE2) have been reported (28-31). The overnight decrease in blood pressure leads to an increase in AVP (32). Therefore, increased blood pressure, even an overnight increase in MAP, may inhibit AVP release from the hypothalamus and result in higher levels of urination during the night (11).

Natriuresis and atrial natriuretic peptide disorders are found in renal disorders (27). The present study showed that the prevalence of nocturia, not nocturnal polyuria, increases with aging ($P = 0.003$ and $P = 0.16$, respectively). This finding is incompatible with a previous study, which showed that the increased prevalence of nocturia by aging is not due to increased urine volume, but other factors such as bladder compliance. In the mentioned study, increased urine volume and nocturnal polyuria increased the prevalence of nocturia by aging.

The observed discrepancy between the mentioned study and the present research may be attributed to differences in the study population and sampling methods. In our study, diabetic patients were not recruited, whereas in the mentioned study, diabetic patients were also evaluated. However, in consistence with the previous study, nocturia and nocturnal polyuria were not significantly correlated with gender and renal transplant duration (33).

The correlation of nocturia and nocturnal polyuria with average dialysis duration before renal transplant was not significant in our patients ($P = 0.19$ and $P = 97$, respectively). This finding was incompatible with a previous study, indicating a significantly longer dialysis duration before transplant in patients with nocturia and nocturnal polyuria (33). This incompatibility is probably due to differences in the average dialysis duration before renal transplant (5 years in the mentioned study vs. 17 months in the present study). Patients waiting for renal transplant, who undergo dialysis, often have decreased urine output and lower urinary tract dysfunctions (34), such as urinary frequency, nocturia, and low bladder compliance. Since patients in the mentioned study had a longer dialysis period before transplant than those in the present study, lower bladder compliance and dysfunction were reported; our findings are consistent with this study.

Regarding the underlying diseases, our patients were mostly in the categories of hypertension (n, 40; 35.1%) and unknown origin (n, 40; 35.1%). The prevalence of underlying diseases was not significantly different in patients with nocturia and polyuria, which can be due to the exclusion of patients with underlying diseases influencing polyuria and nocturia, such as DM and DI. Nevertheless, a previous study stated that DM is a risk factor for polyuria and nocturnal polyuria (32). The findings can be also related to the control of underlying diseases before renal transplant.

Since most of our patients had no edema (111 out of 114 patients), peripheral edema was not correlated with nocturnal polyuria and nocturia ($P = 0.86$ and $P = 0.97$, respectively). Moreover, nocturia and nocturnal polyuria were not significantly correlated with the transplanted kidney size and prostate size. A previous study, performed on 30 500 men for prostate, lung, and colorectal cancer screening, concluded that the posterior surface of the prostate on digital rectal examination (DRE) was significantly correlated with nocturia on multiple analyses (35). The difference between the present and latter studies may be due to the use of ultrasonography for evaluating the prostate size

Table 1. The Demographic Information of the Patients

		Nocturia			Nocturnal Polyuria		
		Yes	No	P Value	Yes	No	P Value
Age		11.06 ± 46.59	13.20 ± 37.48	0.003	11.16 ± 45.38	14.42 ± 41.62	0.160
Gender	Male	46	20	0.700	43	23	0.520
	Female	35	13		34	14	
Transplant duration (months)		51.29 ± 62.72	35.34 ± 52.88	0.170	58.03 ± 50.03	65.00 ± 41.73	0.970
Dialysis duration (months)		19.37 ± 20.94	14.20 ± 20.42	0.190	19.63 ± 21.32	14.14 ± 19.42	0.17
Underlying disease	Hypertension	30	10	0.600	28	12	0.530
	Glomerulonephritis	6	5		7	4	
	Unknown	28	12		28	12	
	Unknown	2	2		1	3	
	Autosomal dominant polycystic kidney disease	6	3		5	4	
	Urologic disease	8	1		7	2	
	Hereditary disease	1	0		1	0	
Edema		2	1	0.860	2	1	0.970
Immunosuppressive drug	Tacrolimus	7	7	0.17	6	8	0.06
	Noncalcineurin inhibitor	6	2		7	1	
	Cyclosporine	68	24		64	28	

in our study, which is more accurate than DRE.

Since patients with nocturia and nocturnal polyuria had a normal PVR (< 50 mL), the correlation of nocturia and nocturnal polyuria with PVR was not significant. In the current study, no level of cyclosporine led to an increase in nocturia or nocturnal polyuria. Some studies have evaluated the impact of immunosuppressive drugs on overnight dipping, showing no significant difference between cyclosporine and tacrolimus in dipping (11) or between sirolimus and cyclosporine in overnight dipping (36).

The day and night MAPs were not significantly different among patients with and without nocturia or nocturnal polyuria. In a previous study, daytime MAP was similar among the patients, ie, patients with transplant duration less than 12 weeks, patients with transplant duration more than 52 weeks, and controls. However, night MAP was significantly higher in patients with transplant duration less than 12 weeks in comparison with the control group (11). The discrepancy with the present study is probably related to the inclusion of a control group in the mentioned study, while no control group was recruited in our study.

In our patients with nocturia and nocturnal polyuria, the number of nondippers and reverse dippers was significantly higher than dippers (P < 0.001; OR, 1.05 in nocturia; OR, 1.06 in nocturnal polyuria). Overnight blood pressure nondipping was associated with decreased day-to-night urine volume ratio in renal transplant recipients. This finding is suggestive of rhythmic disorders in blood pressure among transplant recipients. Previous studies have also shown the effect of overnight hypertension on overnight micturition. Moreover, the following observations were reported: a significant decrease in day-to-night urine volume ratio, a significant increase in night MAP, an insignificant increase in day MAP, abnormal circadian rhythms, and disorders in the 24-hour blood pressure profile with a nondipping pattern (11, 32, 36-39).

In the present study, patients with nocturia had a higher level of overnight urine sodium, compared to patients without nocturia; the same finding was reported in patients with nocturnal polyuria (P = 0.001). Day and night urine osmolarity was not significantly different among

Table 2. The Results of Analyses Among Patients

		Nocturia			Nocturnal polyuria		
		Yes	No	P Value	Yes	No	P Value
Size of transplanted kidney (mm)	Normal	69	24	0.11	66	27	0.25
	Small	2	0		1	1	
	Large	10	9		10	9	
Size of prostate (mm)	Normal	43	16	0.18	40	19	0.32
	Large	4	3		4	4	
Residual urine (mL)	< 50 cc	77	30	0.40	73	34	0.54
	50 - 200 cc	4	3		4	3	
	> 200 cc	0	0		0	0	
Serum cyclosporine level (C0)	< 100	11	10	0.07	11	10	0.11
	100 - 400	55	15		52	18	
	> 400	1	0		1	0	
Mean arterial pressure (mmHg)	Day	90.97 ± 8.74	90.16 ± 9.80	0.73	90.69 ± 8.93	90.89 ± 9.29	0.96
	Night	89.40 ± 10.43	84.76 ± 7.79	0.21	89.68 ± 10.46	84.60 ± 7.77	0.11
Nocturnal blood pressure dipping	Dipper	4	9	< 0.001	1	12	< 0.001
	Nondipper	44	19		44	19	
	Reverse dipper	33	5		32	6	
Urine Na (meq/L)	Activity	60.67	72.60	0.06	58.16	76.54	< 0.001
	Rest	48.30	29.63	< 0.001	47.32	33.70	< 0.001
Urine osmolality (mosm/kg H_2O)	Activity	409.25	393.93	0.59	416.88	397.72	0.18
	Rest	376.91	403.03	0.31	386.75	397.72	0.77
Creatinine clearance (mL/min)	Activity	84.93	98.2	< 0.001	84.90	96.36	< 0.001
	Rest	61.18	51.12	0.04	62.14	50.21	< 0.001

Table 3. The Immunosuppressive Drugs and Nocturnal Blood Pressure Dipping

		Dipper	Nondipper	Reverse dipper	P Value
Immunosuppressive drugs	Tacrolimus	10	53	29	0.48
	Noncalcineurin	3	6	5	
	Cyclosporine	0	4	4	

patients with and without nocturia, similar to nocturnal polyuria. In a previous study, urine osmolality in patients with transplant duration < 12 weeks decreased at night, while in patients with transplant duration > 52 weeks, a slight increase in overnight urine osmolality was observed; however, there was no significant correlation with the average urine osmolality.

There was no significant difference between the 2 groups in terms of total sodium excretion. Since sodium is the most important determinant of osmolarity, the insignificant difference in osmolarity and the significant difference in urine sodium may be justified by the total and overnight fluid intake and increased urine volume due to water diuresis, lower osmolarity, or solute diuresis. The mentioned study showed an insignificant correlation between 24-hour fluid intake and overnight urine osmolality; however, the present study did not evaluate fluid intake volume and its correlation with urine volume and osmolarity (11).

In another study, patients with nocturnal polyuria had more overnight water intake and sodium clearance, while they showed lower overnight osmolarity in comparison

with patients without polyuria (40). It should be noted that this study was not conducted on renal transplant recipients. In the present study, we found that patients with nocturia and nocturnal polyuria had more creatinine clearance at resting time ($P = 0.04$ and $P < 0.001$, respectively) and less creatinine clearance at working time, compared to patients without nocturia or nocturnal polyuria ($P < 0.001$). This finding may be due to differences in the position of the transplanted kidney and its blood supply, which can increase during rest time and lead to higher creatinine clearance.

4.1. Conclusion

Overall, nocturia and nocturnal polyuria are common complaints of renal transplant recipients. In the present study, nocturia increased with aging, while nocturnal polyuria did not, which can be suggestive of factors other than increased urine volume (regardless of underlying diseases such as poor DM control), leading to polyuria. Nocturia and nocturnal polyuria increased with the abnormal circadian rhythm of blood pressure. Therefore, most renal transplant recipients with nocturia or nocturnal polyuria had nondipping patterns, followed by reverse dipping patterns of blood pressure. Moreover, solute diuresis in renal transplant recipients led to the increased prevalence of nocturia and nocturnal polyuria. Whether water diuresis leads to an increase in urine volume or not, total and nighttime fluid intake should be measured in these patients. Since nondipping blood pressure is associated with more tissue damage and poor renal outcomes (6-8, 38), control of hypertension and changes in the time of antihypertensive drug administration (for improving nocturnal blood pressure dipping) may prevent the adverse effects of nondipping patterns, improve the renal outcomes, and decrease tissue damage.

Acknowledgments

This research was supported by the urology research center, Guilan University of Medical Sciences, Rasht, Iran. This study was extracted from the MD thesis of Dr. Seyedeh Narjes Mozafari Chenijani.

References

1. Abbott KC, Oliver J3, Hypolite I, Lepler LL, Kirk AD, Ko CW, et al. Hospitalizations for bacterial septicemia after renal transplantation in the united states. *Am J Nephrol*. 2001;**21**(2):120–7. doi: 10.1159/000046234. [PubMed: 11359019].
2. Laupacis A, Keown P, Pus N, Krueger H, Ferguson B, Wong C, et al. A study of the quality of life and cost-utility of renal transplantation. *Kidney Int*. 1996;**50**(1):235–42. [PubMed: 8807593].
3. Hsieh MC, Hung CW, Chiou HL, Yang SF. Effect of a BK viruria reaction detected by qualitative polymerase chain reaction on the renal function of kidney transplant recipients. *Mol Med Rep*. 2013;**7**(4):1319–23. doi: 10.3892/mmr.2013.1334. [PubMed: 23440392].
4. Mills JN. Diurnal rhythm in urine flow. *J Physiol*. 1951;**113**(4):528–36. [PubMed: 14851256].
5. Rembratt A, Norgaard JP, Andersson KE. What is nocturnal polyuria?. *BJU Int*. 2002;**90 Suppl 3**:18–20. [PubMed: 12445094].
6. Clement DL, De Buyzere ML, De Bacquer DA, de Leeuw PW, Duprez DA, Fagard RH, et al. Prognostic value of ambulatory blood-pressure recordings in patients with treated hypertension. *N Engl J Med*. 2003;**348**(24):2407–15. doi: 10.1056/NEJMoa022273. [PubMed: 12802026].
7. Verdecchia P. Prognostic value of ambulatory blood pressure : current evidence and clinical implications. *Hypertension*. 2000;**35**(3):844–51. [PubMed: 10720605].
8. Graugaard-Jensen C, Rittig S, Djurhuus JC. Nocturia and circadian blood pressure profile in healthy elderly male volunteers. *J Urol*. 2006;**176**(3):1034–9. doi: 10.1016/j.juro.2006.04.046. [PubMed: 16890685].
9. Agarwal R, Andersen MJ. Prognostic importance of ambulatory blood pressure recordings in patients with chronic kidney disease. *Kidney Int*. 2006;**69**(7):1175–80. doi: 10.1038/sj.ki.5000247. [PubMed: 16467785].
10. Davidson MB, Hix JK, Vidt DG, Brotman DJ. Association of impaired diurnal blood pressure variation with a subsequent decline in glomerular filtration rate. *Arch Intern Med*. 2006;**166**(8):846–52. doi: 10.1001/archinte.166.8.846. [PubMed: 16636209].
11. Alstrup K, Graugaard-Jensen C, Rittig S, Jorgensen KA. Abnormal diurnal rhythm of urine output following renal transplantation: the impact of blood pressure and diuretics. *Transplant Proc*. 2010;**42**(9):3529–36. doi: 10.1016/j.transproceed.2010.08.028. [PubMed: 21094810].
12. Berlyne GM, Mallick NP, Seedat YK, Edwards EC, Harris R, Orr WM. Abnormal urinary rhythm after renal transplantation in man. *The Lancet*. 1968;**292**(7565):435–6. doi: 10.1016/s0140-6736(68)90471-6.
13. Chan MK, Varghese Z, Fernando ON, Moorhead JF. Nocturnal polyuria and saluresis in renal allograft recipients. *Br Med J*. 1980;**280**(6208):150–1. [PubMed: 6986946].
14. McMillan R, Evans DB, Lines JG. Reversed rhythm of kidney transplants. *N Engl J Med*. 1969;**280**(3):166. [PubMed: 4881783].
15. Lines JG, McMillan R, Evans DB. Salt and water excretion after renal transplantation. *J Med*. 1970;**1**(6):345–57. [PubMed: 4939617].
16. Zermann DH, Janitzky A, Hohne M, Schubert J. Frequency and nocturia after successful renal transplantation: a normal situation?. *BJU Int*. 2006;**97**(3):555–8. doi: 10.1111/j.1464-410X.2006.05963.x. [PubMed: 16469025].
17. Karam G, Giessing M. Bladder dysfunction following renal transplantation is it predictable?. *Transplant Proc*. 2011;**43**(1):387–90. doi: 10.1016/j.transproceed.2010.12.017.
18. Kasiske BL, Anjum S, Shah R, Skogen J, Kandaswamy C, Danielson B, et al. Hypertension after kidney transplantation. *Am J Kidney Dis*. 2004;**43**(6):1071–81. [PubMed: 15168388].
19. Mange KC, Cizman B, Joffe M, Feldman HI. Arterial hypertension and renal allograft survival. *JAMA*. 2000;**283**(5):633–8. [PubMed: 10665703].
20. Opelz G, Dohler B, Collaborative Transplant S. Improved long-term outcomes after renal transplantation associated with blood pressure control. *Am J Transplant*. 2005;**5**(11):2725–31. doi: 10.1111/j.1600-6143.2005.01093.x. [PubMed: 16212633].
21. Kobashi KC. *Campbell walsh urology*. 11 ed. Canada: Elsevier; 2016. Evaluation and management of women with urinary incontinence and pelvic prolapse.
22. Gilbert BR, Fulgham PF. *Campbell walsh urology*. 11 ed. Canada: Elsevier; 2016. Urinary tract imaging: basic principles of urologic ultrasonography.
23. Roehrborn CG. Benign prostatic hyperplasia: an overview. *Rev Urol*. 2005;**7 Suppl 9**:3–14. [PubMed: 16985902].

24. Roche EF, Menon A, Gill D, Hoey H. Clinical presentation of type 1 diabetes. *Pediatr Diabetes*. 2005;**6**(2):75–8. doi: 10.1111/j.1399-543X.2005.00110.x. [PubMed: 15963033].
25. Asplund R. Nocturia in relation to sleep, somatic diseases and medical treatment in the elderly. *BJU Int*. 2002;**90**(6):533–6. [PubMed: 12230611].
26. Hillier P, Knapp MS, Cove-Smith R. Circadian variations in urine excretion in chronic renal failure. *Q J Med*. 1980;**49**(196):461–78. [PubMed: 7267962].
27. Fukuda M, Motokawa M, Miyagi S, Sengo K, Muramatsu W, Kato N, et al. Polynocturia in chronic kidney disease is related to natriuresis rather than to water diuresis. *Nephrol Dial Transplant*. 2006;**21**(8):2172–7. doi: 10.1093/ndt/gfl165. [PubMed: 16627609].
28. Kamperis K, Rittig S, Jorgensen KA, Djurhuus JC. Nocturnal polyuria in monosymptomatic nocturnal enuresis refractory to desmopressin treatment. *Am J Physiol Renal Physiol*. 2006;**291**(6):1232–40. doi: 10.1152/ajprenal.00134.2006. [PubMed: 16804103].
29. Rittig S, Matthiesen TB, Pedersen EB, Djurhuus JC. Sodium regulating hormones in enuresis. *Scand J Urol Nephrol Suppl*. 1999;**202**:45–6. [PubMed: 10573792].
30. Rittig S, Matthiesen TB, Pedersen EB, Djurhuus JC. Circadian variation of angiotensin II and aldosterone in nocturnal enuresis: relationship to arterial blood pressure and urine output. *J Urol*. 2006;**176**(2):774–80. doi: 10.1016/S0022-5347(06)00594-5. [PubMed: 16813944].
31. Nikolaeva S, Pradervand S, Centeno G, Zavadova V, Tokonami N, Maillard M, et al. The circadian clock modulates renal sodium handling. *J Am Soc Nephrol*. 2012;**23**(6):1019–26. doi: 10.1681/ASN.2011080842. [PubMed: 22440902].
32. Asplund R. Diuresis pattern, plasma vasopressin and blood pressure in healthy elderly persons with nocturia and nocturnal polyuria. *Neth J Med*. 2002;**60**(7):276–80. [PubMed: 12430573].
33. Mitsui T, Moriya K, Morita K, Iwami D, Kitta T, Kanno Y, et al. Risk Factors for Lower Urinary Tract Dysfunction and Symptoms After Successful Renal Transplantation. *Ann Transplant*. 2015;**20**:757–63. [PubMed: 26701811].
34. Serrano DP, Flechner SM, Modlin CS, Wyner LM, Novick AC. Transplantation into the long-term defunctionalized bladder. *J Urol*. 1996;**156**(3):885–8. [PubMed: 8709354].
35. Stone BV, Shoag J, Halpern JA, Mittal S, Lewicki P, Golombos DM, et al. Prostate size, nocturia and the digital rectal examination: a cohort study of 30 500 men. *BJU Int*. 2017;**119**(2):298–304. doi: 10.1111/bju.13613. [PubMed: 27480499].
36. Steigerwalt SP, Brar N, Dhungel A, Butcher D, Steigerwalt S, El-Ghouroury M, et al. Improved 24-hour blood pressure control with sirolimus versus calcineurin inhibitor based immunosuppression in renal transplant recipients. *Transplant Proc*. 2009;**41**(10):4184–7. doi: 10.1016/j.transproceed.2009.07.109. [PubMed: 20005365].
37. Shimada K, Kawamoto A, Matsubayashi K, Nishinaga M, Kimura S, Ozawa T. Diurnal blood pressure variations and silent cerebrovascular damage in elderly patients with hypertension. *J Hypertens*. 1992;**10**(8):875–8. [PubMed: 1325522].
38. Ibernon M, Moreso F, Sarrias X, Sarrias M, Grinyo JM, Fernandez-Real JM, et al. Reverse dipper pattern of blood pressure at 3 months is associated with inflammation and outcome after renal transplantation. *Nephrol Dial Transplant*. 2012;**27**(5):2089–95. doi: 10.1093/ndt/gfr587. [PubMed: 22015441].
39. Boongird S, Shah N, Nolin TD, Unruh ML. Nocturia and aging: diagnosis and treatment. *Adv Chronic Kidney Dis*. 2010;**17**(4):27–40. doi: 10.1053/j.ackd.2010.04.004. [PubMed: 20610352].
40. Weiss JP. Nocturia: focus on etiology and consequences. *Rev Urol*. 2012;**14**(3-4):48–55. [PubMed: 23526404].