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Kidney transplantation and evolution of parathyroid function: results of a single-center study

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Abstract

Background. *The functional status of the parathyroid glands (PTG) in patients with chronic kidney disease (CKD) before and after kidney transplantation (KT) is interrelated. The preoperative optimal blood level of parathyroid hormone (PTH) for the prevention of the post-transplant hyperparathyroidism (HPT) development is unknown.*

The objective *was to study the function of the PTG after KT during the first postoperative year depending on the pretransplant serum PTH level in the target range (150-600 pg/mL).*

Material and methods. *The retrospective cohort single-center study included 157 patients with preoperative blood PTH levels of 150–600 pg/mL who had undergone primary successful KT for CKD G5-G5(D) at least a year before inclusion in the study and had a satisfactory functioning graft within one year after surgery. Serum concentrations of PTH, calcium, adjusted for albumin, phosphorus, and creatinine were studied before KT and at 3 and 12 months after it. Blood PTH no more than 130 pg/mL was a target level after KT.*

Results. *Patients were allocated into three groups: 82 patients with blood PTH of 150-300 pg/mL were included into the 1st group; 41 patients with blood PTH of 301-450 pg/mL comprised the 2nd group, and 34 patients with blood PTH of 451-600 pg/mL made the 3rd group. Three months after KT, blood PTH decreased to 128 (98;169) pg/mL, 180 (121;222) pg/mL, and 247 (154;299) pg/mL (p<0.001) in the 1st, 2nd, and 3rd patient groups, respectively; the target blood PTH level was observed in 58.5%, 34.1%, and 20.6% of patients in the respective groups (p<0.001). No differences in the in PTG values were seen between the groups by the end of the year. A decrease in phosphorus and stable normal blood calcium were recorded. The graft function was similar in the patients of all groups throughout the year. A direct close correlation was established between blood PTH before KT and three months after KT, a less close one after one year; the relationship between blood PTH and graft function was weak after three months and a close one after one year.*

Conclusion. *The process of normalization of PTG function in the early stages after successful KT depends on the preoperative blood PTH level.*

Keywords: kidney transplantation, chronic kidney disease, parathyroid glands, parathyroid hormone, post-transplant hyperparathyroidism

Conflict of interests. Authors declare no conflict of interest

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ALP, alkaline phosphatase
ATN, acute tubular necrosis
CKD, chronic kidney disease
eGFR, estimated glomerular filtration rate
HPT, hyperparathyroidism
KT, kidney transplantation
PTG, parathyroid gland

PTH, parathyroid hormone

Introduction

Kidney transplantation (KT) is the best option to treat the end-stage renal disease, and to ensure a high level of medical and social rehabilitation for the patients. It makes reversible many endocrine-metabolic disorders characteristic of chronic kidney disease (CKD), including hyperfunction of the parathyroid glands (PTGs). An abnormally increased PTG function and the development of secondary hyperparathyroidism (HPT) constitute typical disorders that progress as the renal function is being lost and occur through various pathophysiological mechanisms: phosphorus retention in the body, disruption of the α-Klotho-fibroblast growth factor 23 co-receptor system, hypocalcemia, calcitriol deficiency, skeletal resistance to the calcemic effect of parathyroid hormone (PTH) and other homeostatic shifts [1]. After successful KT, the impact of the above listed factors ceases, but the process of the thyroid gland functional normalization can take a long time, and in some patients, be absent [2, 3].

Preoperative blood level of PTH has a direct impact on its content after KT. The presence of secondary HPT in patients having CKD before surgery significantly increases the risk of secondary HPT persistence after KT, which has a negative impact on clinical outcomes [4–9]. Currently, there is no clear idea of the target blood PTH in KT candidates that would prevent the development of HPT after surgery. Determining the optimal hormone level in patients with CKD that would fit within the PTG adaptive response to a declining renal function is a complex task due to the dependence of target PTH level on many factors [10]. For patients on dialysis, several target ranges of blood PTH have been established, ranging from narrow (2–4 times the upper limit of the reference range, equal to 65 pg/mL) to wide (2–9 times the upper limit of the reference

range) [11–14]. The target blood serum PTH level was determined based on the analysis of adverse outcomes in dialysis patients and has a non-absolute level of evidence (2C) [13]. A recently published study showed the lowest mortality risk in these patients in cases when the blood PTH level was from 2- to 6-fold exceeding the upper limit of the reference range equal to 75 pg/mL [15]. Other authors reported similar data: a stable blood level of PTH exceeding 450 pg /mL is closely associated with high-metabolism bone disease characteristic of HPT, while with a moderately high blood level of PTH (300–450 pg/mL), normal and even low bone metabolism, which are not characteristic of HPT, can be observed [16]. In this regard, the functional state of PTGs and the risk of developing HPT in patients after KT who had different preoperative variants of target blood PTH are of interest.

The aim of this study was to evaluate the functional state of PTGs in kidney transplant recipients during the first postoperative year considering the pretransplant serum PTH level in the target range from 150 to 600 pg/mL recommended by Kidney Disease Improving Global Outcomes (KDIGO).

Material and methods

A retrospective cohort single-center study included 157 patients with CKD G5-G5(D) who underwent KT in 2015-2020. Patient inclusion criteria: 1. The presence of CKD G5-G5(D); 2. Blood PTH level of 150-600 pg/mL before KT; 3. Successful primary KT within the recent 12 months; 4. Functioning renal graft during the first postoperative year. Exclusion/non-inclusion criteria: 1. Previous medical history of primary TP (over 12 months ago); 2. Removal of the renal graft during the first postoperative year; 3. Parathyroidectomy before KT or in the first postoperative year.

The ratio of men and women included in the study was 72/85 (46%/54%), age ranged from 19 to 70 years, the median being 46 (36;53) years. The vast majority of patients suffered from various types of non-diabetic nephropathy (91%). The treatment included hemodialysis in 65%, peritoneal dialysis in 19%, sequentially performed both dialysis methods in 12%; and pre-dialysis KT was performed in 4% of patients; the duration of dialysis therapy varied from 1 to 129 months, median 19 (9;35) months. All patients underwent allotransplantation from a deceased donor: an immediate renal graft function was recorded in 56%, a delayed graft function was noted in 44% of recipients; the duration of acute tubular necrosis (ATN) lasted from 2 to 30 days, median 6 (3;9) days.

Biochemistry tests performed before KT and at 3 and 12 months in the postoperative period included determination of blood level of PTH, calcium, phosphorus, total alkaline phosphatase (ALP) activity and creatinine using standard methods. In candidates for KT, the mean blood levels of PTH, calcium, phosphorus and ALP for 6 months before surgery were used; and in recipients, the mean levels of biochemical parameters determined during repeated testing were used. The target level of PTH in the blood of kidney transplant recipients was considered the serum concentration with a value not exceeding 130 pg/mL (2-fold the upper limit of the reference range, equal to 65 pg/mL) [17, 18]. The estimated glomerular filtration rate (eGFR) was calculated using the formula CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration).

Statistical analysis of the material was performed using GraphPad v.8.0.1 software. The distribution of variables was assessed using the Kolmogorov–Smirnov test. The description of quantitative variables with normal distribution is presented as the arithmetic mean value and a standard deviation (M±SD), of those with asymmetric distribution is presented as the median, 25% and 75% quartiles (Me, Q_1;Q_3). Qualitative

variables are presented as absolute numbers (n) and percentages (%). The Kruskal–Wallis test was used to compare quantitative data, and the χ^2 test was used for qualitative variables. The strength of the relationship between quantitative variables was assessed using the linear correlation coefficient (r). Fisher's exact test was used to analyze the joint distribution of qualitative variables. The relative risk (RR) parameter with calculation of the 95% confidence interval [95% CI] was used as a quantitative measure of the effect when comparing relative parameters. The results were considered statistically significant at p value of < 0.05.

Results

Patients were allocated into three groups regarding the pre-KT serum PTH level within 150 pg/mL. The first group included 82 patients with blood PTH level of 150–300 pg/mL, the second group included 41 patients with blood PTH level of 301–450 pg/mL, and the third group included 34 patients with blood PTH level of 451–600 pg/mL. The groups were comparable in demographic and clinical parameters (Table 1).

Table 1. Patient demographics and clinical characteristics

Parameter	1st group (n=82)	2nd group (n=41)	3rd group (n=34)
Male/female, n (%)	33/49 (40.2/59.8)	20/21 (48.8/51.2)	18/16 (52.9/47.1)
Age, years, Me (Q_1;Q_3)	46 (37;54)	48 (37;53)	42 (34;48)
Kidney disease Non-diabetic nephropathy, n (%)	78 (95.1)	37 (90.2)	28 (82.4)
Dialysis modality Hemodialysis, n (%) Peritoneal dialysis, n (%) Hemodialysis+peritoneal dialysis, n (%) Without dialysis, n (%)	 54 (65.8) 14 (17.1) 9 (11) 5 (6.1)	 27 (65.8) 10 (24.4) 2 (4.9) 2 (4.9)	 21 (61.8) 6 (17.6) 7 (20.6) 0
Dialysis therapy duration, months, Me (Q_1;Q_3)	19 (10;35)	21 (8;32)	16 (11;36)

The dynamics of parameters reflecting the thyroid gland functional condition, i.e. the blood levels of PTH, phosphorus, calcium, and the activity of alkaline phosphatase during the first postoperative year are presented in Table 2.

As can be seen from the Table, at 3 months after KT, a decrease in blood PTH was observed in all patients: the median decrease was 94 (64;124) pg/mL or 42±17% in group 1, 200 (141;249) pg/mL or 54±20% in group 2, 269 (217;377) pg/mL or 50±19% in group 3, ($p<0.001$). Despite a more pronounced decrease in blood PTH, its medians in patients of groups 2 and 3 exceeded the target value. The target blood level of PTH was achieved by more than half of the patients in group 1, in a third of patients in group 2, and in a fifth of patients in group 3. Intergroup differences in the blood level of PTH and the proportion of patients who achieved its target level were statistically significant. Over the next 9 months, a further decrease in blood PTH was recorded: it reached the target level in another 10 of 34 (29%) patients in Group 1, in 15 of 27 (56%) in Group 2, and in 13 of 27 (48%) in Group 3 ($p=0.101$). By the end of the year, the median value of blood PTH was comparable between the groups, with half of the recipients having it within the target range. The proportion of recipients who achieved the target blood PTH was also similar in all groups, although there was a clear trend towards a decrease in the number of such patients in Groups 2 and 3. The lack of statistical significance may be due to the small number of patients included in the study.

A regular pattern in the serum phosphorus content dynamics was observed: if more than half of the candidates for KT had hyperphosphatemia, then 3 months after surgery, the serum phosphorus concentration was in the reference range in most patients. Some exceptions were patients of the 3rd group, in whom hypophosphatemia

was more often noted. A year after KT, the normal blood level of phosphorus retained in most patients; only in isolated cases, hypo- or hyperphosphatemia were seen. Blood calcium was steadily recorded in the target range in almost all patients in the pre-transplant period and during the first postoperative year.

Table 2. Dynamics of parathyroid gland function parameters in patients with chronic kidney disease before kidney transplantation and in the first post-transplant year

Blood parameters, level	1st group (n=82)	2nd group (n=41)	3rd group (n=34)	p_2
PTH, pg/mL, Me(Q_1;Q_3)				
Before KT	225 (186;281)	376 (344;400)	529 (500;574)	<0.001
3 months after KT	128 (98;169)	180 (121;222)	247 (154;299)	<0.001
12 months after KT	106 (90;125)	117 (90;135)	123 (78;190)	0.662
	p_1<0.001	p_1<0.001	p_1<0,001	
PTH, no more than 130 pg/mL, n (%)				
3 months after KT	48 (58.5)	14 (34.1)	7 (20.6)	<0.001
12 months after KT	64 (78)	29 (70.7)	21 (61.8)	0.192
	p_1=0.012	p_1=0.002	p_1=0.001	
Phosphorus, mmol/L, Me (Q_1;Q_3)				
Before KT	1.83 (1.46;2.05)	1.73 (1.43;1.95)	1.97 (1.46;2.29)	0,620
3 months after KT	1.07 (0.97;1.23)	1.03 (0.85;1.18)	1.03 (0.77;1.18)	0.285
12 months after KT	1.09 (0.99;1.34)	1.15 (1.01;1.36)	1.11 (0.96;1.23)	0.426
	p_1<0.001	p_1<0.001	p_1<0.001	
Target phosphorus (0.87–1.49 mmol/L), n (%)				
Before KT	22 (26.8)	13 (31.7)	11 (32.4)	0.775
3 months after KT	74 (90.2)	33 (80.5)	22 (64.7)	0.005
12 months after KT	61 (74.4)	33 (80.5)	28 (82.4)	0.569
	p_1<0.001	p_1<0.001	p_1<0.001	
Phosphorus, more than 1.49 mmol/L, n (%)				
Before KT	60 (73.2)	28 (68.3)	23 (67.6)	0.775
3 months after KT	0	0	0	-
12 months after KT	9 (11)	4 (9.8)	0	0.137
	p_1<0.001	p_1<0.001	p_1<0.001	
Phosphorus, lower than 0.87 mmol/L), n (%)				
Before KT	0	0	0	-
3 months after KT	8 (9.8)	8 (19.5)	12 (35.3)	0.005

12 months after KT	12 (14.6) p_1=0.002	4 (9.7) p_1=0.012	6 (17.6) p_1<0.001	0.602
Calcium (total)$_{corr.}$, mmol/L, Me (Q_1;Q_3)				
Before KT	2.3 (2.2;2.4)	2.3 (2.2;2.5)	2.2 (2.2;2.4)	0.132
3 months after KT	2.3 (2.2;2.4)	2.4 (2.3;2.5)	2.5 (2.3;2.5)	0.662
12 months after KL	2.4 (2.3;2.4) p_1=0.046	2.5 (2.4;2.6) p_1=0.006	2.4 (2.2;2.4) p_1=0.027	0.0 61
Target calcium (2.1–2.6 mmol/L), n (%)				
Before KT	79 (96.3)	39 (95.1)	31 (91.2)	0.514
3 months after KT	82 (100)	41 (100)	34 (100)	-
12 months after KT	82 (100) p_1=0.05	37 (90.2) p_1=0.122	34 (100) p_1=0.045	0.003
Calcium, more than 2.6 mmol/L, n (%)				
Before KT	2 (2.4)	1 (2.5)	0	0.655
3 months after KT	0	0	0	-
12 months after KT	0 p_1=0.133	4 (9.8) p_1=0.067	0 -	0.003
Calcium, lower than 2.1 mmol/L, n (%)				
Before KT	1 (1.3)	1 (2.4)	3 (8.8)	0,1
3 months after KT	0	0	0	-
12 months after KT	0 p_1=0.366	0 p_1=0.365	0 p_1=0.045	-
Increased activity of alkaline phosphatase, n (%)				
Before KT	3 (3.7)	1 (2.4)	2 (5.9)	0.736
3 months after KT	0	0	0	-
12 months after KT	0 p_1=0.05	0 p_1=0.365	0 p_1=0.130	-

Notes: PTG, parathyroid glands; KT, kidney transplantation; CKD, chronic kidney disease; ALP, alkaline phosphatase; blood calcium (total)$_{corr}$, corrected for blood albumin; p_1, statistical significance of differences between parameters in a group; p_2, statistical significance of differences in patient parameters between groups 1, 2, and 3.

An initial and one-year graft function is presented in Table 3.

Table 3. Renal graft function in the first year after surgery

Parameter	Kidney transplant recipients			p_2
	1st group (n=82)	2nd group (n=41)	3rd group (n=34)	
Renal graft function, n (%) - Immediate - Delayed	 49 (59.8) 33 (40.2)	 21 (51.2) 20 (48.8)	 18 (52.9) 16 (47.1)	 0.613
ATN time-length, days, Me (Q_1; Q_3)	7 (3;10)	6 (4;7)	4 (3;7)	0.768
Recording of minimum serum creatinine after surgery, day, Me (Q_1;Q_3)	6 (3;11)	7 (3;11)	6 (5;13)	0.510
Blood creatinine, μmol/L, Me (Q_1;Q_3) - After 3 months - After 12 months.	 110 (90;136) 120 (90;139) p_1=0.201	 110 (80;120) 113 (99;140) p_1=0.104	 110 (80;137) 116 (110;140) p_1=0.156	 0.473 0.977
eGFR, mL/min, Me (Q_1;Q_3) - After 3 months - After 12 months	 58 (47;76) 58 (35;72) p_1=0.206	 61 (49;79) 58 (47;70) p_1=0.142	 64 (54;77) 51 (46;71) p_1=0.165	 0.525 0.925
eGFR lower than 60 ml/min, n (%) - After 3 months - After 12 months	 44 (53.7) 46 (56.1) p_1=0.875	 21 (51.2) 25 (61) p_1=0.504	 18 (52.9) 22 (64.7) p_1=0.460	 0.968 0.668

Notes: ATN, acute tubular necrosis; eGFR, estimated glomerular filtration rate; p_1, statistical significances of differences between parameters in a group; p_2, statistical significance of differences in patient parameters between groups 1, 2 and 3

Statistical analysis showed that the renal graft function parameters in the early postoperative period and during the first year were similar in patients of all groups. Three months after surgery, there were no significant differences in blood PTH levels between the recipients with an immediate renal function versus delayed one; intergroup differences in blood PTH levels were statistically significant between the patients who experienced the graft ATN and who did not (Figure).

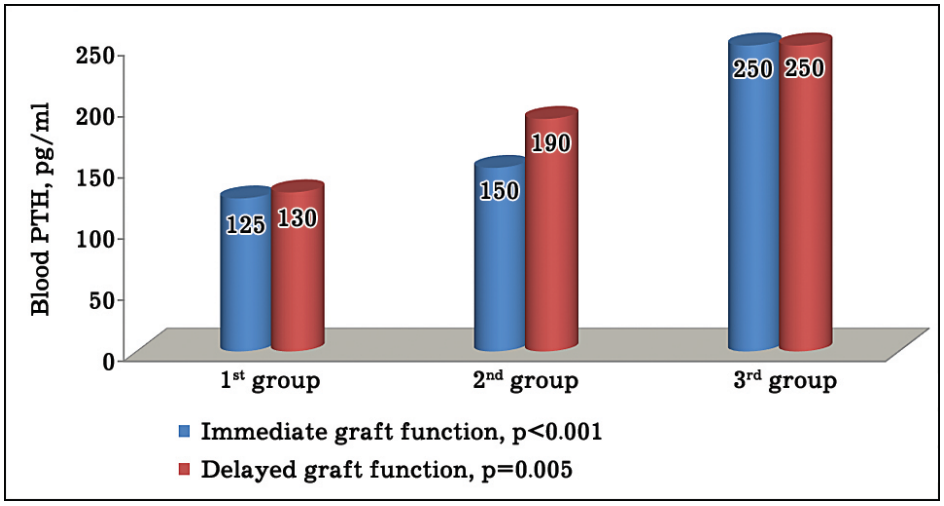

Figure. Blood levels of parathyroid hormone in kidney transplant recipients 3 months after surgery

The relative risk of achieving the target blood PTH level three months after surgery was found to be statistically significantly reduced in patients with preoperative serum PTH levels of 301–450 pg/mL and 451–600 pg/mL compared to that in the patients with preoperative blood PTH levels in the range of 150–300 pg/mL. One year after KT, all patients with pretransplant blood PTH in the range of 150–600 pg/mL had the same relative risk of normal PTG function recovery (Table 4).

Table 4. The effect of preoperative blood parathyroid hormone on the normalization of parathyroid glands function after kidney transplantation

Post-KT period	Target PTH level after KT, n (%)			Relative risk [95% CI]	p
	1st group (n=82)	2nd group (n=41)	3rd group (n=34)		
In 3 months	48 (58.5)	14 (34.1)	7 (20.6)	2-1 0.58 [0.36-0.89] 3-1 0.35 [0.17-0.65]	0.0132 0.0002
In a year	64 (78)	29 (70.7)	21 (61.8)	2-1 0.91 [0.70-1.11] 3-1 0.79 [0.57-1.76]	0.3819 0.1054

Notes: PTH, parathyroid hormone; PTG, parathyroid glands; KT, kidney transplantation; CI, confidence interval

2-1, relative risk in patients of the 2nd group in relation to the patients of the 1st group;

3-1, relative risk in patients of the 3rd group in relation to the patients of the 1st group

The correlation analysis revealed the following. The blood serum PTH level in KT candidates was in a direct close relationship with serum PTH concentration at 3 months after surgery ($r=0.532$, $p<0.001$) and in a less close relationship at 12 months ($r=0.245$, $p=0.002$). At 3 months after KT; there was no relationship between serum PTH concentration and the renal graft function (for creatinine: $r=0.160$, $p=0.046$; for eGFR: $r=-0.105$, $p=0.19$), and after 12 months the relationship was quite close (for creatinine: $r=0.447$, $p<0.001$, for eGFR: $r=-0.264$, $p<0.001$).

Discussion

The results of the conducted study have convincingly demonstrated and confirmed the previously published data: after successful KT, the PTG hormonal activity undergoes significant changes, and the dynamics of blood PTH level of recipients has its own temporal characteristics. In the first months, a rapid, significant and uneven decrease in the blood level of PTH is observed, which is due to the cessation of the effect of the factors stimulating the PTG function and a decrease in its functional mass [2, 19, 20]. As shown by the present study, the intensity of the blood PTH decrease and its steady-state level turned out to be directly associated with the preoperative PTG activity. Thus, three months after KT, the blood level of PTH decreased by maximum of 3.2-3.7 times in patients with preoperative blood PTH in the lower third of the target range; and by 7.4-8.5 times in the patients with preoperative blood PTH in the upper third of the target range; meanwhile, the latter had a higher serum PTH concentration, and the number of recipients with the target postoperative blood PTH level was lower. While the presence of a close relationship between the PTG function before and in the early stages after KT was statistically proven, the relationship between blood PTH and the renal graft function in the same periods was inconclusive. A similar pattern was

established in a previous study for patients with CKD and preoperative HPT [4]. It is important for clinicians to remember that persistently elevated blood PTH levels in the early stages after KT predict HPT in the long term [21, 22].

The mineral metabolism parameters associated with the thyroid gland function, namely the blood levels of phosphorus and calcium, had a regular pattern dynamics after successful KT. The increase in the proportion of recipients with hypophosphatemia in the second and third groups is explained by their higher serum level of PTH, which has a phosphaturic effect.

In the later stages after KT, the process of PTG involution slows down due to the long lifespan of parathyroid cells. With a satisfactory renal graft function, blood PTH stabilizes by the end of the first year or somewhat later [2, 23, 24]. The data obtained in the present study are completely consistent with what has been said: the PTG function leveled out in all recipients one year after KT. It became less dependent on the preoperative serum PTH level and more dependent on the function of the renal graft. This means that recipients with a satisfactory functioning renal graft have a relative risk of achieving normal PTG function if they maintained a stable serum PTH concentration within the target range before surgery as recommended by KDIGO.

The evolution of the PTG function after KT is presented in a number of world studies. Their authors unanimously admit that preoperative blood PTH has a major impact on the PTG functional state after KT [5, 17, 23]. Some studies claim that the blood PTH level of more than 300 pg/mL before KT is closely associated with the development of HPT after KT [24-26]. Our data did not confirm this conclusion, although a clear trend was recorded towards an increase in the number of patients with elevated serum PTH levels by the end of the first year, who had had

blood PTH of more than 300 pg/mL before the operation. The inconsistency of the authors' opinions is highly likely be explained by the inclusion of a heterogeneous group of patients in the study, the use of different target PTH levels after KT and making tests at different times after surgery. Currently, there is no clear understanding of which post-transplant serum PTH level is the graft function adaptive response aimed at maintaining an equilibrium bone metabolism, and which indicates the development of HPT.

The study demonstrates the appropriateness of performing a thorough analysis of PTG function and achieving a stable target blood PTH level in KT candidates in actual clinical practice, as well as the dynamic monitoring of PTG function after KT. Further studies are warranted to determine the optimal serum PTH level for both KT candidates and kidney transplant recipients.

Conclusion

The functional state of the parathyroid glands in patients with chronic kidney disease before and after kidney transplantation is closely interrelated. In the early stages after successful kidney transplantation, the blood level of parathyroid hormone directly depends on its preoperative level and is almost independent of the renal graft function. In the later stages after surgery, this dependence weakens; the renal graft function becomes a decisive factor for the synthesis and secretion of parathyroid hormone. Patients with a preoperative blood level of parathyroid hormone of 150–600 pg/mL have equal chances of restoring normal function of the parathyroid glands with a satisfactorily functioning renal graft.

Based on the study results we have made the following conclusions:

1.Three months after successful kidney transplantation, in patients with preoperative target parathyroid hormone levels (150–600 pg/ml), the parathyroid gland function restores to normal with uneven patient distribution: in 58.5%, 34.1%, and 20.6% of patients ($p<0.001$) with serum blood levels PTH in the ranges of 150–300 pg/mL, 301–450 pg/mL, and 451–600 pg/mL, respectively.

2.By the end of the first year following successful kidney transplantation, patients with the target blood levels of parathyroid hormone between 150–600 pg/mL before surgery had equal chances of normal parathyroid gland function.

3.The post-transplant blood level of parathyroid hormone in the early stage after surgery is closely related to its pre-operative serum level, and to the renal graft function in a later period ($p<0.001$).

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