Exercise capacity and body composition in living-donor renal transplant recipients over time

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Abstract

Background. Renal transplantation (RTx) restitutes the function of the failing organ and induces convalescence of the entire organism. Our study investigates whether this is accompanied by improvements in cardiovascular function and structural changes.

Methods. A total of 25 Caucasian patients (14 male, median age 44.2 ± 9.2 years, BMI 23.7 ± 4.0 kg/m²) were assessed in a prospective trial before, 1, 3 and 12 months after RTx from living donors by clinical examination, cardiopulmonary exercise testing, dual X-ray absorptiometry (DEXA) and analysis of plasma indices.

Results. Creatinine clearance improved from 8.0 ± 3.1 to 60.9 ± 18.1 mL/min at 1 month, but declined at 3 months (51.6 ± 16.3 mL/min) and 12 months (53.6 ± 20.8 mL/min, \( P = 0.04 \) versus month 1). Body composition shifted from lean towards fat tissue (25.8 ± 12.5–31.2 ± 11.2% body fat content, \( P = 0.0001 \)). Only baseline lean weight correlated with fat increase over time (\( r^2 = 0.28, P = 0.008 \)). Patients with fat content above median (\( n = 13 \)) had a 3-fold increased hazard ratio of infection (CI 1.04–9.41, \( P = 0.042 \)) and overall hospitalization (hazard ratio 2.95, CI 1.10–7.93, \( P = 0.03 \)). PeakVO₂ decreased over RTx (23.2 ± 6.0–17.6 ± 5.1 mL/min) and returned to baseline levels not until 1 year later (\( P < 0.001 \)). After an initial decline, muscle oxidative capacity (peakVO₂/lean mass) improved from 33.6 ± 10.1 to 35.0 ± 8.2 mL/kg/min at 12 months after RTx (\( P < 0.001 \)).

Conclusions. After RTx, body composition shifted continuously towards fat tissue, and baseline lean weight significantly correlated with fat increase over time. Both severe infections and hospitalizations are associated with a higher fat content before RTx. Exercise capacity (peakVO₂) worsened after RTx and restitutes during follow-up, with muscle quality (peakVO₂/lean) even exceeding baseline levels after 12 months.

Keywords: body composition; exercise; kidney transplantation; metabolism; peakVO₂

Introduction

Among all cardiovascular risk factors, renal failure is associated with the highest mortality [1–3]. Renal failure causes a variety of metabolic changes that may damage the cardiovascular system: retention of electrolytes and water, increase in renin and decrease in erythropoietin, kinines and nitric oxide, followed by the release of cytokines and other inflammatory stimuli. Chronic inflammatory activation then induces tissue wasting and leads to a loss in body...
Renal transplantation (RTx) constitutes not only the function of the failing organ but may induce convalescence of the entire organism [8]. Nevertheless, allogenic transplantation requires immunosuppression and will be complicated by a number of new concomitant hazards. Due to this complex interaction between regained organ function and immunosuppression, single surrogate parameters were not able to identify RTx candidates at risk for cardiovascular events after transplantation [9–11]. Therefore, the evaluation of more global parameters is necessary, and these parameters should characterize cardiovascular capacity [12,16,17] and overall metabolic balance (body composition, [13–15]). Data on exercise parameters in RTx patients are rare [12], changes of body composition in the first months after RTx have not been evaluated and the relation between recovered but unulating kidney function and the respective parameters is not yet defined.

Thus, our study prospectively investigated primarily the course of body composition (body lean mass $m_{\text{Lean}}$, proportion of body fat) and of cardiovascular functional capacity [e.g. maximum oxygen uptake, peak$V\text{O}_2$; ventilatory efficiency, VE/VCO$_2$-slope (slope of the relationship between ventilation and carbon dioxide output)] before and sequentially after RTx from living donors (RTx-LD). Second, we hypothesized an influence of body composition or exercise capacity on clinical outcome, defined as hospital admission due to infection or rejection within the first 12 months.

Methods

Study population

A total of 25 patients [14 male, mean age of 44.2 ± 9.2 years (range 26.4–61.3), body mass index (BMI) 23.7 ± 4.0 kg/m$^2$] were prospectively included in the RTx-LD programme at the out-patient Kidney Transplantation Centre of the Charité University Medicine, Berlin, between December 2004 and September 2006. We investigated patients after RTx from living donors (i.e. first degree relatives, spouses) due to scheduled transplantations. Thus, there was no relevant delay between baseline investigation and operation day. Time interval between first dialysis and baseline visit (pre-RTx-visit) was 20–26 h. All patients underwent subsequent organ transplantation with primary graft function, and no patient was lost to follow-up. The mean time from first diagnosis of renal failure to Tx was 9.0 ± 6.6 years and the mean time from first dialysis to Tx was 3.0 ± 5.4 years. Respective aetiologies of renal failure were glomerulonephritis ($n = 5, 20\%$), IgA-nephropathy and polycystic kidney degeneration (both $n = 4, 16\%$), diabetic nephropathy, medication-induced nephropathy and congenital hypoplasia (both $n = 2, 8\%$), M. Fabry, Wegener’s Granulomatosis, Alport’s syndrome and post-pyelonephritic single kidney (all $n = 1$, overall $n = 4, 16\%$). In two patients, the diagnosis remained unknown (8%). The following concomitant diseases were found: arterial hypertension ($n = 24, 96\%$), coronary heart disease ($n = 4, 16\%$), diabetes mellitus type II ($n = 5, 20\%$) and diabetes mellitus type I ($n = 1, 4\%$). Medication at the time of Tx included ACE-inhibitors, AT$_1$-receptor antagonists or both ($n = 13, 52\%$), beta-blockers ($n = 12, 46\%$), diuretics ($n = 11, 44\%$), calcium antagonists ($n = 8, 32\%$), statins ($n = 6, 24\%$), allopurinol ($n = 5, 20\%$) and other antihypertensive drugs such as central alpha-blockers, peripheral alpha-blockers, clonidine and L-Dopa. Data before and after transplantation were obtained during regular outpatient visits. At the time of post-transplant exercise testing, no patient had a recent graft rejection or severe infection. Mild upper airway infection was present at 1 and 3 months in one patient. An infection was regarded as severe if hospitalization was required or in cases of intravenous ganciclovir administration.

Medication and clinical course after transplantation

Immunosuppression was induced using basiliximab 20 mg i.v. at Days 0 and 3 after RTx, and all patients received continuous oral immunosuppression with tacrolimus, mycophenolate mofetil (MMF) and prednisolone. Target plasma levels of tacrolimus were 10–15 ng/mL during the first month and 8–12 ng/mL during follow-up. MMF was monitored by leukocyte count and T-cell-differentiation. Prednisolone treatment followed a decreasing dosing scheme beginning at 10 mg/kg/day body weight in the first week and descending to 0.1 mg/kg/day at 3 months, but not lower than 4 mg/day absolutely. No patient was permanently withdrawn from this combination therapy during the study interval. Anti-infective prophylaxis was established in the first month consisting of acyclovir 400 mg bid, cotrimoxazole 960 mg every 2nd day and 5 mL/day solution of amphotericin B. All patients received prophylaxis for secondary osteoporosis (calcium 1–3 g/day, cholecalciferol 1000 IU/day). Antihypertensive medications were reduced after RTx but still included ACE-inhibitors or AT$_1$-receptor antagonists (52% of patients), beta blockers (46%), calcium channel blockers (24%) and/or diuretics (20%). After transplantation, the patients had 0–3 (median: 0.9) rejection episodes leading to 21 hospitalizations. Infections required treatment in 27 episodes (mean 1.1/patient) and affected the urogenital tract ($n = 13$), lower airways ($n = 5$), gut (Clostridium difficile diarrhea, $n = 1$), blood and kidney (cytomegalovirus infections, $n = 5$) and skin (severe Herpes simplex infection, $n = 1$). A total of 13 hospitalizations occurred due to infections and 8 further hospitalizations were caused by sequential operations (lymphocele, urter revision, bleeding, AV nodal re-entry tachycardia).

Exercise testing

A symptom-limited cardiopulmonary exercise test was performed on a treadmill according to the modified Naughton protocol. Expired gas was sampled through a Rudolph mask, conveyed to a spirometer and to oxygen and carbon dioxide detectors (MedGraphics, MN, USA). $V\text{O}_2$ and $V\text{CO}_2$, end-tidal expiratory gas concentrations $p_{\text{ET}}\text{O}_2$ (end-tidal partial pressure of oxygen) and $p_{\text{ET}}\text{CO}_2$ (end-tidal partial pressure of carbon dioxide) and ventilation per minute $VE$ were measured breath-by-breath, and the average of 5 of $7$ breaths was calculated automatically. All patients were monitored with a continuous 12-lead electrocardiogram (CardioPerfect, Welch Allyn, NY, USA) and non-invasive blood pressure measurement at rest, at every stage of exercise and during recovery. Data at rest and forced expiratory volume in the first second (FEV1) were determined after 3 min of quiet standing and breathing into the mask. Exercise time was recorded and symptoms at peak exercise were documented. All patients exercised until limited by symptoms. For peak$V\text{O}_2$, peak$V\text{CO}_2$ and peakVE (peak ventilation volume per minute), the highest readings of each parameter in the final 30 s of exercise were used. Respiratory exchange ratio (RER), a marker of exhaustion, was calculated from peak$V\text{CO}_2$ and peak$V\text{O}_2$. Ventilatory efficiency during exercise was measured by plotting VE against $V\text{CO}_2$; values due to hyperventilation (acidosis) in the last minutes of exercise were excluded and the slope of the revealed linear relationship ($VE$/VCO$_2$-slope) was calculated by linear regression and accepted if correlation coefficient was $r > 0.95$.

Dual energy X-ray absorptiometry (DEXA)

At this time, the most exact method to determine body fat and lean body mass is DEXA, a method that has been validated in patients with renal failure before and after transplantation [14,18]. The patients were scanned in a supine position after removal of all X-ray-dense material (coins, belt buckles, etc.), and neck and head were excluded from automatic analysis by defining regions of interests. We used a LunarProdigy densitometer (GE Healthcare, Chalfont St Giles, UK) with a radiation dose per patient and visit of 5 $\mu$Sv (cumulatively 20 $\mu$Sv after 4th visit) and the official approval as stated below.
Peripheral venous blood samples were taken at the beginning of the outpatients’ visit after 30 min resting without eating or drinking before and analysed immediately.

Statistical analysis

All data are given as mean ± standard deviation for parametric variables (i.e. fat, lean mass, peakVO$_2$ lean at singular time points). Parameters before RTx are labelled as ‘baseline’. Repeated measurements ANOVA for parametric and the Wilcoxon signed-rank test for non-parametric variables were used to identify changes over time of quantitative values (exercise-, DEXA, laboratory parameters), and differences between visits and gender were calculated using Student’s paired t-test and Student’s unpaired t-test, respectively. Mann–Whitney testing was used to compare qualitative parameters (symptoms at exercise, medication) during follow-up. Correlations between different quantitative parameters (e.g. age versus peakVO$_2$ or BMI versus weight change) were assessed by linear regression. Multiple regression analyses required a preceding condensation of data: because peakVO$_2$, VE/VCO$_2$-slope and other parameters showed an early postoperative worsening and a recovery in further follow-up resulting in U- or J-like shaped curves, differences to baseline were summarized: $(\Delta \text{baseline }- \Delta \text{t 1 month }+ \Delta \text{baseline }- \Delta \text{t 3 months }) + (\Delta \text{baseline }- \Delta \text{t 12 months })$ = sum of differences (so $\Delta$). so $\Delta$ was also used in multivariate stepwise analyses. The calculation of risk factors for rejection, infection or hospitalization after RTx was performed using Cox proportional hazard analysis. A Kaplan–Meyer analysis was performed with high/low fat as a grouping variable and time to these three events as sensing time. P < 0.05 was considered significant. All analyses were performed using StatView 5.0 (SAS Institute Inc., NC, USA). The study was approved by the local ethics committee (Ethikkommission Charité, Nr. 160/2003) and by the German Federal Office for Radiation Protection (BfS, Nr. ZS-22462/2-2004-010). Informed written consent was obtained from all patients.

Results

Blood pressure, heart rate and BMI

Systolic blood pressure at rest before RTx was 130.1 ± 17.4 mmHg, decreased after RTx significantly to 106.7 ± 17.2 mmHg and re-increased continuously in follow-up to 109.8 ± 10.9 mmHg. Blood pressure at the end of exercise followed the same scheme with systolic values of 166.8 ± 27.4 mmHg before and 139.8 ± 27.3 resp. 151.7 ± 22.7 mmHg in follow-up (all $P < 10^{-4}$ versus baseline). The variety of changes in dosage and combination made it impossible to calculate a relation between medication and changes in blood pressure. Heart rate at rest (80.6 ± 18.1 before RTx to 75.0 ± 10.7/min at 12 months) and exercise (137.4 ± 32.81 to 134.2 ± 27.1/min) did not change significantly. Patients lost weight from 71.7 ± 18.3 kg before RTx to 69.5 ± 17.5 kg at 1 month ($P = 0.02$) and increased weight reaching baseline values at 3 months (70.7 ± 17.6 kg), and at 12 months (72.2 ± 18.8 kg, both $P > 0.2$ versus baseline).

Kidney function

Creatinine clearance (by Modification of Diet in Renal Disease (MDRD) formula [19,20]) was calculated to consider both patients on dialysis with residual urinary production and patients immediately before first dialyses (pre-emptively transplanted patients, $n = 6$). The very low clearance before RTx (7.98 ± 3.1 mL/min, range 3.8–15.3 mL/min) improved as expected to 60.9 ± 18.1 mL/min at 1 month after transplantation ($P < 10^{-4}$) but declined significantly at 3 (51.6 ± 16.3 mL/min, $P = 0.005$ versus 1 month) and 12 months (53.6 ± 20.8 mL/min, $P = 0.04$ versus 1 month). This rapid-increase/slow-decrease kinetics neither correlated with parameters of exercise (peakVO$_2$), body composition (fat%, lean mass%) nor was it associated with clinical events (infection, hospitalization). Exclusion of pre-emptively transplanted patients did not change these calculations, even though the pre-emptive subgroup had a higher clearance than chronic dialysis patients (10.3 ± 4.1 versus 7.3 ± 9.1 mL/min; $P = 0.03$).

Body composition

Total fat. The changes of total weight were mentioned above. Similarly, the BMI showed slight but significant changes over time (ANOVA repeated measures $P < 0.01$), from 23.7 ± 4.2 kg/m$^2$ before to 22.9 ± 4.3 at 1 month (lowest value) and to 24.0 ± 4.5 kg/m$^2$ at 1 year. Interestingly, the body composition expressed as fat % and lean weight in % of total body weight changed without initial descent and continuously during the entire study. Thus, the proportion of fat increased from 26.6 (IQR 23.9) to 31.2 ± 11.2% and the proportion of lean mass decreased from 69.1 (IQR 22.6) to 66.3 ± 10.7% (both $P < 10^{-4}$; Figures 1 and 2). In order to investigate which patients

**Fig. 1.** Fat content in % of body weight at baseline and in follow-up. **+**$P < 0.01$ versus baseline. Boxes: 75th percentile and mean, lines: 90th percentile.

**Fig. 2.** Lean mass in % of body weight at baseline and in follow-up. **+**$P < 0.01$ versus baseline. Boxes: 75th percentile and mean, lines: 90th percentile.
gained the most fat, a multiple regression analysis containing BMI, age, lean weight at baseline and time since renal failure was performed. Only lean weight at baseline correlated with the fat increase over time, as well as in absolute values (fat in kg, expressed as soΔfat = −12.4 + 0.28lean mass; r² = 0.17, P = 0.04) as in relative values (soΔfat = −28.4 + 0.55masslean; r² = 0.28, P = 0.008, Figure 3). This indicates that the leanest patients gained the most fat tissue after RTx. Neither fat nor lean mass content was dependent on age (age versus lean mass r² = 0.014, and age versus fat mass r² = 0.04; both P > 0.5), and there was no difference in the fat or lean mass proportion between both sexes at any time (all P > 0.3).

Fat distribution. The different distribution of body fat in men and women was mirrored by the ratio between body and leg fat, that amounted to 0.52 ± 0.28 in men and 0.98 ± 0.21 in women (P < 0.001). Female patients did not change their distribution of fat in the follow-up (P = 0.8). Male patients significantly stored fat in their legs if they were slim at baseline and increased their trunk fat if they were overweight at baseline (r² = 0.46; P < 0.008). This inverse relation between body fat (in %) at baseline and the ratio body/leg fat (soΔ) is shown in Figure 4.

There was no correlation between fat content and cumulative steroid doses (P > 0.7).

**Exercise parameters**

There was a significant decrease in peakVO₂ from 23.2 ± 6.0 mL/min/kg to 17.6 ± 5.1 mL/min/kg at 1 month after Tx, and values reached baseline level not until one year later (23.6 ± 6.5 mL/min/kg; ANOVA P < 0.001; Figure 5). As shown above, the proportion of lean tissue decreased continuously after RTx, and because nearly the entire oxygen consumption at exercise depends on lean tissue, a decrease in peakVO₂/lean mass over time parallel to the lean body mass was assumed. However, peakVO₂/lean mass decreased from 31.9 (IQR 11.8) mL/min/kg before RTx to a minimum of 26.1 (12.2) mL/min/kg at 1 month and even exceeded baseline values at 12 months [34.4 (12.5) mL/min/kg; P < 0.001, Figure 6].

The worsening in ventilatory efficiency (VE/VCO₂-slope) was less pronounced. The patients recovered at 3 months after Tx (31.4 ± 6.7 at baseline versus 31.6 ± 5.6) and had an improved VE/VCO₂-slope at 12 months (28.7 ± 3.3; ANOVA P = 0.03). The wide individual variation in oxygen uptake is comparable to the normal population and was mainly dependent on age, and the correlation between peakVO₂ and age was proved at every follow-up [e.g. at 12 months: peakVO₂ = 74.5–13.6*ln(age); P < 0.006]. The respiratory ratio (RER = VCO₂/VO₂) at maximum exercise may serve as a measure of exhaustion and remained unchanged over time (1.14 ± 0.11–1.13 ± 0.10; P > 0.8). A total of 60% of patients complained of muscular exhaustion or muscular pain as the symptom that limited
exercise before RTx, and these symptoms of fatigue remained present (60–72%) at follow-up despite increased muscle quality (peakVO\textsubscript{2}/lean mass).

Beyond heart, lung and muscle function, peakVO\textsubscript{2} normally depends on the haemoglobin concentration. In our study population, a weak correlation between peakVO\textsubscript{2} and Hb was found before RTx (peakVO\textsubscript{2} \(= 1.3^*\)Hb + 7.5; \(r^2 = 0.16\); \(P = 0.048\)), but could not be confirmed during follow-up (\(r^2 < 0.1\), \(P > 0.4\)). No correlation between laboratory parameters (creatinine, urea, uric acid, albumin, cholesterol, C-reactive protein) and exercise parameters after RTx was found. Moreover, lung capacities [forced ventilatory capacity (FVC), FEV\textsubscript{1}] and the FEV\textsubscript{1}/FVC-ratio were within the normal limits and remained unchanged over time.

Metabolism

Because of the potential induction of diabetes by the immunosuppression, all patients were monitored for fasting plasma glucose and HbA\textsubscript{1c}. There was neither a significant change in plasma glucose (102 ± 29 mg/dL before, 99 ± 27 at 1, 97 ± 13 at 3, 93 ± 21 at 12 months) nor in HbA\textsubscript{1c} (5.6 ± 0.3 at baseline to 5.3 ± 0.7% at 12 months). Similarly, the serum cholesterol (188 ± 38–181 ± 56 mg/dL) remained unchanged. Only serum albumin followed the drop-and-recovery scheme with 4.3 ± 0.3 mg/dL before, 3.8 ± 0.3 at 1 month (\(P < 0.001\)), 4.0 ± 0.3 at 3 and again 4.2 ± 0.2 mg/dL at 12 months (both \(P > 0.05\) versus baseline). There was no intravenous albumin supplemented.

Baseline parameters and clinical outcome

The main criteria of the clinical course after RTx were rejection, infection and hospitalization. The only baseline parameter that increased the risk for both severe infection and hospitalization was body fat before RTx. The patients with a fat content above median (>25.4% fat, \(n = 13\)) had a more than 3-fold risk of severe infection [hazard ratio 3.17, confidence interval (CI) 1.05–9.56, \(P = 0.04\)] and overall hospitalization (hazard ratio 2.95, CI 1.10–7.93, \(P = 0.03\)). Time to first re-hospitalization or severe infection was significantly shorter, as shown in Kaplan–Meyer plots (Figure 7a and b). Because immunosuppression (steroids and tacrolimus) could induce diabetes and thus affect infection rate, we analysed HbA\textsubscript{1c} and plasma glucose at every follow-up. Differentiating between the high- and low-fat group, there were neither differences in HbA\textsubscript{1c} nor in fasting plasma glucose (\(P = 0.28\) to 0.89, Figure 8a and b). Furthermore, the risk of rejection was not associated with any of the baseline indices. Demographic data including history of diabetes, hypertension or coronary heart disease did not influence rate or severity of post-RTx infection or hospitalization (all \(P > 0.1\), Cox proportional hazard).

The hypothesized influence of dialysis on clinical follow-up could not be confirmed. Neither time since diagnosis of renal failure, time since first dialysis nor quality of dialysis (creatinine clearance) was associated with an increased risk of infection, rejection or hospitalization (all \(P > 0.1\)). Similarly, neither time since onset of renal failure (\(P = 0.45\)) nor time since first dialysis (\(P = 0.27\)) correlated with ex-
Exercise parameters at baseline or at the end of the follow-up. Vice versa, peakVO₂ before RTx did not correspond to the clinical course after RTx.

Discussion

RTx restitutes renal function. However, our study demonstrates that the postoperative convalescence of the entire organism lasts for about 6–12 months with a wide variation of respective parameters. To our knowledge, this is the first prospective study with a closely meshed follow-up of clinical events, fat metabolism and exercise parameters both before and after RTx. Moreover, body composition in chronic renal failure has been discussed controversially under a phenomenon termed 'reverse epidemiology' [21], and our study adds three new findings to this field. First, fat tissue (in percent) increases continuously and not only in the first months when steroid dosages are the highest [14,15]. Second, only lean weight at baseline correlates with fat increase over time, and third, slim men stored more fat in the legs than in the body trunk. We have demonstrated earlier that transplantation of the failing organ might cure cachexia after heart [22] or lung transplantation [23], and only the shorter follow-up and the smaller proportion of cachectic patients in the present study may have prevented a comparable increase in BMI here. Nevertheless, gender differences and the gain in trunk fat of obese men require a more discriminative analysis of plasma hormone levels (e.g. testosterone, estrogens, cortisol) in the future.

The role of fat tissue in recovery is emphasized by the fact that both severe infections and hospitalization are associated with higher fat content before RTx, and fat was the only baseline parameter with this association. Chang et al. [24] showed a similar association between higher BMI and infection, but the exact measurement of fat in our study allowed a calculation with far fewer patients. It would be of interest to evaluate changes in body weight and fat already before transplantation, but these data were not available. Thus, we used the body fat content at baseline as a surrogate parameter for a possible catabolic state.

An improvement in peakVO₂ after RTx has been shown in previous studies [12,25]. Our study broadens these findings in that we demonstrate a statistically and clinically relevant drop in peakVO₂ early after RTx. Moreover, this decrease in exercise capicity was not counterbalanced until 1 year after RTx, and our positively selected population with relatively few comorbidities and transplantation at most favourable conditions might recover even better than patients receiving kidneys from post-mortem donors. This decrease-and-recovery scheme in peakVO₂ is not only a postoperative adaptation process, but also a function of muscle quality: Oxygen consumption at exercise depends on lean tissue and the latter decreases continuously after RTx. The relevant proportion of lean tissue under exercise conditions is the muscle, and oxygen uptake per kg lean mass can serve as a means for muscle quality. Because at the end of our follow-up peakVO₂ was equal or higher than at baseline, and lean tissue respectively muscle mass was lost, the quality of the remaining muscle must have improved. The histological basis of these changes remains speculative. A shift in myosin heavy chain isoform composition was excluded [14], whereas Topp et al. [26] found an increase in type II muscle fibres, and Matsumoto et al. [27] assumed better mitochondrial oxygen consumption. The reported correlation between time of renal failure and exercise capacity [10] could not be confirmed. This might be due to the limited number of study patients.

The cumulative steroid intake over 12 months was dependent on the number of rejections. Nevertheless, no correlation between fat content at 12 months and cumulative steroid dose, number of rejections, infections or hospitalizations was found (all \( P > 0.7 \)), which is in line with previous studies [14,15,28]. Exercise parameters or laboratory findings at 12 months were not correlated with the cumulative steroid dose (all \( P > 0.25 \)). Notably, plasma glucose and HbA1c remained unchanged throughout the entire follow-up. Counterbalancing due to increased dosages of oral antidiabetic drugs or insulin must be assumed, but finally, the diabetogenic adverse effects of immunosuppression were covered. Precisely this glucose control might have prevented the expected dysfunction of neutrophiles and monocytes as a secondary effect of immunosuppression.

Summary

RTx not only restitutes the function of the failing organ but induces convalescence of the entire organism. This concerns the body composition with a continuous increase in fat tissue in all patients and a positive correlation of lean weight at baseline with fat increase over time, but is contradicted by a decrease in exercise capacity (peakVO₂) that did not recover to baseline level until 1 year after Tx. These changes do not correlate with restored kidney function, which was optimal at 1 month after RTx and declined during follow-up. Where clinical outcome is concerned, both severe infections and hospitalization are associated with higher fat content before RTx, and fat was the only baseline parameter showing this association. The complex processes with a coinciding increase in fat tissue and muscle quality and a decline in exercise capacity require further studies on the metabolic and structural changes after RTx.

Conflict of interest statement. None declared.

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