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ORIGINAL PAPER

Changes in ocular biometric parameters after renal transplantation

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Abstract

Purpose This study aimed to investigate the changes in postoperative ocular biometric parameters in end-stage renal disease patients who underwent renal transplantation.

Material and methods This retrospective study included a total of 33 eyes of 33 patients. The ocular biometric measurements which were evaluated were axial length (AL), central corneal thickness (CCT), anterior chamber depth (ACD), corneal keratometry (K1 and K2), degree of astigmatism, lens thickness (LT), and intraocular pressure (IOP). Refractive prediction error (RE) was calculated before and after renal transplantation using the same diopter (D) for intraocular lens (IOL) power calculation and evaluated for potential cataract surgery.

Results The study included 15 male (45%) and 18 female (55%) patients. Mean patient age was 31.55 ± 8.24 (range: 18–49 years). In the comparison of preoperative and 1-month postoperative measurements, there was a statistically significant difference in AL, LT, ACD, and CCT ($p < 0.001$). There was no statistically significant difference between K1, K2, and astigmatism measurements ($p = 0.72$; $p = 0.35$; $p = 0.62$, respectively). There was no statistically significant difference in RE ($p = 0.61$-Holladay 2).

Conclusion While renal transplantation surgery does not lead to significant changes in astigmatism, predicted refractive error, corneal keratometry, or intraocular pressure, it causes significant decrease in axial length, lens thickness, and central corneal thickness and significant increase in anterior chamber depth. However, these changes do not result in significant changes in IOL power calculation in planned cataract surgery.

Keywords Ocular biometric parameters · Cataract surgery · Central corneal thickness · Axial length · Lens thickness

Introduction

Chronic renal disease is a serious public health issue that affects 8–16% of the adult population [1]. End-stage renal disease (ESRD), or stage 5 kidney failure, is characterized by glomerular filtration rate of less than 15 mL/min [2]. The United States renal data system reported 124,411 new diagnoses of ESRD in 2015. Furthermore, incidence is reported as an average of 20,000 per year [3, 4]. In ESRD, metabolic and endocrine dysfunction leads to various clinical

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symptoms in which fluid, electrolyte, and acid–base balance cannot be maintained [5].

New developments in renal transplantation surgical techniques and postoperative immunosuppression regimens have greatly increased renal allograft survival rates. Renal transplantation is currently the preferred treatment method in ESRD patients [6].

Berindan et al. reported decreased visual acuity, keratoconjunctivitis sicca, pinguecula, arcus lipoides, glaucoma, retinal drusen, decreased RNFL thickness, and hypertensive or atherosclerotic retinopathy in the post-renal transplantation period. They also observed cataracts in 57.1% of patients and established a positive correlation between age and methylprednisolone use [7]. Jayamanne et al. observed retinal veno-occlusion, optic atrophy, proliferative diabetic retinopathy, central retinal artery occlusion, and irreversible decrease in vision in patients during an 8-year follow up period after renal transplantation. Posterior subcapsular opacity was also observed in 30% of patients [8]. According to the literature, changes in LT are due to glucose [9], electrolyte and uremic toxin [10] levels. In ESRD, increased levels metabolic products such as 500–1500-dalton uremic toxins also affect cornea endothelia and lens epithelium function [11]. Renal changes cause changes in acid–base and electrolyte balance [6]. We believe that the renal removal of metabolic molecules such as 500–1500 Da uremic toxins and the kidney's regulatory effect on acid–base balance after renal transplantation may cause change in CCT and LT.

Since there is no study in the literature which examines the changes in biometric parameters after renal transplantation, the effect of renal transplantation on ocular biometric parameters as well as its effect on IOL power calculation in potential cataract surgery is unknown. Our hypothesis was that changes in biometric parameters due to renal transplantation may also lead to changes in IOL power calculation.

This study aimed to determine whether or not changes in renal function parameters would impact ocular biometric measurements and also investigate whether these changes would cause differences in intraocular lens power calculation when planning cataract surgery.

Material and methods

Study population

Within the framework of Helsinki Declaration protocol, this retrospective study included the routine preoperative and one-month postoperative biometric measurements of patients admitted to the Baskent University Medical Faculty, Department of Ophthalmology, who were diagnosed with ESRD (seconder to glomerulonephritis, reflux nephropathy and nephrolithiasis diseases) and underwent renal transplantation. This study received ethical board approval from the Baskent University Scientific Research Projects Advisory Board.

Between November 1975 to October 2019,3059 renal transplant procedures were performed in Baskent University. This retrospective study included 33 eyes of 33 patients who had undergone renal transplant surgery between December 2015 and January 2017. Patients with history of eye operation, diabetes mellitus, graft-kidney rejection, any particular systemic imbalance that would possibly affect the biometric measurements, chronic ocular disease (glaucoma, uveitis, macular edema, AMD, etc.), incomplete ophthalmological examination and high refractive error (Cycloplegic autorefractometer value) over $-3.00/+3.00$ D were excluded from the study. The patients included in the study constituted the dependent group with available preoperative and one-month postoperative biometric measurements. Postoperative treatment regimen was constant administered to all patients (acetylsalicylic acid, trimethoprim sulfamethoxazole, valganciclovir, tacrolimus, prednisolone, mycophenolate). Patients with high-quality biometry taken with IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany) were included in the study.

Procedure and measurements

Ocular biometric parameters (IOLMaster 700, Carl Zeiss Meditec AG, Jena, Germany) were evaluated in patients with available best-corrected visual acuity, noncontact tonometry (Reichert 7-R7), and IOP measurements, biomicroscopic anterior segment examination, and dilated fundus examination results. In all patients who met inclusion criteria, AL, CCT, ACD, corneal keratometry (K1 and K2), keratometry

astigmatism degree, LT, and IOP were evaluated as well as prediction RE for potential cataract surgery using the same diopter (D) for IOL power calculation.

IOLMaster 700 automatically captures swept source optical coherence tomography (ss-OCT) scans and measures AL, in addition to CCT, ACD, and LT. In IOLMaster 700, the operator can cover the entire scan image, and visually check the eye geometry and axis of the measurements. Besides, the foveal scan identifies correct fixation of the participant. SD values of the ACD, LT, and AL measurements are also assessed and the device warns the operator in regards to low-quality results (i.e. SD for ACD $>$ 0.021 mm, for LT $>$ 0.038 mm and for AL $>$ 0.027 mm). IOLMaster 700 does not give a composite scan or a signal-to-noise ratio. Therefore, analysis of each scan was conducted separately and noted as successful if the device was able to provide a value for axial eye length. According to the protocol of the IOLMaster, a scan was only defined as successful if there was no warning. In routine application, IOLMaster 700 is regularly calibrated according to manufacturer recommendations before measurement. All measurements were made by researchers of the same experience in standard dim light according to manufacturer criteria. In order to ensure that measurements were within the visual axis, all measurements were made after stabilizing the device's fixator light. In routine application, five consecutive measurements are made for each eye. The consistencies of these measurements were evaluated among themselves. Only results of proper measurement were included in the study. All IOL power calculations were made with the SRK/T, Holladay 2, Hoffer Q and Haigis Suit formula with a 118.40 constant.

Statistical analysis

The results of an a priori power analysis using power and sample size (PASS; version 11, NCSS, LLC, Utah, USA) calculation software required the enrollment of at least 33 eyes from each group in the study. Accordingly, the power of the study was found to be 86.5%.

Statistical analysis of all data was performed with the SPSS program (Version 22.0, IBM Co., Chicago, IL, USA). There was high correlation between biometric parameter measurements of both eyes. Analysis was made using measurements of only right eyes. The Kolmogorov Smirnov test was used to determine the conformity of the preoperative and postoperative measurements to the parametric measurement criteria (normal distribution). Measurements that met parametric measurement standards were statistically analyzed with paired-sample t test. The value of $p < 0.05$ was considered statistically significant. All values were expressed as mean $\pm$ standard deviation (SD).

Results

A total of 33 eyes of 33 patients who underwent renal transplantation were included in the study, in which 15 patients (45%) were male and 18 (55%) were female. Mean age was 31.55 $\pm$ 8.24 years (range:18–49). The mean duration of dialysis time was 3.6 years.

When preoperative and postoperative biometric parameters were compared, there was a statistically significant difference in AL, LT, ACD, and CCT measurements ($p < 0.001$). The mean and range values of biometrics parameters and IOP measurements taken before renal transplantation and 1one month after renal transplantation are shown in Table 1.There was no statistically significant difference in predicted RE for potential cataract surgery before and after renal transplantation using the same diopter for IOL power calculation. Statistical analysis according to SRK T, Holladay 2, Hoffer Q and Haigis Suite formulations is shown in Table 2.Mean preoperative RE was $-$ 0.19 $\pm$ 0.11 D and mean postoperative RE was $-$ 0.21 $\pm$ 19 D (According to Holladay 2 formula).

Preoperative and one-month post-transplantation expected refractive errors according to Holladay 2, Hoffer Q and Haigis Suite formulations are presented in Table 3. There was no statistically significant difference in preoperative and postoperative K1, K2, IOP, and astigmatism measurements. Statistical results of preoperative and one-month post-transplantation IOP and IOL Master 700 parameters are shown in Table 4.

Discussion

This study investigated the effect of renal transplantation operation on ocular biometric parameters

Table 1 IOL Master 700 biometry and IOP measurements before and one month after renal transplantation

	Measurement	Mean ± SD	Range (min–max)
AL (mm)	Preoperative	23.14 ± 0.98	21.03–24.47
	Postoperative	23.11 ± 0.99	21.03–24.43
LT (mm)	Preoperative	3.85 ± 0.29	3.41–3.51
	Postoperative	3.8 ± 0.29	3.37–4.50
ACD (mm)	Preoperative	3.36 ± 0.31	2.49–3.78
	Postoperative	3.41 ± 0.31	2.54–3.90
K1	Preoperative	42.67 ± 1.22	40.72–45.20
	Postoperative	42.69 ± 1.22	40.77–45.32
K2	Preoperative	43.7 ± 1.47	41.60–46.12
	Postoperative	43.77 ± 1.4	41.35–46.15
ASTIGMATISM	Preoperative	− 1.1 ± 0.75	− 3.35/− 0.13
	Postoperative	− 1.13 ± 0.77	− 3.53/− 0.26
CCT	Preoperative	541.6 ± 40.35	455–613
	Postoperative	536.58 ± 38.77	449–601
IOP	Preoperative	14.71 ± 0.81	12.11–17.14
	Postoperative	15.14 ± 2.16	12.35–18.20

AL axial length, *LT* lens thickness, *ACD* anterior chamber depth, *K1–K2* corneal keratometry, *CCT* central corneal thickness, *IOP* intraocular pressure

Table 2 Statistical analysis of predicted RE before and one month after renal transplantation

	95% CL of difference of mean	Paired sample *t* test *t* value	Paired sample *t* test *p* value
RE (SRK T)	− 0.06/0.11	0.63	0.53
RE (Holladay 2)	− 0.1/0.13	0.69	0.61
RE (Hoffer Q)	− 0.04/0.06	0.51	0.48
RE (Haigis Suite)	− 0.13/0.15	0.47	0.51

RE refractive error

Table 3 Predicted RE before and one month after renal transplantation

	Measurement	Mean	Range (min–max)
RE (SRK T)	Preoperative	0.17 ± 0.12	− 0.50/− 0.01
	Postoperative	− 0.2 ± 0.21	− 1.00/0.11
RE (Holladay 2)	Preoperative	0.19 ± 0.11	− 0.48/− 0.12
	Postoperative	0.21 ± 0.19	− 0.71/0.08
RE (Hoffer Q)	Preoperative	0.16 ± 0.08	− 0.41/− 0.05
	Postoperative	0.18 ± 0.15	− 0.80/0.12
RE (Haigis Suite)	Preoperative	0.15 ± 0.09	− 0.38/− 0.06
	Postoperative	0.17 ± 0.16	− 0.75/0.1

RE refractive error

(IOLMaster 700). Renal transplantation was observed to cause statistically significant changes in AL, LT, ACD, and CCT measurements. However, there was no effect on predicted RE, K1, K2, IOP, or astigmatism measurements.

There was significant thinning of LT in the postoperative period compared to preoperative measurements. It is known that renal failure causes changes in electrolyte balance and accumulation of toxic materials (urea, uric acid, etc.) in the body [12]. LT depends on the osmolarity caused by the

Table 4 Statistical analysis of IOL Master 700 biometry and IOP measurements before and one month after renal transplantation

	95% CL of difference of mean	Paired sample *t* test *t* value	Paired sample *t* test *p* value
AL (mm)	0.017/0.049	4.24	0.001 >
LT (mm)	0.3/0.65	5.53	0.001 >
ACD (mm)	− 0.07/− 0.03	− 6.12	0.001 >
K1	− 0.17/0.12	− 0.36	0.72
K2	− 0.18/0.07	− 0.95	0.35
ASTIGMATISM	− 0.1/0.17	0.5	0.62
CCT	2.43/7.63	3.94	0.001 >
IOP	0.02/0.05	3.99	0.09

AL axial length, *LT* lens thickness, *ACD* anterior chamber depth, *K1–K2* corneal keratometry, *CCT* central corneal thickness, *IOP* intraocular pressure

electrolytes of lens material (e.g., sodium, potassium, uric acid) [13]. In the presence of toxic materials, LT also increases due to increased permeability of the lens capsule membrane [10]. After renal transplantation, acid–base balance, electrolyte values, and lens osmolarity improves as levels of toxic materials such as uric acid return to normal. We believe that the decrease in the amount of toxic substances in the aqueous humor and normalizing of lens capsule permeability attributes to the thinning of the lens thickness after renal transplantation. In another scenario, studies have shown a link between body hydration and LT. In a study by Chen H. et al. [14], decrease in LT was observed after dialysis and attributed to the amount of fluid loss following dialysis. Decreased hydration following renal transplantation is well known [15] and we believe this may cause thinning of LT.

Increased ACD was observed in the postoperative period. Studies in the literature have investigated and reported inverse correlation between LT and ACD [16, 17]. We believe the increase in ACD observed in our study was most likely caused by postoperative decrease in LT.

We observed thinning of CCT in the postoperative period. Oghuro V. et al. showed that uremic toxins caused polymegathism and pleomorphism leading to increased CCT [18]. Another study found a correlation between blood urea levels and corneal thickness, endothelial density, and endothelial variation [19]. We believe the normalization of levels of 500–1500 Da molecules (such as urate, hippurate, nucleic acid metabolism products, polyamines, and phenols), which are toxic to corneal function and cause increased corneal thickness, after renal transplantation cause thinning of CCT [11].

In this study we found that CCT decreased from 541.6 ± 40.35 mm to 536.58 ± 38.77 mm postoperatively. This change was found to be statistically significant. Keratometric values increased postoperatively. K1 increased from 42.67 ± 1.22 D to 42.69 ± 1.22 D and K2 from 43.70 ± 1.47 D to 43.7 ± 1.47 D. However, the change in keratometry was not statistically significant. In a previous study, it was reported that with increasing base curve (flattening) of the cornea, there was an increase in CCT [20]. Our study revealed similar results since we found that with decreased CCT, keratometry tended to be steeper. However, the lack of statistical significance in increased keratometry values may be due to the lower number of patients in our study.

We also noticed decreased AL in the postoperative period. Bernardo et al. found decreased AL after cataract surgery in pseudophakic eyes, whereas there was no significant change in fellow eyes and aphakic eyes. The authors concluded that, changing the AL measurement modality from phakic to pseudophakic during IOLMaster acquisition is not sufficient to correct the AL measurement result [21]. However, in our study, this possibility was out of question, due to lack of intraocular surgical procedure, and the fact that IOLMaster measurements before and after were phakic. This was interpreted as actual decrease in AL, regardless of error in IOLMaster measurements. Rosa et al. evaluated AL of myopic eyes after PRK. While AL significantly decreased one month after PRK, no significant change was observed six months

after PRK [22]. We believe the decrease in AL observed in our study is associated with renal transplantation surgery, since none of the patients underwent any eye-related operations. Studies have also showed thinning of choroidal thickness with history of chronic renal disease. Choroidal thinning has also been found to be associated with low glomerular filtration rate and severe proteinuria [23]. We believe that increased choroidal thickness due to normalized proteinuria and GFR in the postoperative period is followed by a secondary decrease in biometric AL measurement. Besides, postoperative normalization of proteinuria and GFR is expected to be persistent with subsequent stabilization of postoperative SFCT increment. GFR of the patients might also have positive correlation with SFCT measurements. However, as the present study had only 1 month of postoperative follow-up time, future prospective studies with longer follow-up period and searching for this possible correlation would enlighten these hypotheses more in detail.

IOL power was calculated before and after renal transplantation using the same D selection for potentially planned cataract surgery and there was no statistically significant difference in RE. AL is known to be an important parameter in calculating IOL power. Shammas and Hoffer showed that a 0.02 mm difference in AL accounts for up to 0.05 D difference in IOL power calculation [24]. We believe decreased AL, taken into consideration with thinning of CCT in the same patient group, does not cause clinically significant change in IOL power calculation.

In conclusion, renal transplantation surgery leads to significant decrease in axial length, lens thickness, and central corneal thickness, and significant increase in anterior chamber depth. However, these changes do not attribute to significant changes in IOL power calculation in planned cataract surgery.

Study limitations

As the effect of renal transplantation surgery on ocular biometric changes has not been studied before, this study will encourage direction of further studies. However, the retrospective nature of the study, the limited patient number, relatively short follow-up period and the unknown effects of the postoperative drugs on ocular biometric parameters were limitations of the study. There is a need for further prospective studies on this subject with larger patient population.

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Compliance with ethical standards

Conflict of interest The authors declared that there is no Conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional Ethics Review Board of Baskent University and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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