

## Do Changes in Cumulative Dissipated Energy cause Retinal Microcirculation Changes after Cataract Surgery?

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### KEYWORDS

Cumulative Dissipated Energy, OCTA, vascular density full, best corrected visual acuity, cataract surgery.

### ABSTRACT:

**Background:** There are obvious changes in retinal parameters after complicated phacoemulsification surgeries but there is a need to elucidate the relationship between surgical parameters and retinal outcomes after an uncomplicated cataract surgery also. Thus, we decided to study the impact of changes in cumulative dissipated energy (CDE) on retinal parameters after phacoemulsification.

**Methods:** Ninety subjects who underwent uncomplicated phacoemulsification for cataract were followed up as a cohort and assessed at baseline, 2 weeks, 6 weeks and 3 months. We divided CDE into two groups i.e. up to 15 and more than 15, and assessed the retinal parameter changes among these 2 groups. Central retinal thickness (CRT), central retinal thickness average (CRTA), vessel perfusion central (VPC), vessel perfusion full (VPF), central retinal volume (CRV), vessel density central (VDC) and vessel density full (VDF) were the retinal parameters taken using OCT angiography (OCTA). Functional outcome in the form of best corrected visual acuity (BCVA) log MAR was also assessed at all visits.

**Results:** There was a significant difference between the CDE among the 2 groups, i.e. 9.89 vs 20.78 ( $p < 0.001$ ) but despite this the only retinal parameter which showed a significant difference among the 2 study groups was the vascular density full (VDF). The difference in VDF was maintained at all three follow-up assessments i.e. 2 weeks ( $p = 0.026$ ), 6 weeks ( $p = 0.022$ ) and 3 months ( $p = 0.017$ ).

**Conclusions:** In our study, both high-CDE and low-CDE groups did not have a significant impact on retinal microcirculation, except with vessel density full (VDF). There was no deterioration in BCVA at any visit in either group. A long-term follow-up study is needed to study the persistence of these changes and the development of pseudophakic cystoid edema (PCME) in these subjects.

### INTRODUCTION

Cataract surgery is a routine and developmentally informed procedure for many adults surviving up to their late age. The outcome of cataract surgery is uneventful in most cases and especially with newer techniques like phacoemulsification in hands of an experienced surgeon.

Is there any change in retinal microvasculature or functional visual outcomes even after an uncomplicated surgery? This has been a point under consideration for long. Recently, Gawrecki et al studied long-term changes in retinal parameters after uncomplicated phacoemulsification cataract surgery and found that despite an improvement at 90 days, there was a spontaneous decline over the next few months in these except the vascular perfusion in the central macular area. They couldn't find any significant effect of changes in CDE on these parameters.<sup>1</sup>

However, it is known that the parameters during phacoemulsification can affect the retinal parameters in at least the shortterm, mediated via ultrasonic vibrations, fluidics and inflammatory cytokines.<sup>2</sup> The most commonly reported parameters in cataract surgery during phacoemulsification by machines are the cumulative dissipated energy (CDE), ultrasound time (UST) and total aspirated fluid (TAF) and total aspiration time.<sup>3</sup> As per our literature review, we decided to study the impact of variations in CDE on the retinal parameters. We designed our study to understand the relationship between CDE and changes in retinal microcirculation parameters both in terms of a correlation analysis and by grouping patients according to the CDE values.

Cumulative dissipated energy (CDE) is the total amount of ultrasound energy delivered to the eye during the surgery, whereas effective phacoemulsification time (EPT) represents the actual time the phaco machine is used at full power to emulsify cataract. CDE is a measure of the total energy used, while EPT is a measure of the

time that energy was applied at full power.<sup>4</sup> In simple terms, the value of CDE is always higher than EPT for a phaco procedure. It is calculated by the machine and displayed on the user interface.

## **MATERIAL AND METHODS**

**Study Design:** The study was carried out at the Upgraded Department of Ophthalmology, S.M.S. Medical College, Jaipur. Consecutive patients were taken from 1st January 2023 till the sample was completed. The study universe included patients attending the outpatient department of the college. This was a prospective observational study without a comparator or control group.

### **Inclusion Criteria:**

All patients with age-related cataracts who underwent uncomplicated phacoemulsification.

### **Exclusion criteria:**

Any ocular problem potentially affecting transparency of optical media which could reduce quality of scans of OCTA (<3/10), any significant vitreoretinal pathology, systemic disease causing ocular problems like diabetes, hypertension and others, high myopia, glaucoma, uveitis, any other pre-existing ocular disease, any complication during surgery or patient attrition.

**Sample size:** At confidence level of 95%, and study power of 80%, the required sample size was 90 cases of uncomplicated cataract surgery. Patients were enrolled in both groups (Group A <15 seconds CDE and Group B >15 seconds CDE) till the sample size of 45 was reached in each group.

**Clinical Examination:** All participants underwent a comprehensive ocular examination. OCTA imaging before surgery was done to record VDC in mm/mm<sup>2</sup>, VDF in mm/mm<sup>2</sup>, CRT in  $\mu$ m, CRTA in  $\mu$ m, CV in mm<sup>2</sup>, VPF and VPC in %. Group-wise division based on CDE levels was done, and patients with CDE up to 15 and more than 15 were compared to assess its effect on post-surgical retinal parameters. This division was based on a previous study by Khokhar et al., who reported that in most uncomplicated phacoemulsification procedures, a level of nearly 14 was achieved for CDE.<sup>3</sup>

Uniformity in surgical procedure was obtained by using a modern phacoemulsification system (Centurion Silver System) with implantation of the same type of intraocular lens in the capsular bag. All procedures were done by a single surgeon. CDE and TAF were recorded carefully after each phacoemulsification surgery from the display panel. Finally, OCTA Scans were taken after surgery at follow-up visits at 2 weeks, 6 weeks & 3 months.

**Statistical Analysis:** Microsoft Excel/ Office for Windows 11 was used for data entry and statistical analysis. Mean values and standard deviations (SD) were calculated. Inter-group comparisons were made using independent t-tests for continuous variables, and correlation was assessed using the Pearson coefficient. A p-value <0.05 was considered statistically significant.

**Ethical statement-** The study was part of a thesis work and was initiated after obtaining appropriate institutional ethics committee (IEC) approval. All participants were explained about study's purpose and procedure, and written informed consent was obtained.

## **RESULTS**

A total of 90 subjects were followed up over 3 months, and the phacoemulsification specifications during the procedure and retinal parameters at follow-up were studied. The average specifications for all 90 patients of CDE and TAF were 15.3 ( $\pm$ 6.3) and 168.6 cc ( $\pm$ 63.4), respectively. On dividing the subjects group-wise, the comparison revealed that there was a significant difference in mean CDE values in both groups, but a similar difference in TAF values was not seen [Table 1].

CRT at baseline for the 2 groups was 259.2  $\mu$ m and 257.8  $\mu$ m and had no significant difference. There was no significant difference at all the follow-ups as well. A similar pattern was seen in rest of the retinal parameters at baseline i.e. CRTA was 264.6  $\mu$ m and 261.4  $\mu$ m, CV was 9.3 mm<sup>3</sup> and 9.4 mm<sup>3</sup>, VDC 7.1 mm/mm<sup>2</sup> and 6.9 mm/mm<sup>2</sup>, VPC was 12.5% and 11.4% and VPF was 26.8% and 26.6% except VDF [Table 2-8]. VDF had no significant difference at baseline in the two groups, 13.4 mm/mm<sup>2</sup> and 14.7 mm/mm<sup>2</sup> (p=0.095), but at all the follow-up thereafter, there was a significant difference found between two groups. At 2 weeks, VDF was

16.5mm/mm<sup>2</sup> and 18.5mm/mm<sup>2</sup>(p=0.026), at 6 weeks, 16.8 mm/mm<sup>2</sup>and 18.9 mm/mm<sup>2</sup>(p=0.022) and 3 months 17.3 mm/mm<sup>2</sup>and 19.3 mm/mm<sup>2</sup>(p=0.017).

The correlation between CDE and retinal parameters was assessed for all the 90 patients in study. The correlation studied using the Pearson coefficient showed a significant positive correlation only among CDE and VDF. i.e. at 2 weeks p=0.025, 6 weeks p=0.023 and 3 months p=0.027. Along with CDE, the correlation of TAF with the retinal parameters was also studied. On similar lines as the CDE, a significant positive correlation was found only with the VDF, i.e. at 2 weeks p=0.031, 6 weeks p=0.028 and 3 months p=0.031 [ Table 9].

Pseudophakic cystoid macular edema was not noted in any case in both groups at the end of 3 months in our study.

## DISCUSSION

The study included 90 patients who had an average CDE and TAF of 15.3 (±6.3) and 168.6 cc (±63.4), respectively. The groups were formed based on CDE less than 15 and more than 15 seconds. The mean CDE and TAF for Group A were 9.8 (±3.3) and 117.8 cc (±41.3), and for Group B were 20.7 (±2.9) and 220.6 cc (±33.4), respectively.

On comparison of retinal parameters of both the groups, the only significant difference was noted in the VDF values at all three points of measurement, i.e. 2 weeks (p= 0.026), 6 weeks (0.022) and 3 months (0.017). The relationship between the CDE and various variables, when analysed for correlation, also revealed a significant association with only VDF.

Vascular density full refers to the measurement of blood vessel density across the entire area scanned, whereas vascular density central refers to the designated central region of the same image.<sup>5</sup> Looking at the values, we can hypothesize that the central area, i.e. the fovea (1 x 1 mm on OCTA), is mostly avascular; therefore, changes in microcirculation in normal retinal tissue after an uncomplicated surgery are not significant in this area. Inflammatory changes due to altered ocular perfusion and possible functional hyperemia affect only the total area studied (3 x 3 mm macular cube on OCTA), which is rich in blood supply.

As the vessel density is minimal at the fovea, pseudophakic cystoid macular edema is frequently noted here, which is mostly a self-reversing reaction. However, the rest of the retina shows an increased vessel density post cataract surgery.<sup>6</sup> Another study reported a significantly increased perfusion, vascular density and the retinal thickness in the intermediate capillary plexus and the deep capillary plexus after cataract surgery. This study did not report any significant change in the superficial capillary plexus. All the changes observed returned to baseline over ninety days, confirming their inflammatory nature.<sup>7</sup>

In our study, a significant increase in retinal thickness and vessel density full was seen in both study groups. Another study similarly reported a significant correlation between the retinal thickness and vascularity in healthy subjects on OCTA.<sup>8</sup>

The question that arises is whether this increased vessel density, which significantly correlates with the CDE during phacoemulsification (more in high CDE than low CDE group), is a prognostic sign for any future complications or just another self-limiting inflammatory process. In the literature review, we find studies reporting such changes in diabetic patients, and information about normal subjects is derived from the controls in such studies.<sup>9,10,11</sup> A study conducted in 2022 reported that macular circulation was affected in eyes operated by machines using the gravity-fluidics system than in eyes operated on an active fluidics system.<sup>12</sup> They also reported that the vessel density of the eyes of the gravity-fluidics reached a steady state at 3 months, while the same happened at 1 month in the eyes operated on active-fluidics. In our study, the Centurion silver was used to perform all the surgeries which uses gravity-fluidics. A standard bottle height of 90cm was used for all cases. This could be one of the reasons for the increase in vessel density full (VDF) till 3 months in our study. Longer follow-up is needed to ascertain the persistence of these changes beyond 3 months. The total estimated fluid aspirated (EFA) during phacoemulsification was also noted in our study, and we found that it followed the same pattern as CDE, with no significant correlation with any retinal parameters except VDF at all visits. The post-surgical dilatation of retinal vessels, due to multiple factors like inflammation, decreased IOP or functional hyperaemia, could be the cause of this result. Additionally, the post-surgical opening of retinal capillaries could also contribute to these changes in microcirculation.

A study involving 32 patients who underwent phacoemulsification and were followed for up to 3 months postoperatively found a mean 6% and 3% increase in vessel density at the parafoveal and perifoveal regions, along with a mean 27% reduction in the foveal avascular zone. The mean increase in inner retinal thickness was 15%, 10%, and 7% at the fovea, parafovea, and perifovea, respectively. Compared to the parafovea and

perifovea, the fovea experienced a significantly higher percentage of change in inner retinal thickness and retinal microcirculation (all  $P < .001$ ).<sup>13</sup> However, in our study, the microcirculation changes were more significant in the perifoveal area. The central and average retinal thickness showed a significant increase, which persisted at 3 months and did not cause any loss of vision. VDF significantly increased in high CDE group than low CDE group. However, No pseudophakic cystoid macular edema was noted in any patient in our study at the end of 3 months.

So what is the long-term impact of high CDE in phaco procedure on retinal parameters? Bui et al. reported no long-term adverse impact of high CDE on postoperative visual acuity in normal subjects undergoing cataract surgery.<sup>14</sup> But a study comparing diabetic and non-diabetic subjects undergoing phacoemulsification found that there was a significant increase in macular thickness in both groups. The superficial capillary plexus vascularity increased in the diabetic group, which may put a person at risk for the proliferation of diabetic retinopathy.<sup>9</sup> Another known complication of high CDE during phaco is corneal endothelial cell loss.<sup>15</sup> In our study, the diabetics were excluded, and specular microscopic assessment of corneal endothelium was not done. Further studies can be done to assess the impact of CDE on retinal parameters in diabetics and to assess the correlation between CDE, endothelial count, and its impact on retinal microcirculation.

Regarding changes in retinal microcirculation after uncomplicated phacoemulsification in normal subjects, the jury is out as to whether any long-term changes occur due to high CDE. Most short-term studies (up to 3 months) have reported significant changes, but most long-term studies up to 1 year have reported the resolution of these changes spontaneously. More studies are required in Indian eyes to assess these changes in different scenarios to draw clinically useful conclusions.

## CONCLUSION

In an uncomplicated cataract surgery, cumulative dissipated energy (CDE) did not have a significant impact on retinal microcirculation except with vessel density full (VDF). This statistically significant increase in VDF in a high-CDE group as compared to the low-CDE group needs to be assessed further with a longer follow-up study to determine its clinical and research value. No patient recruited in the study developed pseudophakic cystoid macular edema (PCME) at 3 months, which suggests that chances of developing PCME in cases who underwent uncomplicated phaco procedure might not be CDE dependent and other contributing factors may lead to this pathology.

## REFERENCES

1. Gawęcki M, Prączyńska N, Karska-Basta I. Long-term variations in retinal parameters after uncomplicated cataract surgery. *J Clin Med*. 2022; 11: 3426.
2. Mackenbrock LH, Baur ID, Łabuz G, Auffarth GU, Khoramnia R. Impact of phacoemulsification parameters on central retinal thickness change following cataract surgery. *Diagn*. 2023; 13: 2856.
3. Khokhar S, Aron N, Sen S, Pillay G, Agarwal E. Effect of balanced phacoemulsification tip on the outcomes of torsional phacoemulsification using an active-fluidics system. *J Cataract Refract Surg*. 2017; 43: 22-8.
4. Fernández-Muñoz E, Chávez-Romero Y, Rivero-Gómez R, Aridjis R, Gonzalez-Salinas R. Cumulative Dissipated Energy (CDE) in Three Phaco-Fragmentation Techniques for Dense Cataract Removal. *Clin Ophthalmol*. 2023; 17: 2405-12.
5. Lin B, Zuo C, Gao X, Huang D, Lin M. Quantitative Measurements of Vessel Density and Blood Flow Areas Primary Angle Closure Diseases: A Study of Optical Coherence Tomography Angiography. *J Clin Med*. 2022; 11: 4040.
6. Haleem A, Aziz-ur-Rehman, Saleem A, Memon S, Memon N, Fahim MF. Cystoid macular oedema after phacoemulsification with and without type 2 diabetes mellitus; a hospital-based clinical prospective trial in Karachi. *J Pak Med Assoc*. 2017 Mar; 67: 395-9.
7. Pilotto E, F. Leonardi, G. Stefanon et al., "Early retinal and choroidal OCT and OCT angiography signs of inflammation after uncomplicated cataract surgery," *Br J Ophthalmol*. 2019; 103: 1001-7.
8. Yu J, Gu R, Zong Y, Xu H, Wang X, Sun X et al. Relationship between retinal perfusion and retinal thickness in healthy subjects: an optical coherence tomography angiography study. *IOVS*. 2016; 57: 204-10.
9. Feng L, Azhati G, Li T, Liu F. Macular vascular density changes following cataract surgery in diabetic patients: an optical coherence tomography angiography study. *J Ophthalmol*. 2021; 66: 41944.



10. Tarek N, Khali NM, El Sheikh HF, Shousha SM. Evaluation of macular and peri-papillary blood vessel density following uncomplicated phacoemulsification in diabetics using optical coherence tomography angiography. *Indian J Ophthalmol.* 2021; 69: 1173–7.
11. Kim J, Kim S, Borrelli E, Park MS, Cho BJ, Kwon S. Alterations in optical coherence tomography angiography parameters after cataract surgery in patients with diabetes. *Sci Rep.* 2024; 14: 23814.
12. Luo Y, Li H, Chen W, Gao Y, Ma T, Ye Z et al. A prospective randomized clinical trial of active-fluidics versus gravity-fluidics system in phacoemulsification for age-related cataract (AGSPC). *Ann Med.* 2022; 54: 1977-87.
13. Zhao Z, Wen W, Jiang C, Lu Y. Changes in macular vasculature after uncomplicated phacoemulsification surgery: Optical coherence tomography angiography study. *JCRS.* 2018;44: 453-8.
14. Bui AD, Sun Z, Wang Y, Huang S, Ryan M, Yu Y et al. Factors impacting cumulative dissipated energy levels and postoperative visual acuity outcome in cataract surgery. *BMC Ophthalmol.* 2021; 21: 1-9.
15. Vital MC, Jong KY, Trinh CE, Starck T, Sretavan D. Endothelial cell loss following cataract surgery using continuous curvilinear capsulorhexis or precision pulse capsulotomy. *Clin Ophthalmology.* 2023; 17: 1701-8.

## RESULTS

**Table 1 Cumulative dissipated energy (CDE) and total aspirated fluid (TAF) comparison according to the groups based on CDE values**

	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
	Mean (SD)	Mean (SD)		
CDE	9.89 (3.35)	20.78 (2.98)	16.294	<0.001
TAF	117.8 (41.3)	220.6 (33.4)		

**Table 2 Central retinal thickness (CRT) at different follow up compared according to the groups based on CDE values**

CRT	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	259.2	257.8	0.145	0.442
2 weeks	267.3	263.1	0.437	0.332
6 weeks	273.3	271.8	0.148	0.441
3 months	278.3	276.3	0.197	0.421

**Table 3 Central retinal thickness average (CRTA) at different follow up compared according to the groups based on CDE values**

CRTA	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	264.6	261.4	-0.334	0.369
2 weeks	269.7	265.9	0.404	0.343
6 weeks	270.9	270.4	0.054	0.478
3 months	273.8	271.5	0.230	0.409

**Table 4 Central volume (CV) at different follow up compared according to the groups based on CDE values**

CV	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	9.3	9.4	-0.738	0.231
2 weeks	9.5	9.6	-0.900	0.185
6 weeks	9.7	9.8	-0.945	0.173
3 months	9.9	10.1	-0.852	0.198

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**Table 5 Vascular density full (VDF) at different follow up compared according to the groups based on CDE values**

VDF	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	13.4	14.7	-1.320	0.095
2 weeks	16.5	18.5	-1.967	0.026
6 weeks	16.8	18.9	-2.033	0.022
3 months	17.3	19.3	-2.149	0.017

**Table 6 Vascular density central (VDC) at different follow up compared according to the groups based on CDE values**

VDC	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	7.1	6.9	0.026	0.489
2 weeks	9.3	9.2	0.093	0.463
6 weeks	9.4	9.4	0.006	0.497
3 months	9.6	9.7	-0.123	0.451

**Table 7 Vascular perfusion central (VPC) at different follow up compared according to the groups based on CDE values**

VPC	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	12.5	11.4	0.901	0.184
2 weeks	17.2	15.6	1.130	0.130
6 weeks	17.1	15.5	1.030	0.152
3 months	16.9	15.3	1.132	0.130

**Table 8 Central volume (CV) at different follow up compared according to the groups based on CDE values**

VPF	CDE up to 15 (N 45)	CDE more than 15 (N 45)	t value	p value
Baseline	26.8	26.6	0.503	0.308
2 weeks	32.9	33	-0.098	0.467
6 weeks	33.3	33.6	-0.223	0.413
3 months	33.8	34.1	-0.174	0.431

**Table 9 Overall correlation between phacoemulsification and retinal parameters using Pearson correlation for all 90 subjects**

Correlation between Cumulative Dissipated Energy (CDE) and vascular density			
		r coefficient	P value
Vascular density central	Baseline	0.012	0.910
	2 weeks	0.057	0.596
	6 weeks	0.035	0.743
	3 months	0.050	0.637
Vascular density full	Baseline	0.186	0.086
	2 weeks	0.236	0.025 (S)

	<b>6 weeks</b>	0.239	0.023 (S)
	<b>3 months</b>	0.232	0.027 (S)
<b>Correlation between Total Aspirated Fluid (TAF) and vascular density</b>			
		<b>r coefficient</b>	<b>P value</b>
<b>Vascular density central</b>	<b>Baseline</b>	0.006	0.955
	<b>2 weeks</b>	-0.053	0.619
	<b>6 weeks</b>	0.037	0.729
	<b>3 months</b>	0.048	0.653
<b>Vascular density full</b>	<b>Baseline</b>	0.173	0.102
	<b>2 weeks</b>	0.226	0.031 (S)
	<b>6 weeks</b>	0.231	0.028 (S)
	<b>3 months</b>	0.225	0.032 (S)