

# Association of Cumulative Dissipated Energy and Postoperative Foveal Thickness among Patients with Age-related Cataract who Underwent Uncomplicated Phacoemulsification

Joel M. Perez, MD, Manuel Benjamin B. Ibanez IV, MD,  
Sherman O. Valero, MD

Department of Ophthalmology  
Carlos L. Sevilla Eye Center  
Makati Medical Center,  
Makati City, Philippines

Correspondence: Sherman O. Valero, MD  
Room 157 Makati Medical Center  
2 Amorsolo St., 1229 Makati City, Philippines  
Email: valeromd@yahoo.com, jmperezmd@gmail.com

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## ABSTRACT

**Purpose:** Cumulative dissipated energy (CDE) is a phacoemulsification unit parameter designed to monitor the amount of energy delivered during phacoemulsification. Studies have already shown that lower CDE levels have better surgical outcomes, specifically in corneal recovery. However, few literature exists regarding the correlation between CDE and foveal thickness.

**Methods:** In this prospective study, subjects with age-related cataract underwent cataract surgery by phacoemulsification. Central subfield thickness (CST), cube volume (CV), and cube average thickness (CAT) of the macula were measured by spectral-domain optical coherence tomography (OCT) at three separate time-points: preoperative, 1 day, and 14 days after cataract surgery. To determine the correlation between parameters, Pearson's correlation coefficients and degree of association, and coefficient of determination ( $r^2$ ) were used.

**Results:** One hundred eyes from 93 subjects were analysed. Preoperatively, mean CST was  $247.71 \pm 21.44 \mu\text{m}$ , CV was  $9.38 \pm 0.82 \text{ mm}^3$ , and CAT was  $262.94 \pm 22.15 \mu\text{m}$ . At  $12.42 \pm 11.05$  of mean CDE exposure, the fovea increased in thickness in all measured parameters. The relationship between CDE and the change in foveal thickness values from baseline to postoperative Day 1 and Day 14 were examined. The correlation coefficients obtained for CST, CV, and CAT had low association to CDE. Furthermore, only the correlation coefficients of the difference

between baseline and Day 1 of CST, and the difference between baseline and Day 14 observations of CV were significant (0.279 and -0.206,  $p=0.005$  and  $p=0.040$ , respectively) but still with a low degree of association.

**Conclusion:** There is a low, significant, direct association of the difference of CST on Day 1 from baseline with CDE, and a low, significant, indirect association of the difference of CV on Day 14 from baseline with CDE after routine phacoemulsification.

**Keywords:** Phacoemulsification, Cumulative dissipated energy, Foveal thickness, OCT, Age-related cataract, Macular edema

According to the World Health Organization (WHO), cataract is the leading cause of blindness worldwide, accounting for 51% of the total cause of blindness.<sup>1</sup> The advent of phacoemulsification has proved invaluable in curtailing the increase in blindness due to cataract.<sup>2</sup> Phacoemulsification with posterior chamber intraocular lens implantation generally has been considered safe and successful. However, like all surgeries, the procedure has its risks and postoperative complications. Postoperative complications of phacoemulsification include endothelial cell loss of the cornea sometimes resulting in pseudophakic bullous keratopathy and postoperative intraocular pressure spike, both of which can be easily avoided through proper and efficient technique in phacoemulsification. One well studied and significant postoperative complication of phacoemulsification is macular edema. Studies have shown a 0.4% to 2% incidence of visual loss due to macular edema.<sup>2</sup> In postoperative macular edema, foveal thickness is found to be increased. With foveal thickness being a factor in post-surgical outcomes of phacoemulsification specifically visual acuity, a rarely addressed relationship is how the amount of phacoemulsification energy over time is related to postoperative foveal thickness.

Phacoemulsification energy expended, measured as cumulative dissipated energy (CDE), is total phacoemulsification time in minutes multiplied by average phacoemulsification power % divided by 100.<sup>3,4</sup> CDE is a phacoemulsification unit designed as an aid for surgeons to monitor the amount of energy delivered into the ocular tissues during phacoemulsification and is specifically a built-in feature in Alcon Infiniti machines.<sup>3</sup> Studies have already shown that less CDE during a phacoemulsification procedure results to a better surgical outcome, specifically in corneal recovery.<sup>5</sup> However, few literature exists regarding the correlation of CDE and foveal thickness. There is still no definite consensus on the correlation of the postoperative foveal thickness

as measured by optical coherence tomography (OCT) with regards to cumulative dissipated energy.

The purpose of this study is to determine the association between the amount of CDE and postoperative foveal thickness in uncomplicated phacoemulsification cases. With this study, if a strong correlation between CDE and postoperative foveal thickness is established, CDE can be introduced as a measure of surgical efficiency that may aid in improving surgical outcomes in phacoemulsification in terms of foveal thickness.

## METHODOLOGY

One hundred eyes of 93 patients diagnosed with age-related cataract who underwent uncomplicated phacoemulsification and intraocular lens (IOL) implantation were enrolled in this prospective cross-sectional study. Informed consent was obtained from all subjects that participated in this study. All patients underwent surgery at the Department of Ophthalmology, Makati Medical Center between August 2014 and September 2015. This study was approved by the Institutional Review Board of the Makati Medical Center.

Patients with any ophthalmic pathology that significantly affected vision especially those with macular involvement such as known cases of uveitis, glaucoma, and diabetic and hypertensive retinopathy with central macular involvement were excluded from this study. Any intraoperative complication was also considered as exclusion criteria.

All eyes underwent basic ophthalmic examination preoperatively, which included visual acuity testing, slit lamp examination, intraocular pressure (IOP) measurement, and dilated fundus exam.

OCT examination using Cirrus HD-OCT (Carl

Zeiss Meditec, Dublin CA, USA) was done and measured by a single technician preoperatively, 1 day and 14 days postoperatively. The scanning protocols that were used in all patients were Macular Cube 512 x 128 in order to assess the macular thickness parameters (Central Subfield Thickness [CST], Cube Average Thickness [CAT], Cube Macular Volume [CV]). The macular cube 512 x 128 protocol performs 512 horizontal B-scan sections with 128 A-scans for each section over an area of 6 mm x 6 mm, providing a thickness map with concentric sectors that comprised the 9 macular map regions of the Early Treatment Diabetic Retinopathy Study (ETDRS) (Figures 1 and 2).<sup>6</sup>

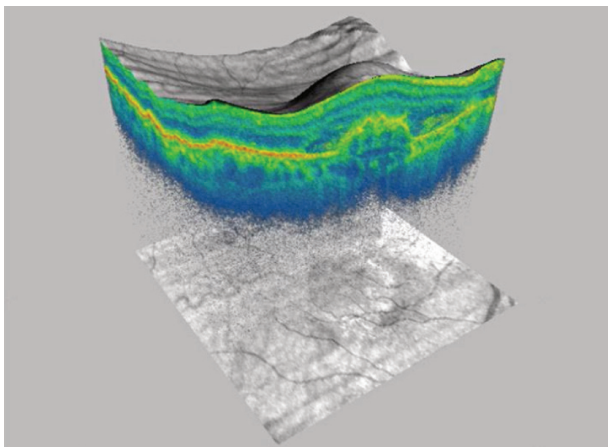


Figure 1. 3D visualization of macular cube over a 6x6 mm region. The CV and CAT refer to the internal limiting membrane to retinal pigment epithelium tissue layer over the entire 6x6 mm square scanned area.

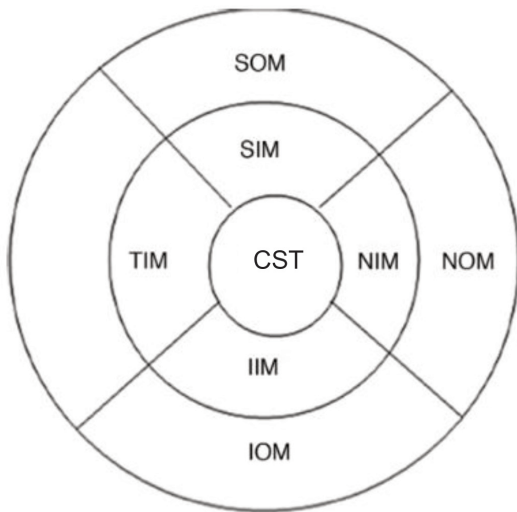


Figure 2. Diagram with the 9 regions of the ETDRS macular map. The concentric circles have a diameter of 1 mm, 3 mm, and 6 mm. CST: central subfield thickness.

Patients were operated by different surgeons using the Infiniti Phacoemulsification System (Alcon Inc., Fort Worth, TX, USA) under local anesthesia with topical and intracameral anesthesia. Foldable intraocular lenses were implanted. CDE was recorded at the end of each procedure. Fourth-generation quinolone eye drops and prednisolone acetate eye drops were prescribed to all patients postoperatively. No topical nonsteroidal anti-inflammatory drug (NSAID) eye drops were given before or after the surgery.

Parameters were summarized using mean and standard deviation. To determine the correlation between parameters, Pearson's correlation coefficients and degree of association, and coefficient of determination ( $r^2$ ) were used. All valid data were included in the analysis. Null hypothesis was rejected at 0.05 alpha level of significance. STATA 12 was used for data analysis.

## RESULTS

A total of 100 eyes from 93 subjects were examined for foveal thickness and CDE exposure post-phacoemulsification. At  $12.42 \pm 11.05$  of mean CDE exposure, the fovea increased in thickness in all measured parameters: central subfield thickness; cube volume; and cube average thickness (Table 1).

**Table 1. Average baseline and postoperative foveal thickness and CDE exposure among patients who underwent uncomplicated phacoemulsification (n = 100)**

	Pre-Op (Baseline)	Day 1	Day 14	Difference from Pre-Op to Day 14
Central subfield thickness ( $\mu\text{m}$ )	$247.71 \pm 21.44$	$246.13 \pm 23.11$	$250.13 \pm 23.40$	$4 \pm 8.48$
Cube volume ( $\text{mm}^3$ )	$9.38 \pm 0.82$	$9.36 \pm 0.75$	$9.72 \pm 0.63$	$0.37 \pm 0.46$
Cube average thickness ( $\mu\text{m}$ )	$262.94 \pm 22.15$	$262.97 \pm 19.76$	$271.65 \pm 16.66$	$8.68 \pm 12.54$

The relationship between CDE measured intra-operatively and the change in foveal thickness values from baseline to postoperative Day 1 and Day 14 were examined. The correlation coefficients obtained for CST, CV and CAT had low association to CDE. Furthermore, only the correlation coefficients of the difference between baseline and Day 1 of CST, and the difference between baseline and Day 14 observations of CV were significant (0.279 and -0.206,  $p=0.005$  and  $p=0.040$ , respectively) but still with low degrees of association. The results may reflect the possibility that the sample size was insufficient to produce evidence to determine an association between the other foveal thickness parameters and CDE.

Based on Figures 3 and 4, the difference of Day 1 from baseline and the difference of Day 14 from baseline of central subfield thickness values had a direct and low association with CDE. That is, the higher the CDE, the higher is the difference of Day 1 from baseline and Day 14 from baseline of CST. However, Figures 5 to 8 revealed that the difference of Day 1 from baseline and the difference of Day 14 from baseline of CV and CAT had an inverse and low association with CDE. That is, the higher the CDE, the lower the difference of Day 1 from baseline and Day 14 from baseline of CV and CAT.

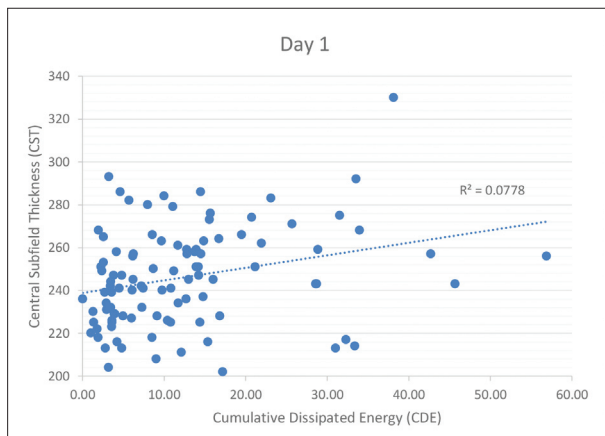


Figure 3. Correlation between the difference of central subfield thickness (CST) of Day 1 from baseline and cumulative dissipated energy (CDE) values

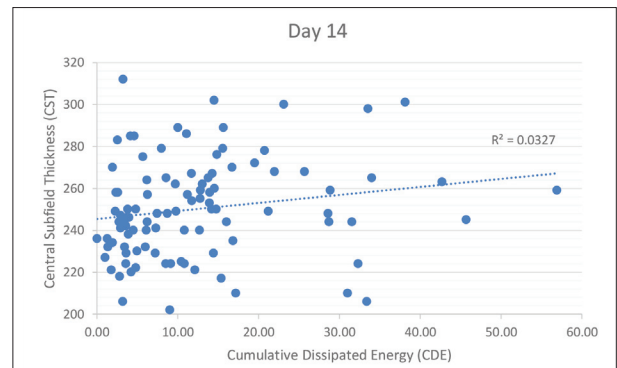


Figure 4. Correlation between the difference of central subfield thickness (CST) of Day 14 from baseline and cumulative dissipated energy (CDE) values

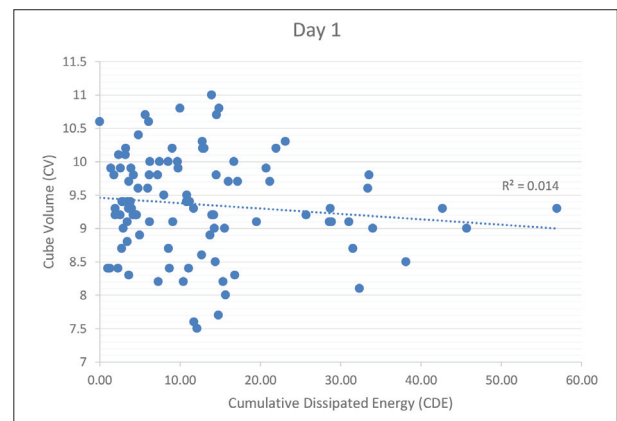


Figure 5. Correlation between the difference of cube volume (CV) of Day 1 from baseline and cumulative dissipated energy (CDE) values

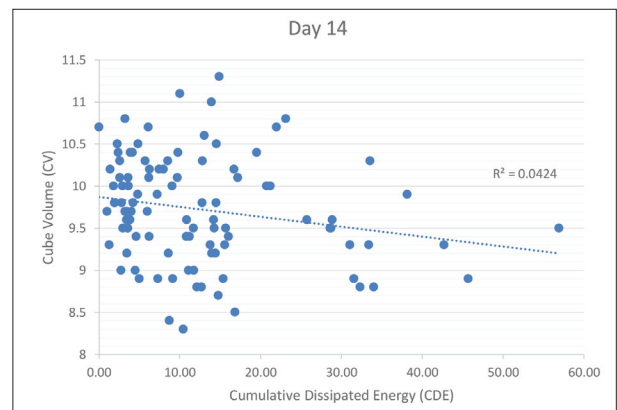


Figure 6. Correlation between the difference of cube volume (CV) of Day 14 from baseline and cumulative dissipated (CDE) energy values

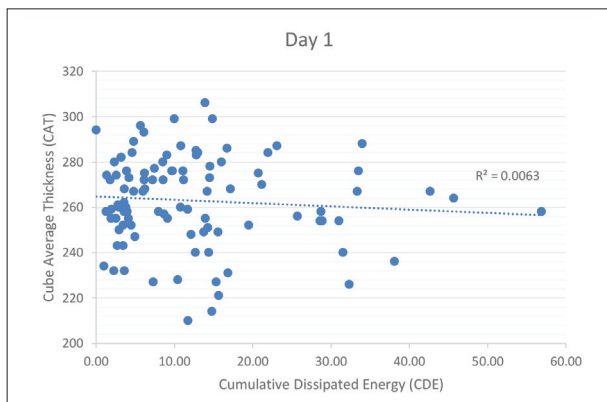


Figure 7. Correlation between the difference of cube average thickness (CAT) of Day 1 from baseline and cumulative dissipated energy (CDE) values

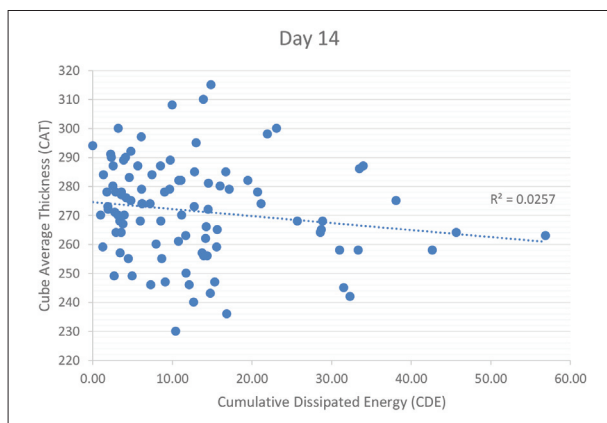


Figure 8. Correlation between the difference of cube average thickness (CAT) of Day 14 from baseline and cumulative dissipated energy (CDE) values

## DISCUSSION

Despite advances in phacoemulsification techniques and technology, cystoid macular edema (CME) can occur in 0.6 to 6% of patients after uncomplicated cataract surgery.<sup>7</sup> Though rare in occurrence, the most important cause of permanent decrease in visual acuity after cataract surgery is CME.<sup>8</sup> An increase in prostaglandin production due to free-radical release following surgical trauma causes changes in the macula. Prostaglandin and other inflammatory factors are concentrated in the aqueous humor, penetrate the vitreous body, and alter the blood-retina barrier permeability at the macula, resulting to accumulation of fluid in extracellular spaces.<sup>9</sup> Since CDE equates to amount of phacoemulsification power or duration of surgery which result in more damage to ocular tissue, it is hypothesized that an increased CDE may result

in a higher or longer release of inflammatory factors, thus thicker foveal thickness after surgery.

In this study, the fovea increased in thickness postoperatively in all measured parameters (CST, CV and CAT). Degenring et al. found an increase in foveal area thickness on postoperative days 7, 30 and 60.<sup>10</sup> Using OCT, Lobo found postoperative increases in retinal thickness that peaked at 6 weeks and were still present in 22% of patients 30 weeks after surgery.<sup>11</sup> Other studies, however, have not come to the same conclusion. Ching et al. in 2006 showed thicker pre-operative foveal thickness than postoperatively.<sup>2</sup> This could be due to a variety of factors, including the use of different instruments, different methods for analyzing data, and dissimilar control groups. Another element to consider is that OCT examinations can be influenced by any media opacity, such as lens opacity and postoperative corneal edema, which may explain the difference in the measurement of retinal thickness.<sup>12</sup>

The low association of the foveal parameters to CDE may be due to the possibility that the sample size was inadequate. The researchers would have preferred to include more patients with higher CDE values. However, the inability to obtain a reliable OCT scan due to increased density of the cataract made it unfeasible. In addition, the use of minimal phacoemulsification energy resulted in overall lower CDE values which may make it insufficient to produce evidence to determine association between foveal thickness and CDE.

The regression plots shown in Figures 3 to 8 show the association of CST, CV and CAT to CDE. The direct correlation shown in Figures 3 and 4 compared to the inverse correlation shown in Figures 5 to 8 implies that thickening in the central 1 mm subfield centered at the fovea is more prominent as compared to the peri- and parafoveal areas. Similarly, a study by Mourgela et al. analyzed macular thickness after uncomplicated cataract surgery. The results showed significant increase of macular thickness parameters, both at 1<sup>st</sup> and 3<sup>rd</sup> month postoperative visits while CV and CAT were significantly decreased between postoperative visits.<sup>13</sup>

This study is limited by the relatively homogenous CDE values obtained and a short follow-up period of 2 weeks. A longer follow-up is necessary in order to further assess macular thickness changes. The subjects' systemic illnesses were not taken into account in this

study. The presence of hypertension or diabetes, even in the absence of retinopathy, should be taken into account as they may have an effect on postoperative foveal thickening that may be independent of CDE exposure.

Even though postoperative increase in foveal thickness may be minimal and clinically asymptomatic, it represents a key occurrence which may lead to formation of CME. Taking into account the increasingly large number of patients undergoing phacoemulsification surgery, despite the fact that clinically significant CME is rare, it is critical for us to comprehend the mechanisms and postoperative changes in the macular region in relation to cataract surgery. Further studies are needed to investigate a possible relation between CDE and foveal thickness.

## CONCLUSION

There is a low, significant, direct association of the difference of CST on Day 1 from baseline with CDE, and a low, significant, indirect association of the difference of CV on Day 14 from baseline with CDE after routine phacoemulsification.

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