• Brief Report •

Incidence and predisposing factors of anterior chamber gas bubbles during femtosecond laser flap creation

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Abstract

● **AIM:** To investigate the incidence and the predisposing factors of anterior chamber (AC) gas bubbles during femtosecond laser (FS) flap creation for laser *in situ* keratomileusis (LASIK).

● **METHODS:** All patients who underwent FS-LASIK surgery at CMU LASIK Center between January 2013 and May 2016 were retrospective reviewed. Preoperative and intraoperative data including keratometry, white-to-white (WTW) corneal diameter, flap parameters (diameter, thickness, hinge position, and tunnel length) and pulse energy were reviewed and compared between incident group and control group. To determine the risk factors, univariate and multivariate conditional logistic regression were used; the eye was unit of analysis.

● **RESULTS:** The incidence of AC gas bubbles was 1.6% (22 out of 1378 eyes). The median WTW in the AC bubbles group was 11.5 mm (range 11.1-12.1), which was significantly different from the control group (11.7 mm, range 10.5-12.8, P=0.021). The result of the median WTW minus the flap diameter in the AC bubbles group was 2.5 mm (range 2.1-3.2), which was statistically different to the control group (2.7 mm, range 1.5-3.8, P=0.008). The logistic regression analysis showed that the result of the WTW minus the flap diameter in the AC bubbles group had an adjusted odds ratio of 0.204 (95%CI; 0.056-0.747, P=0.016).

● **CONCLUSION:** Development of AC gas bubbles during FS flap creation is not an uncommon event in Asian eyes which typically have a small WTW. The flap diameter when adjusted relatively to the WTW is a predisposing factor to the possibility of AC gas bubbles occurrence.

● **KEYWORDS:** anterior chamber; gas bubble; LASIK; femtosecond laser

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INTRODUCTION

The frequency of corneal flap creation in laser *in situ* keratomileusis (LASIK) surgery using the femtosecond laser (FS) has increased extensively since its introduction in 2002[1]. Many advantages of FS laser flap creation over the using of mechanical microkeratome have been mentioned[2-4]. However, it has unique complications related to the gas bubbles formation from the photodisruption of FS in the corneal stroma[5]. Gas bubbles usually be dissolved or released through the venting canal at the hinge of the flap in order to negate the formation of the opaque bubble layer (OBL)[6-7]. Bubbles may also migrate anteriorly into the subepithelial space, which may break through and cause a flap tear[8-10]. The formation of anterior chamber (AC) gas bubbles during flap creation with an FS is not an uncommon event, especially in Asian eyes who typically have a small white-to-white (WTW) corneal diameter[11-21].

These gas bubbles may not affect the outcome of the LASIK surgery, however, the bubbles may interfere the excimer laser tracking system and surgeon will need to either manually center the ablative treatment or alternatively delay lifting the flap for between several minutes to several hours while waiting for the bubbles to fully dissipate.

In this paper, we describe the incidence and the predisposing factors of AC gas bubbles during FS flap creation to avoid this complication.

SUBJECTS AND METHODS

Ethical Approval In accordance with the principle of the Declaration of Helsinki, this article was approved by the Research and Ethics Committee, Faculty of Medicine, Chiang Mai University No.363/2016 in September 22, 2016. Informed consent for the collection and analysis of data from the patient's record was obtained from each patient.

A retrospective review of charts and videos was conducted on all FS-assisted LASIK cases performed at Chiang Mai University LASIK Center, Chiang Mai, Thailand, between January 2013 and May 2016. All patients were Asian. All cases of FS-assisted LASIK were performed using the WaveLight FS200 (Alcon, Fort Worth, TX, USA).

A review of the preoperative data included patient demographics (sex, age, and eye site), visual acuity, manifest refraction, pupil size, keratometry, horizontal WTW corneal diameter, and central corneal thickness. The intraoperative data included the flap parameters (diameter, thickness, hinge position, and tunnel length), docking times, pulse energy and number and size of gas bubbles. Flap diameter were set in 8.5 or 9.0 mm and flap thickness were set between 100-120 μm.

Statistical analysis was carried out using Stata/IC 14.2 for Windows. Since the data were not normally distributed, the median values and interquartile range were used to describe the characteristics in an eye with AC bubbles (investigative group) and an eye without AC bubbles (control group). The Wilcoxon rank-sum (Mann-Whitney) test was used to identify the differences between the two groups. Univariate, and multivariate logistic regression were used to determine the risk factors, using the eye as the unit of analysis.

RESULTS

FS-assisted LASIK surgery was performed on 1378 eyes during the study period. The incidence of AC gas bubbles occurred in 1.6% of cases (in 22 out of 1378 eyes). An eye with AC gas bubble is shown in Figure 1. These cases were classed as the investigative group. The remainders of the cohort were classed as the control group. The characteristics of patients with AC bubbles and the control group, such as sex, median age, and eye site, are presented and compared as shown in Table 1. Gas bubbles appeared at a higher frequency in the left eye (72.7%, P=0.029). Ten percent of patients (2/20) had AC bubbles bilaterally. All 22 eyes were myopic, the median spherical equivalent was -4.81 diopters (range -0.75 to -11.5), however it was not statistically different to the control group (P=0.787). The median average keratometry value was 43.7 diopters (range 42.7-47.33), again this was not statistically different to the control group (P=0.653). The eyes with AC bubbles had a median WTW corneal diameter of 11.5 mm (range 11.1-12.1), which was statistically different to the control group that was 11.7 mm (range 10.5-12.8; P=0.021). The other parameters including flap diameters, canal length, pulse energy both at the side cut and bed cut did not differ between the AC bubbles and the control group.

However, the result of the median WTW corneal diameter minus the flap diameter in the AC bubble group was 2.5 mm

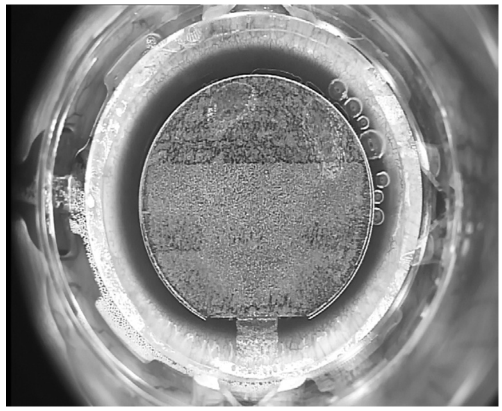

Figure 1 An eye with AC gas bubbles during FS flap creation.

Table 1 Patient characteristics

Parameters	Air bubble group (n=22 eyes)	Control group (n=1356 eyes)	P
Sex, n (%)			
Male, patients	5 (25.0)	304 (44.8)	0.078
Female, patients	15 (75.0)	374 (55.2)	
Male, eyes	6 (27.3)	600 (44.2)	0.112
Female, eyes	16 (72.7)	756 (55.8)	
Age, y			
Median (min-max)	31 (19-56)	29 (14-64)	0.455[a]
p25-p75	23-36	24-36	
Site, n (%)			
Right eye	6 (27.3)	688 (50.7)	0.029
Left eye	16 (72.7)	668 (49.3)	
Spherical equivalent			
Median (min-max)	-4.81 (-11.5 to -0.75)	-4.75 (-17.62 to 2.75)	0.787[a]
p25-p75	-6 to -3	-6.62 to -3	
Average K, diopter			
Median (min-max)	43.7 (42.7-47.33)	43.9 (39.7-48.5)	0.653[a]
p25-p75	43.3-45.1	43.05-44.85	
WTW, mm			
Median (min-max)	11.5 (11.1-12.1)	11.7 (10.5-12.8)	0.021[a]
p25-p75	11.4-11.7	11.4-11.9	
Flap diameter, mm			
Median (min-max)	9 (8.5-9)	9 (8.5-9)	0.688[a]
p25-p75	9-9	9-9	
Canal length, mm			
Median (min-max)	0.7 (0.3-0.9)	0.7 (-0.4-1.3)	0.768[a]
p25-p75	0.6-0.8	0.6-0.8	
Pulse energy bed cut, μJ			
Median (min-max)	0.83 (0.80-0.85)	0.83 (0.80-0.86)	0.058[a]
p25-p75	0.82-0.84	0.82-0.84	
Pulse energy side cut, μJ			
Median (min-max)	0.86 (0.8-0.89)	0.87 (0.80-0.91)	0.079[a]
p25-p75	0.85-0.87	0.86-0.88	
WTW-flap diameter, mm			
Median (min-max)	2.5 (2.1-3.2)	2.7 (1.5-3.8)	0.008[a]
p25-p75	2.4-2.7	2.5-3.0	

p25-p75: Interquartile range. [a]Wilcoxon rank-sum (Mann-Whitney) test.

Table 2 Univariate and logistic regression analysis

Parameters	No. of eyes	Air bubble (%)	Univariate analysis			Logistic regression analysis		
			OR	95%CI	*P*	AOR	95%CI	*P*
Sex								
Male	606	6 (0.99)	Ref.					
Female	772	16 (2.07)	2.12	0.78-6.64	0.112			
Site								
Right eye	694	6 (0.86)	Ref.					
Left eye	684	16 (2.34)	2.74	1.01-8.62	0.029	2.719	1.056-7.004	0.038
WTW	1378	22 (1.60)	0.285	0.086-0.941	0.039			
WTW-flap diameter	1378	22 (1.60)	0.202	0.056-0.736	0.015	0.204	0.056-0.747	0.016

WTW: White to white corneal diameter; OR: Odds ratio; AOR: Adjusted odds ratio.

(range 2.1-3.2), which was statistically different to the control group (2.7 mm, range 1.5-3.8, *P*=0.008). When using a univariate, and multivariate logistic regression to determine the risk factors, an adjusted odds ratio was 0.204 (95%CI, 0.056-0.747, *P*=0.016; Table 2).

DISCUSSION

The incidence of AC gas bubbles during FS flap creation in this study is 1.6% of 1378 eyes, which is higher than that seen in previous studies, 1.02% in 786 eyes[11], 0.14% in 2886 eyes[19] and 0.3% in 902 eyes[22].

Opinions on the mechanisms involved in the cause of AC gas bubbles are different proposed. Lifshitz *et al*[12] suggested that the gas bubbles migrate through the posterior stroma and endothelium without being absorbed by the endothelium pump, and then appear in the AC. However, Tomita *et al*[16] showed that there is an absence of endothelial damage following gas bubble migration into the AC, so this hypothesis is not supported in their study. Utine *et al*[18] demonstrated that the OCT images of eyes with AC gas bubbles obtained on the first day after surgery, showed that the pocket extended to the limbal area with a stromal bed thickness of >600 μm in that area. Hence, they proposed that a possible cause of the scattering of air bubbles is a result of the FS beam produced a direct photodissociation of the aqueous humor, or a direct cavitation effect in the aqueous humor due to rapid pressure changes in the corneal lamellar interface during the FS procedure[18]. Moreover, many studies suggested that the gas bubbles enter through Schlemm's canal *via* the trabecular meshwork[13-15,17,20,23]. Soong and de Melo Franco[17] also demonstrated, using video evidence, that gas bubble entry occurs via the trabecular meshwork.

There are various postulations regarding the risk factors pertaining to the development of AC bubbles including smaller cornea, larger flap, and high applanation pressures[23-24]. Robert *et al*[20] also confirmed in their series of studies, that there was a statistically significant trend in a correlation of the larger flap diameter between AC gas bubbles appeared eye and paired contralateral eyes (*P*=0.04). In our series, most cases were performed using a relatively large flap, one with a median of 9.0 mm in diameter. We also found that the median WTW corneal diameter in eyes with AC bubbles was statistically significant different in eyes without AC bubbles, 11.5 mm, and 11.7 mm (*P*=0.021).

We have shown that the result of the median WTW corneal diameter minus the flap diameter in the AC bubble group was 2.5 mm (range 2.1-3.2), which was statistically different to the control group (2.7 mm, range 1.5-3.8, *P*=0.008), and the odds ratio being 0.204 (95%CI; 0.056-0.747, *P*=0.016). So, in Asian eyes, we recommend reducing the flap diameter. This is because Asian eyes typically have a small WTW corneal diameter, so a reduced flap diameter would avoid the border of flap being close to the limbus, which could allow the migration of the gas bubbles into the AC through the trabecular meshwork.

The limitation of this study was its retrospective nature and a large sample size would be necessary to demonstrate the other predisposing factors. The other one is that the WTW corneal diameter is determined by the WaveLight ALLEGRO Topolyzer VARIO, which represent only the horizontal diameter, while all these eyes were performed with the superior hinge.

In conclusion, development of AC gas bubbles during FS flap creation is a not uncommon event when the operation is carried out on Asian eyes. The flap diameter when adjusted relative to the WTW corneal diameter is the predisposing factor to the possibility of the occurrence of AC gas bubbles. The recommendation therefore is that, in operating on Asian eyes, the flap should be less than 9.0 mm in order to reduce the possibility of the formation of AC gas bubbles.

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