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GENERAL ARTICLE

Translating data and measurements from stratus to cirrus OCT in glaucoma patients and healthy subjects

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Abstract

Aim: our study tried to find a mathematical conversion method of the measurements obtained in Time Domain (TD) OCT to Spectral Domain (SD) OCT.

Material and method: A prospective randomized, double blind study that included 244 eyes, from 121 patients (normal subjects, glaucoma suspects, glaucoma), in whom we analyzed the retinal nerve fiber layer (RNFL) and the optic disc in the same session by using TD OCT (Stratus) and SD OCT (Cirrus), was performed. The means for RNFL thickness (overall value and per quadrants), neural area and cup/ disc (C/ D) ratio, were measured.

Results: We found statistically significant differences between parameters measured in TD OCT and SD OCT ($p<0.001$). Powerful correlations were calculated between parameters measured with the two OCT machines. Data dispersion showed a linear relation between measurements. One can use the following mathematical equations for conversion:

Mean RNFL (Cirrus) = 15.77 + 0.748 x Mean RNFL (Stratus)
Mean neural area (Cirrus) = 0.508 + 0.388 x Mean neural area (Stratus)
Mean C/ D ratio (Cirrus) = 0.157 + 0.792 x Mean C/ D (Stratus)

Conclusions: data based on our calculated mathematical conversion equations can be converted into SD OCT. Therefore, we offered a useful tool for the long term monitoring of our patients although the initial measurements in TD OCT made comparisons for patients later measured with SD OCT impossible.

Keywords: Stratus TD OCT, Cirrus SD OCT, conversion, glaucoma

Abbreviations: RNFL = retinal nerve fiber layer, TD OCT = time domain optical coherence tomography, SD OCT = spectral domain optical coherence tomography, VF = visual field, CI = confidence interval, ISNT segments = inferior, superior, nasal, temporal segment.

Introduction

Glaucoma is an optic neuropathy characterized by structural changes to the optic nerve head and retinal nerve fiber layer (RNFL), with corresponding functional changes, particularly visual field (VF) loss [**1,2**]. RNFL loss is thought to precede the measurable optic nerve

head and visual field damage and is observed in 60% of the eyes approximately 6 years before any detectable VF defects [**3**]. Therefore, the evaluation of RNFL damage is of vital importance for the diagnosis of glaucoma in the early stages.

Several techniques are currently available for the detection and quantification of RNFL damage, such as clinical examination, red-free fundus photography, and modern imaging devices. The optical properties of the RNFL have allowed recent advances in ocular imaging technology to obtain thickness measurements. Optical coherence tomography (OCT) is a new technology that allows the quantitative assessment of RNFL thickness. It offers objective, real-time assessment of the RNFL within a very short time span at a single visit [**4**]. The ability of time domain Stratus OCT to provide quantitative and reproducible measurements of RNFL thickness parameters has been documented in many studies [**5,6**]. Several studies investigating the performance of Stratus OCT in glaucoma with manifest VF defect have shown promising results [**7,8**]. However, it has been demonstrated that Stratus OCT has a relatively low sensitivity in identifying localized RNFL defects in preperimetric glaucoma [**9**]. Spectral-domain HD OCT has recently been introduced, with improved image resolution, imaging speed, and sensitivity. Cirrus OCT, which has recently become commercially available, acquires OCT data approximately 70 times faster and with a better resolution (8–10 μm axial resolution in tissue), compared to Stratus OCT technology (5 μm). Due to these improvements and the very good intra-test and inter-test reproducibility, both devices offer efficient tools in glaucoma progression.

The problem appears in daily practice when the clinician tries to compare, translate and monitor patients in whom RNFL was measured first with Stratus TD OCT, then with SD Cirrus HD OCT. Conversion might offer a method to follow patients in a reliable manner, although two different devices were used.

Material and method

We designed a prospective, longitudinal randomized trial that included 244 eyes, from 122 subjects based on 3 data sets from healthy eyes (40 subjects), glaucoma suspects (40 subjects) and glaucoma patients (42 subjects). Both SD OCT (Cirrus) and TD OCT (Stratus) were performed in each eye. Patients were randomized regarding the order of eye scanning (right, left) and the order scanning with the two OCT (Stratus first, Cirrus afterwards). RNFL thickness (overall mean value, mean RNFL per quadrants), mean neural area and mean cup/ disc (C/ D) ratio, were measured. Correlations between parameters were calculated, then based on the level of these correlations the conversion equations from TD OCT to SD OCT Cirrus were calculated.

Cirrus OCT scan

Subjects were measured with the Optic Disc Cube 200 × 200 program of the Cirrus HD-OCT model 4000 (software version 3.0). All Cirrus OCT scans were obtained after achieving pupillary dilation, followed by Stratus OCT Fast RNFL scan. The Optic Disc Cube 200 × 200 program obtains 200A-scans from 200 linear B-scans evenly distributed in a 6-mm^2 area centered over the optic nerve.

Cirrus OCT extracts from the data cube 256 A-scan samples along the path of the calculation circle. Based on the RNFL layer boundaries in the extracted circle scan image, the Cirrus OCT calculates the RNFL thickness at each point along the calculation circle. Using these data, Cirrus OCT provides the 12-clock-hour thicknesses, four quadrant thicknesses, a global 360° average thickness, and TSNIT thickness profiles. The Cirrus OCT software provides a classification (within normal limits, borderline, or outside normal limits) for each parameter, based on comparison with an internal normative database. A parameter is classified as outside normal limits if its value falls lower than the 99% confidence interval (CI) of the healthy, age-matched population. A borderline result indicates that the value is between the 95% and 99% CI, and a within-normal-limits result indicates that the value is within the 95% CI. Segments of the TSNIT thickness graph located below the yellow band (outside of the 95% normal limit) and in the red band (outside of the 99% normal limit) were defined as OCT RNFL defects by TSNIT graph at the 5% and 1% level, respectively.

Stratus OCT scan

Subjects were measured after achieving pupillary dilation to a minimum diameter of 5 mm. An internal fixation target was used, since it offers a better reproducibility. Data were analyzed with the Stratus system software (version 4.0). Three scan images were acquired from each subject, with each image consisting of 256 A-scans along a 3.4-mm-diameter circular ring around the optic disc. These values were averaged to yield 12 clock-hour thicknesses, four quadrant thicknesses, and a global average RNFL thickness measurement. The Stratus OCT software provides a classification (within normal limits, borderline, or outside normal limits) for each parameter, based on comparison with an internal normative database. In Stratus OCT, TSNIT thickness profiles were also obtained, which displayed thicknesses at each A-scan location along the path of the scan circle. In Stratus OCT, OCT RNFL defects by TSNIT graph were defined in the same way as in the Cirrus OCT.

Quality assessments of OCT scans were performed by two experienced examiners masked to the subject's identity and the results of the other tests. Satisfactory quality was defined as: (1) well-focused images, (2) the presence of a centered circular ring around the optic disc, and (3) a signal strength ≥ 7 (10 = maximum). Any subject with less than satisfactory Stratus OCT image quality was excluded.

Data Analysis

All analyses were performed with SPSS for Windows (Version 19.0; SPSS Inc., Chicago, IL). *P* < 0.05 was considered statistically significant. Student's *t*-tests were used to evaluate RNFL thickness differences between Cirrus OCT and Stratus OCT. Pearson correlation tests were used for correlations between parameters.

Results

The mean age in our study was 49.48 +/ -14.44 years old. Distribution per decades of age can be followed in **Fig. 1**. Mean RNFL thickness obtained by the two measurements (Cirrus vs. Stratus OCT) was 83.77 +/ -18.90 µm vs. 92.52 +/ - 18.56 µm (**Fig. 2**).

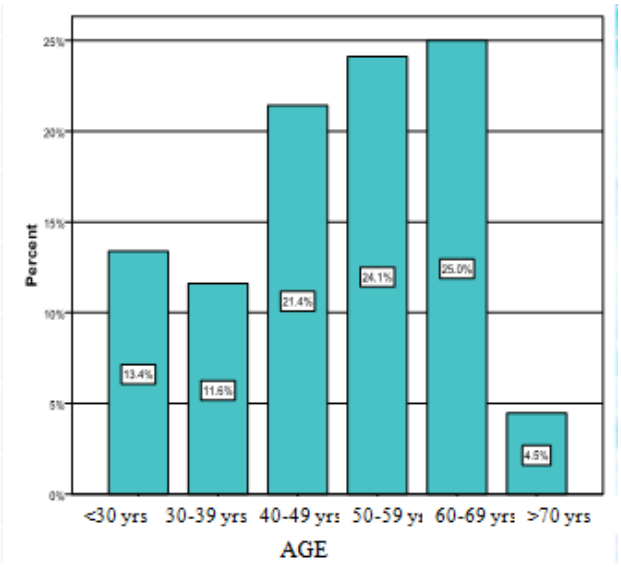


Fig. 1 Age distribution (per decades)

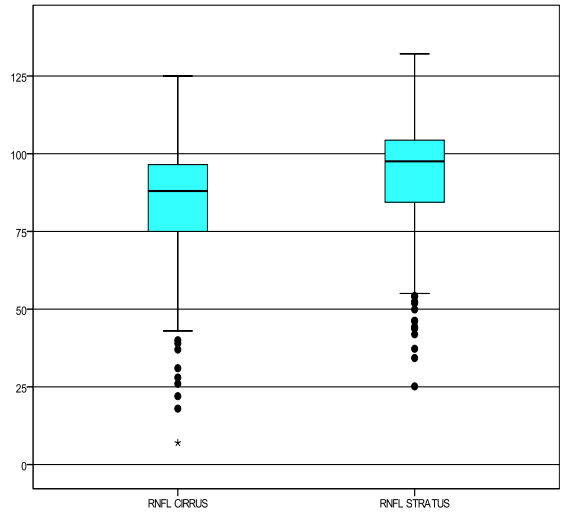


Fig. 2 Mean RNFL thickness (Cirrus OCT vs. Stratus OCT)

T student test showed a significant difference between the two type of measurements for mean RNFL thickness (t=-8.83, df=238), p=0.000. Moreover, the mean values were strongly and positively correlated (Pearson correlation coefficient r=0.862, p=0.000). Prediction analysis revealed that 74.4% from the Cirrus OCT mean measurements explain Stratus OCT findings (p=0.000). Due to a powerful correlation, a regression equation could be calculated between the two mean RNFL measurements in Cirrus OCT and Stratus OCT to

show how they "model" and influence each other (**Table 1**). We used the R square statistical measure (coefficient of determination) to quantify how close the data fitted into the regression line. The higher its value, the better the model fits the model of regression (**Fig. 3,4**). Two separate equations were calculated showing similar dispersion (distribution) of values; clinical meaning for this aspect is that the results are similar and over imposable, therefore the conversion equation represents a valuable tool to translate results from one instrument into another.

Table 1. Conversion equations between Stratus OCT to Cirrus OCT and Cirrus OCT to Stratus OCT

Stratus OCT to Cirrus OCT conversion mathematical model	**Cirrus OCT to Stratus OCT conversion mathematical model**
$y = 9.99 + 0.96 \times K_1$ K_1 = measured value of RNFL in Cirrus OCT	$y = 16.61 + 0.741 \times K_2$ K_2= measured value of RNFL in Stratus OCT

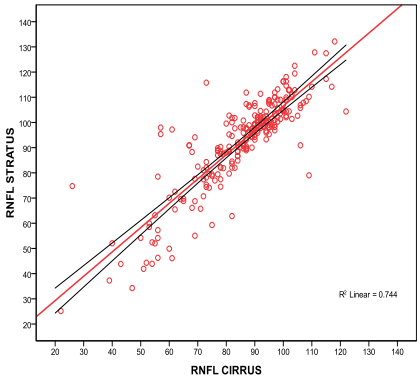


Fig. 3 Linear regression equation (Stratus to Cirrus OCT); $R^2 = 0.744$

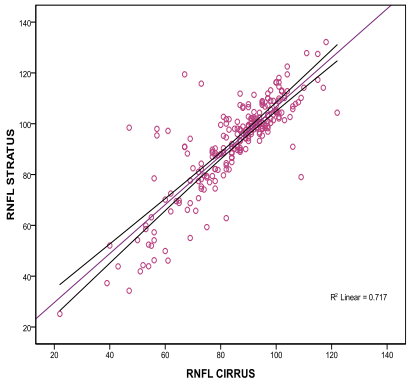


Fig. 4 Linear regression equation (Cirrus to Stratus OCT); $R^2 = 0.717$

Regarding comparisons and correlations between RNFL thickness per quadrants in TD vs. SD OCT we obtained similar results (statistically significant differences p=0.000 in all quadrants) and high positive correlations - Pearson correlation coefficient r= 0.666, p=0.000 in temporal quadrant, r= 0.726, p=0.000 in nasal quadrant, r= 0.795, p=0.000 in inferior quadrant and r= 0.692, p=0.000 in superior quadrant). Further, the optic disc parameters were analyzed.

For neural area we also obtained good correlations (r=0.734, p=0.000) and statistically significant differences between Stratus OCT and Cirrus OCT (0.91 mm2 vs. 0.82 mm2, p=0.000). C/ D ratio calculations had no statistically significant difference (0.63 in Stratus OCT 0.65 in Cirrus OCT, p>0.05). Conversion equations neural area and C/ D ratio are displayed below.

Mean neural area (Cirrus OCT) = 0.508 + 0.388 x Mean neural area (Stratus OCT)

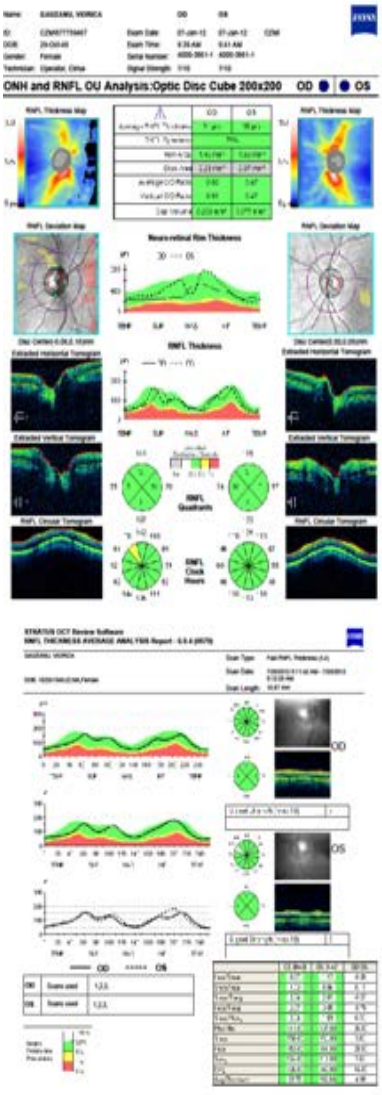
Mean C/ D ratio (Cirrus OCT) = 0.157 + 0.792 x Mean C/ D (Stratus OCT)

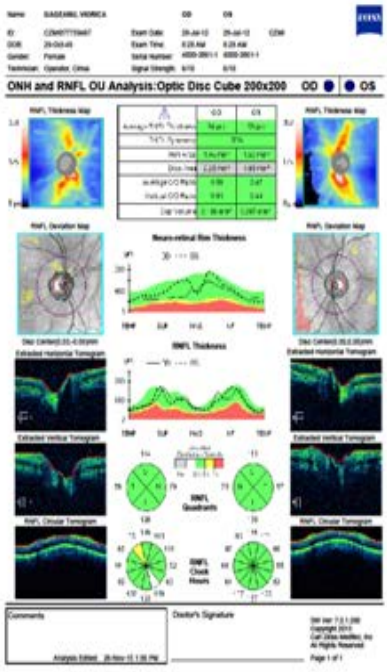
We present two clinical examples that explain our results, meaning that Cirrus OCT gives higher values for lower RNFL thickness in Stratus OCT and offers lower values in increased RNFL measurements by Stratus OCT. C/ D ratio in Cirrus OCT is estimated as smaller than in Stratus OCT, whereas the neural area appears larger in Cirrus OCT vs. Stratus OCT. Practically, this proves an obvious clinical finding, that the smaller the excavation is, the more the neural tissue remains.

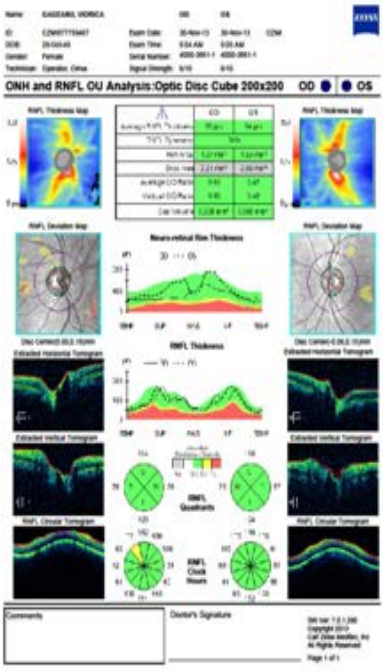
Case 1

A 67-year-old female patient, early stage POAG; IOP well compensated under topical treatment – Cosopt® (Santen) and Travatan® (Alcon) - IOP RE= 18 mmHg, IOP LE = 17 mmH). Previous argon laser trabeculoplasty (ALT) treatment in the RE and selective laser trabeculoplasty (SLT) in the LE were performed. Visual field (Humphrey Field Analyzer II, SITA Standard strategy, central 24-2) showed bilateral generalized reduction of retinal sensitivity, but no glaucoma changes were present (minimal scotoma criterion absent). OCT scan by Cirrus detected a mild RNFL thinning in the superotemporal quadrant, which was not confirmed in Stratus OCT scanning. Using our

mathematical conversion equation, we translated the results from Cirrus OCT to Stratus OCT and vice versa to compare results. Indeed, when converted from Stratus OCT to Cirrus OCT, the increased thicknesses in Stratus OCT (green), were more decreased in Stratus OCT (yellow defect in one quadrant).





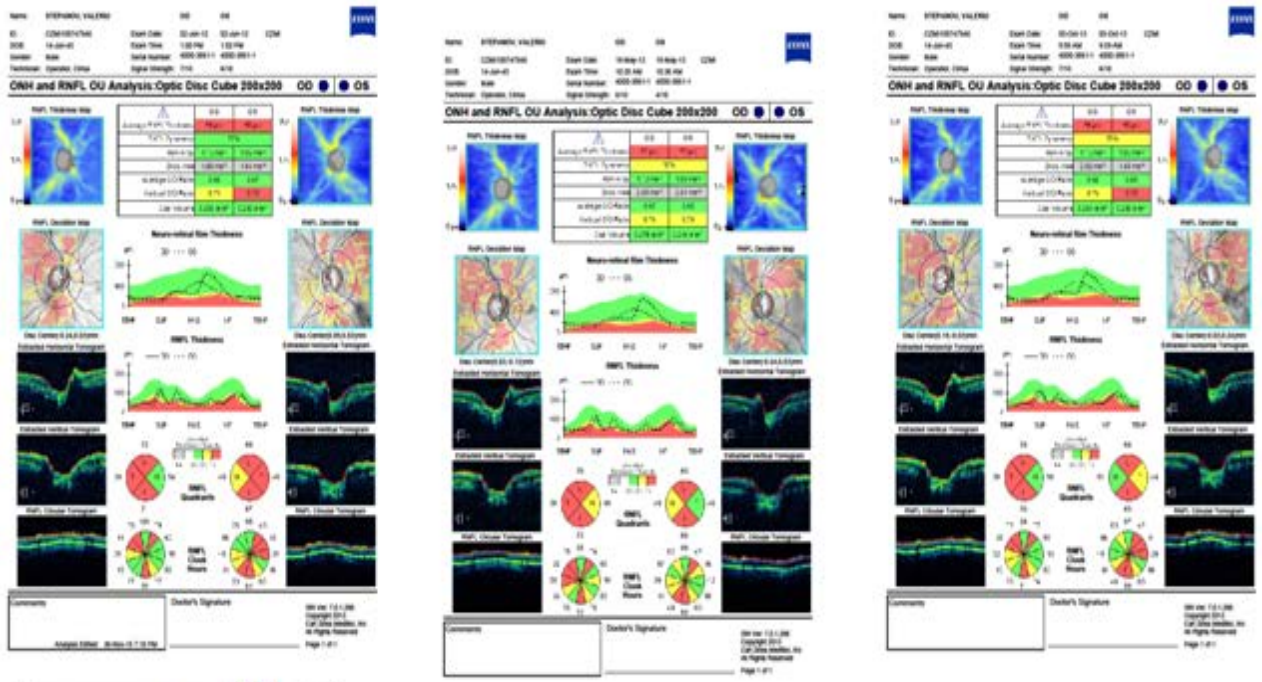


	Stratus to Cirrus (mean RNFL)	**Cirrus to Stratus** (mean RNFL)
RE	98.95 µm → 104.07 µm	94 µm → 86.01 µm
LE	102.64 µm → 92.66 µm	93 µm → 85.07 µm
		Cirrus to Stratus (mean neural area)
RE		2.14 → 1.34 mm2
LE		2.08 → 1.31 mm2
		Cirrus to Stratus (mean C/ D ratio)
RE		0.60 → 0.63
LE		0.45 → 0.56

Fig. 5 Stratus vs. Cirrus RNFL measurements in an early form of POAG

Case 2

A 69-year-old male patient, moderate stage POAG; IOP well compensated under topical treatment – Azarga® (Alcon) and Lumigan® (Allergan) (IOP RE = 17 mmHg, IOP LE = 15 mm Hg). Previous selective laser trabeculoplasty (SLT) in the RE was performed. Visual field (Humphrey Field Analyzer II, SITA Standard strategy, central 24-2) showed a bilateral generalized reduction of retinal sensitivity, and paracentral scotomas. OCT scannings revealed comparable defects in both OCT machines (**Fig. 6**).



	Stratus OCT to Cirrus OCT (mean RNFL)	Cirrus OCT to Stratus OCT (mean RNFL)
RE	59.38 µm → 66.99 µm	59 µm → 60 µm
LE	56.93 µm → 64.64 µm	56 µm → 58 µm
		Cirrus to Stratus (mean neural area)
RE		1.69 → 1.16 mm2
LE		1.65 → 1.14 mm2
		Cirrus to Stratus (mean C/ D ratio)
RE		0.67→ 0.68
LE		0.67 → 0.58

Fig. 6 Stratus OCT vs. Cirrus OCT RNFL measurements in a moderate form of POAG

Discussion

With the rapid improvements in OCT technology, the faster spectral domain is widely replacing the time domain Stratus, making it difficult to accurately compare measurements taken by Cirrus to the measurements taken by measurements in these two machines in our practice [**10-12**]. Several publications have reported failures of threshold algorithm in nerve fiber layer measurement between time domain Stratus OCT and spectral domain Cirrus OCT, with the latter providing a higher resolution and speed. In addition, there have been reports of a lack of agreement between Stratus OCT and Cirrus OCT [**11,13**].

Our study demonstrated that there is a large difference between the two models. This difference in parameter measurements may be due to different technical specifications, imaging protocols and different retinal segmentation algorithms. In particular, Cirrus OCT includes the retinal pigment epithelium, while Stratus OCT measures the retinal thickness from the vitreoretinal and internal limiting membrane interface to a segmentation line right above the photoreceptor inner and outer segment junction. Based on our results, we proposed the following

equation for the conversion of Stratus OCT to Cirrus OCT measurements:

Mean RNFL (Cirrus OCT) = 15.77 + 0.748 x Mean RNFL (Stratus OCT)

Mean neural area (Cirrus OCT) = 0.508 + 0.388 x Mean neural area (Stratus OCT)

Mean C/ D ratio (Cirrus OCT) = 0.157 + 0.792 x Mean C/ D (Stratus OCT)

Some aspects in our study may limit the clinical significance of our results because we also included healthy subjects in our analysis; hence, we cannot be certain that the transformation equation will maintain its accuracy in various clinical pathologies.

The clinical practical application for this study consists in offering a viable solution that allows the info transfer. Thus, data obtained via an older device can be compared and translated to a newer one, which is based on the same functioning principle, but on different scanning strategies. Therefore, we can "conserve" and use on long term all the measurements on different machines, acquired for the same patient**.** Our model contradicts the paradigm that states a true impossibility to transfer data from one type of OCT to another. The first step in this transition could be easier if the two machines belonged to the same producer and had similar functioning principles. The long-term strategy is to create a mathematical model capable of converting and transferring all the parameters between non-similar devices, belonging to different companies. The final aim in this direction is to compare different technologies/ instruments in real life terms.

In conclusion our study demonstrated a statistically significant difference between Stratus OCT and Cirrus OCT measurements. Our model proved that a linear regression equation could transform and convert values between two different OCT devices, allowing the clinician to interpret data without any problem.

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