ORIGINAL RESEARCH

Effect of Sleeping Position on the Retinal Nerve Fiber Layer in Individuals with Glaucoma

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Abstract

Aims and background: To evaluate the effect of sleeping in the lateral decubitus position on the average thickness of the retinal nerve fiber layer (RNFL) in the peripapillary region of the optic nerve since the effect of posture on intraocular pressure (IOP) and glaucoma progression is not yet sufficiently understood.

Materials and methods: A cross-sectional observational study was carried out with 40 volunteers who preferably slept in a right lateral decubitus (RLD) (RLD group $N = 20$) and left lateral decubitus (LLD) (LLD group $N = 20$) position. IOP was measured in both eyes, first in the sitting position and again after 10 minutes in a supine position, right lateral, and LLD, respectively. The mean thickness of the RNFL and the vertical papillary cup were measured by optical coherence tomography.

Results: The average age of the volunteers was 60.53 ± 7.26 years. There were 32 female and eight male. There was an increase in IOP with the change from the sitting position to the lateral decubitus of 2.7 and 3.6 mm Hg in the RLD group ($p < 0.001$) and an increase of 3.0 and 3.15 mm Hg in the LLD group ($p < 0.001$), right eye (RE) vs left eye (LE), respectively. However, there was no difference in IOP values between the groups. The average thickness of the RNFL was in the RLD group—75.10 vs 78.05 µm ($p = 0.325$) and in the LLD group—81.55 vs 79.95 µm ($p = 0.580$). Vertical papillary excavation was in the RLD group—0.70 vs 0.65 ($p = 0.175$) and in the LLD group—0.65 vs 0.65 ($p = 1.000$), RE vs LE, respectively.

Conclusion: We found no relationship between the lateral decubitus position when adopted preferentially for sleeping and the reduction of the RNFL.

Clinical significance: Search for risk factors for the asymmetrical development of glaucoma, especially in well-controlled IOP in daytime measurements.

Keywords: Glaucoma, Intraocular pressure, Optical coherence tomography, Posture, Sleep period.

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Introduction

Glaucoma is a multifactorial disease, and so far, its pathophysiology is still not fully understood.[1] However, increased intraocular pressure (IOP) is the most consistently known risk factor and the only modifiable one.[2–4] Intraocular pressure can be influenced by age, genetics, physical exercise, circadian rhythm, and postural variations.[5] Postural variation causes an increase in IOP due to choroidal vascular congestion and an increase in episcleral venous pressure (EVP).[6,7]

Knowledge about the influence of IOP fluctuation dependent on the postural effect is not yet sufficiently understood.[8] The increase in IOP resulting from postural variation could be responsible for the onset or progression of the disease,[5,9] since two-thirds of IOP peaks in 24 hours occur at night and are not detected during routine consultations.[10,11] Moreover, this increase occurs despite clinical treatment to reduce IOP.[5,12]

The IOP is known to be greater in the supine position than in the sitting position,[6,7,12–14] but this increase is even higher in patients with glaucoma.[5,15,16] It is believed that the way glaucoma patients sleep can alter IOP.[17] Some studies have looked for a relationship between the preferred sleeping position, the position of the head and eye in relation to the support surface, IOP, and the progression of glaucoma.[7,9,12,15,16] During sleep, the position of the body changes more frequently between the supine position and the lateral decubitus position.[13] The lateral decubitus position appears to be the most commonly adopted

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by adults and the elderly[14,16] and may be associated with the eye having the worst visual field.[13] The higher prevalence of asymmetrical visual fields in normal pressure glaucoma may be the result of a mechanism independent of the IOP seen during the day.[18] As individuals spend almost a third of their lives asleep, the primary sleep position may play a role in asymmetric glaucoma damage.[18]

This study verified the hypothesis regarding the connection between the preferred lateral sleeping position and the average thickness of the retinal nerve fiber layer (RNFL) in the peripapillary region of the optic nerve, aiming to find risk factors for the asymmetric progression of glaucoma.

Materials and Methods

Participants

A cross-sectional observational study was carried out at the Santa Luzia Foundation, Recife, Pernambuco, Brazil, from August 2019 to October 2020. It was duly approved by the CEP (CISAM-PE) and complied with the Declaration of Helsinki. An informed consent form was signed by all participants who underwent a complete ophthalmologic examination—far and near visual acuity, refraction, Goldmann's applanation tonometry, gonioscopy with Sussman four-mirror lens, ultrasonic pachymetry, color retinography, computerized campimetry (SITA 24-2 Humphrey Field Analyzer, Carl Zeiss Meditec, Dublin, California, United States of America), and optical coherence tomography (Cirrus Optical Coherence Tomography, Carl Zeiss Meditec).

We recruited 40 volunteers being followed up at the glaucoma outpatient clinic who met the following criteria—aged between 40 and 80 and primary open-angle glaucoma on gonioscopy and/or normal pressure glaucoma with diagnostic criteria—typical glaucomatous lesion in the optic nerve and/or optic nerve cupping asymmetry ≥0.2, IOP of >21 mm Hg and reproducible lesion in the visual field. Glaucomatous alterations of the optic disk were characterized as focal or diffuse thinning of the neuroretinal rim. Excluded were those with retinal disease, previous ocular surgery, narrow-angle on gonioscopy, past ocular inflammation or trauma, refractive error > 4.00 D, nuclear sclerosis of the lens ≥3, strabismus, corneal scarring, and inability to remain in a horizontal position.

Technical Procedures

A sequence of IOP measurements was taken in different positions, always once on the central cornea, in both eyes, and with the Perkins portable applanation tonometer (Mk2; Clement Clarke International). IOP was first measured on the seated patient. The patient was instructed to lie down in the supine position without elevating the head, and IOP was measured after 10 minutes in this position. The patient was then instructed to switch to the right lateral decubitus (RLD) and had another measurement taken in 10 minutes; finally, another measurement was taken after 10 minutes, in which the patient remained in the left lateral decubitus (LLD). The choice of right eye (RE) or left eye (LE) to start the IOP measurement in the positions mentioned was made by simple random drawing. To reduce the consequence of diurnal variation, the verification was always carried out between 2 and 4 PM by the same researcher. There was no head elevation in the lying position.

Proxymetacaine hydrochloride 0.5% ophthalmic solution and fluorescein sodium 1% ophthalmic solution were used for the tonometry tests.

The selected patients answered a questionnaire about their sleeping habits and preferred sleeping positions.

Optical coherence tomography was performed using the Cirrus HD-OCT 4000 device (Carl Zeiss Meditec, United States of America) under mydriasis, using the optic nerve head protocol (RNFL thickness) to acquire images with a diameter of 3.46 mm and analyze the thickness of the RNFL in the peripapillary region of the optic nerve, as well the vertical excavation/disk ratio in each eye.[19]

Statistical Analysis

The sample size was determined after carrying out a pilot study with 24 volunteers divided into two groups—the group that slept in RLD and the group that slept in LLD; the margin of error was 5.0%, and power was 80%. The difference between the means of the two groups and the combined standard deviation of the two samples of the RNFL variable, considering the eye with the lowest RNFL, indicated a necessary sample of 34 patients (17 in each group).

Quantitative variables were descriptively analyzed using mean, standard deviation (SD) (mean ± SD) or median and interquartile range 25 and 75 [median (P25; P75)]. Pearson's Chi-squared or Fisher's exact tests were used to assess the categorical variables in the comparison between the two groups (DLD means RLD group and DLE means LLD group).

The numerical variables compared between the groups were tested using the student's *t*-test with equal or unequal variances. If the hypothesis of normal distribution was rejected in at least one of the groups, the Mann–Whitney *U* test was chosen. In the comparison between paired data (RE and LE in the same group), the paired student *t*-parametric test and the paired nonparametric Wilcoxon test were utilized. The *F*-test [analysis of variance (ANOVA)] for repeated measures and Bonferroni's multiple comparison tests in the event of significant differences were used to compare the measurement positions. The normality hypothesis was checked using the Shapiro–Wilk test, and the equality of variances was tested using Levene's *F*-test. The margin of error utilized in the statistical analyzes was 5%. Software Excel was used to enter all the data. IBM Statistical Package for the Social Sciences version 25 was the program performed for the statistical tests.

Results

A total of 40 volunteers participated in the study and were divided according to their preference of sleeping position into two groups (20 patients in the RLD group and 20 in the LLD group). There were 32 female and eight male volunteers. The average age was 60.53 ± 7.26 years. The sample characteristics regarding sleep habits are shown in Table 1.

The IOP values according to the eye, group, measurement position, and evaluation time are presented in Table 2 and Figures 1 and 2. Significant differences ($p < 0.05$) in IOP values were verified between the positions. Multiple comparison tests indicated the following significant differences—right lateral decubitus (RLD) group—the RE in sitting and supine positions different from RLD to LLD positions; in the LE between each of the four positions; in the LLD group, both in the RE and in the LE; with the exception of the RLD and LLD positions, there are significant differences between the other pairs of positions.

Table 1: Sample characteristics in the total group and by group

	Preferred sleeping position			
Variable	*RLD*	*LLD*	*Total group*	*p-value*
Age: mean ± SD	59.95 ± 5.89	61.10 ± 8.54	60.53 ± 7.26	$p^{(1)} = 0.623$
Median (IQR)	59.50 (10.25)	61.00 (9.50)		
Gender: *n* (%)				$p^{(2)} = 1.000$
Masculine	4 (20.0)	4 (20.0)	8 (20.0)	
Feminine	16 (80.0)	16 (80.0)	33 (80.0)	
Time you usually sleep: *n* (%)				$p^{(3)} = 0.337$
Until 22:00 hours	13 (65.0)	10 (50.0)	23 (57.5)	
Later than 22:00 hours	7 (35.0)	10 (50.0)	17 (42.5)	
Hours of sleep per night: *n* (%)				$p^{(3)} = 0.288$
<8	13 (65.0)	16 (80.0)	29 (72.5)	
8 or more	7 (35.0)	4 (20.0)	11 (27.5)	
Use pillow: *n* (%)				$p^{(2)} = 1.000$
Yes	19 (95.0)	20 (100.0)	39 (97.5)	
No	1 (5.0)	–	1 (2.5)	

(1), Student *t*-test with equal variances; (2), Fisher's exact test; (3), Pearson's Chi-squared test; IQR, interquartile range; LLD, left lateral decubitus; RLD, right lateral decubitus; SD, standard deviation

Table 2: IOP results by measurement position, assessment time chronology, assessed eye and group (preferred sleeping position)

			Preferred sleeping position		
			RLD	*LLD*	
			Mean ± SD	*Mean ± SD*	
Position of measure	*Time*	*Eye evaluated*	*Median (IQR)*	*Median (IQR)*	*p-value*
Sitting		Right	15.25 ± 2.77	13.45 ± 2.39	$p^{(1)} = 0.036$*
			15.00 (5.75)	12.50 (3.00)	
		Left	14.25 ± 2.47	12.85 ± 2.03	$p^{(2)} = 0.058$
			14.00 (3.00)	13.00 (2.00)	
p-value			$p^{(3)} = 0.074$	$p^{(4)} = 0.062$	
Supine	10 minutes	Right	15.95 ± 3.44	14.85 ± 1.95	$p^{(1)} = 0.243$
			16.00 (2.75)	14.50 (1.75)	
		Left	15.65 ± 2.66	14.55 ± 1.79	$p^{(2)} = 0.133$
			16.00 (3.75)	14.00 (3.00)	
p-value			$p^{(3)} = 0.509$	$p^{(3)} = 0.268$	
RLD	10 minutes	Right	17.95 ± 3.25	16.15 ± 2.74	$p^{(2)} = 0.066$
			17.50 (4.50)	16.00 (4.00)	
		Left	17.85 ± 3.53	16.00 ± 2.34	$p^{(1)} = 0.058$
			18.00 (4.00)	15.50 (4.00)	
			$p^{(4)} = 0.943$	$p^{(4)} = 0.679$	
LLD	10 minutes	Right	17.50 ± 2.74	16.45 ± 2.87	$p^{(1)} = 0.245$
			17.002,75	16,004,00	
		Left	17.05 ± 2.91	16.00 ± 2.62	$p^{(1)} = 0.104$
			17.00 (4.50)	15.50 (2.75)	
			$p^{(4)} = 0.275$	$p^{(4)} = 0.131$	
p-value		Right	$p^{(5)} < 0.001$*	$p^{(5)} < 0.001$*	
p-value		Left	$p^{(5)} < 0.001$*	$p^{(5)} < 0.001$*	

*, Significant difference at 5%; (1), Mann–Whitney *U* test for comparison between groups (in each position and evaluated eye); (2), student *t*-test with equal variances for comparison between groups (in each position and evaluated eye); (3), paired Wilcoxon test for comparison between REs and LEs (in each position and group); (4), paired student *t*-test for comparison between REs and LEs (in each position and group); (5), *F*-test (ANOVA) for repeated measures with Bonferroni comparisons for comparison between measurement positions in each eye and group); IOP, intraocular pressure; IQR, interquartile range; LLD, left lateral decubitus; RLD, right lateral decubitus; SD, standard deviation

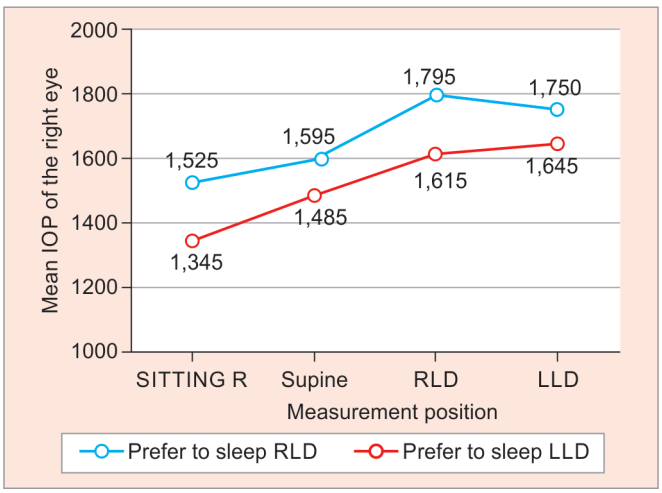

Fig. 1: Mean IOP of the RE by measurement position according to sleeping position preference; IOP, intraocular pressure; LLD, left lateral decubitus; RLD, right lateral decubitus; SITTING R, sitting right

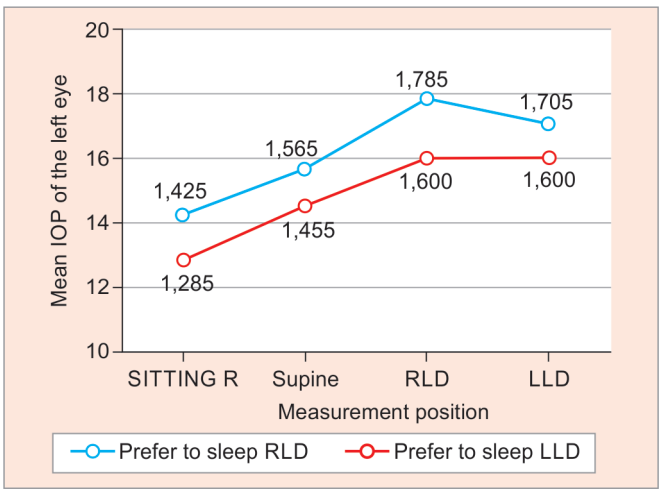

Fig. 2: Mean IOP of the LE by measurement position according to sleeping position preference; IOP, intraocular pressure; LLD, left lateral decubitus; RLD, right lateral decubitus; SITTING L, sitting left

Table 3: Results of RNFL thickness per eye according to group (preferred sleeping position)

	Preferred sleeping position		
	RLD	*LLD*	
	Mean ± SD	*Mean ± SD*	
Eye evaluated	*Median (IQR)*	*Median (IQR)*	*p-value*
Right	81.55 ± 10.67	75.10 ± 10.44	$p^{(1)} = 0.026$*
	84.00 (11.00)	74.00 (17.25)	
Left	79.95 ± 10.69	78.05 ± 12.84	$p^{(2)} = 0.614$
	80.50 (10.50)	79.00 (19.75)	
p-value	$p^{(3)} = 0.580$	$p^{(3)} = 0.325$	

*, Significant difference at 5%; (1), Mann–Whitney *U* test for comparison between groups (in each eye); (2), student *t*-test with equal variances for comparison between groups (in each eye); (3), paired student *t*-test for comparison between eyes (by group); IQR, interquartile range; LLD, left lateral decubitus; RLD, right lateral decubitus; RNFL, retinal nerve fiber layer; SD, standard deviation

Table 4: Results of papillary excavation per eye according to group (preferred sleeping position)

	Preferred sleeping position		
	RLD	*LLD*	
	Mean ± SD	*Mean ± SD*	
Eye evaluated	*Median (IQR)*	*Median (IQR)*	*p-value*
Right	0.65 ± 0.11	0.70 ± 0.09	$p^{(1)} = 0.191$
	0.66 (0.08)	0.71 (0.15)	
Left	0.65 ± 0.12	0.65 ± 0.13	$p^{(1)} = 0.789$
	0.64 (0.16)	0.65 (0.19)	
p-value	$p^{(2)} = 1.000$	$p^{(2)} = 0.175$	

(1), student *t*-test with equal variances for comparison between groups (in each eye); (2), paired student *t*-test for comparison between eyes (by group); IQR, interquartile range; LLD, left lateral decubitus; RLD, right lateral decubitus; SD, standard deviation

Table 3 presents data on RNFL thickness per eye and per group, where it is emphasized that RNFL thickness was lower in the RE and LE in the LLD group. In addition, there was a difference in thickness among the REs when compared between the RLD and LLD groups ($p = 0.026$). Table 4 presents the vertical papillary excavation statistics compared between eyes and between groups.

Discussion

Knowledge about sleep behavior and how sleeping position influences the onset and evolution of glaucoma is lacking.[20] However, the lateral decubitus position has been reported as being preferred for sleeping, especially among elderly patients.[12,13,16,20] Our study sought to determine a relationship between the habit of sleeping in the lateral decubitus position and the thickness of the RNFL, as well as variation in IOP values with postural changes, seeking clarification on the pathogenesis of asymmetrical glaucoma. Our results confirm the findings of other studies on IOP increase with the change from a sitting position to a horizontal position.[5,7,13,21] However, we were unable to relate the lateral decubitus position with the asymmetric damage of the RNFL and the vertical papillary excavation of the optic nerve.

The mechanism of the elevation in IOP after changing from supine to lateral decubitus remains debatable. Just as the increase in IOP occurs due to the increase in EVP, pressure in the ophthalmic artery, gravity, or detachment of body fluid in the supine position, these mechanisms could also play a part in the lateral decubitus position.[12,15] Another mechanism of IOP increase involves changes in the uveoscleral flow rate due to increased choroidal blood volume.[12] The utilization of pillows in the lateral position can restrict the flow of the jugular vein during sleep and increase the EVP.[15,22] It is important to analyze this data because most individuals use pillows to sleep, that is, 95% of respondents, based on our survey. Therefore, the use of some eye protection in contact with the pillow during sleep could be an additional treatment option for patients with glaucoma.[22]

We observed an IOP increase of 2.7 mm Hg in the RE and 3.6 mm Hg in the LE with the change from a sitting position to the lateral decubitus position in the RLD group, with a peak observed in the RE and greater fluctuation in the LE. In the LLD group, the increment in IOP with the change from the sitting position to the lateral decubitus position was 3.0 mm Hg in the RE and 3.15 mm Hg in the

LE, with a peak in the RE and greater fluctuation in the LE. These data differ from previous studies because they did not find statistically significant differences in IOP values between eyes in the same group and because there was no relationship between the highest IOP in the dependent eye in the lateral decubitus position preferred for sleeping.[12,13,23] Although IOP is often reported to be superior in the dependent eye, other studies have also found no significant difference between eyes.[24] Furthermore, at the minimum, in one study, the nondependent eye had the highest IOP.[24]

Mean IOP was higher in the REs in both groups. It has already been postulated that this difference can be attributable to the difference in EVP between the eyes, as the vessels that leave the RE take a shorter path until they flow into the superior vena cava compared to those that leave the LE. Therefore, vessels derived from the RE possibly have a higher EVP.[24]

We also observed that the IOP had a direction toward stabilization at the end of the experiment, corroborating the findings of Nelson et al. The findings of these researchers suggest that after a very quick response, IOP changes less and more gradually as it reaches a new steady state after a period of about 10 minutes to 1 hour.[25] This behavior could be assigned to aqueous humor dynamics and ocular hemodynamics.[15,26] On the contrary, there is evidence that this compensatory mechanism is reduced in glaucomatous patients, exposing them to longer periods of elevated IOP.[5]

A significant difference was observed between the mean RNFL thickness values between the REs in the RLD and LLD groups. However, no discrepancy was observed between means of vertical papillary cupping between eyes and between groups, diverging from what was postulated and what we expected. The means of papillary excavation were higher in the LLD group. In addition, the mean RNFL thickness was reduced in this group. However, IOP means were higher in the RLD group. Thus, greater glaucomatous damage correlated to increased IOP motivated by posture was not observed.

Our study reinforces the increment in IOP caused by postural movements, both in the supine position and in the lateral decubitus position. In this way, ophthalmologists should pay attention to the increase in IOP at night due to postural changes and the circadian rhythm for the best management of glaucoma patients. Above all, the more advanced cases, in which even small fluctuations in IOP may be relevant for disease progression.

This study does have limitations. The information concerning the posture adopted for sleeping was collected through a questionnaire. However, Kaplowitz et al., through videos in a sleep laboratory, found a significant association between the verified and reported position of the research subjects.[18] In addition, IOP measurements were taken in the afternoon, which does not exactly reflect the same environmental and physiological conditions as at night. Our study did not find a relationship between the habit of sleeping in the lateral decubitus position and the reduction in RNFL between the groups, contradicting the hypothesis initially proposed. However, as a means to understand the effect of posture on the progression of glaucoma, more research is needed.

Clinical Significance

Glaucoma is a major public health problem, and its progression often has no known cause and can lead to a gradual deterioration of the visual field, even in patients whose IOP appears to be under control. It is, therefore, crucial to understand the various risk factors associated with the advance of the illness.

Investigating the effect of sleeping position on the progression of the disease can contribute to the development of preventive measures related to sleeping habits and create clinical guidelines for the management of glaucoma.

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