Association between lateral decubitus sleeping position and asymmetric visual field loss and its progression in primary open-angle glaucoma patients

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Research Article

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Abstract

Background: To investigate the association between lateral decubitus sleeping position (LDSP) and asymmetric visual field (VF) loss and progression in primary open-angle glaucoma (POAG) patients.

Methods: This was a prospective, cohort study. Sixty-eight POAG (53 normal tension glaucoma, NTG) patients with asymmetric VF loss were included from the Wenzhou Glaucoma Screening Program (WGSP) and followed up. A questionnaire was used to determine the LDSP. Asymmetric VF loss was defined as at least 2-dB difference in mean deviation (MD) between the 2 eyes at baseline. According to these values, the better eye and worse eye were defined. The number of those preferring the worse eye LDSP versus the better eye LDSP was compared. The number of progressive eyes with LDSP and fellow eyes of LDSP were also compared.

Results: Forty-five (66.2%) POAG and 34 (64.2%) NTG patients preferred the LDSP. Of these, 24 (53.3%, $p=0.66$) and 16 (47.1%, $p=0.73$) preferred the worse eye LDSP, respectively. Twenty-six eyes of the 45 POAG patients with both asymmetric VF loss and LDSP were judged as progression until the last follow-up (24.7 ± 9.5 months). Among which, there were 12 (46.2%) eyes with LDSP and 14 (53.8%) fellow eyes of LDSP ($p=0.70$).

Conclusions: Approximately two thirds of the POAG/NTG patients preferred the LDSP. However, we could not draw the conclusion that lateral decubitus sleeping position is associated with asymmetric VF loss or glaucoma progression.

Keywords: primary open-angle glaucoma; normal tension glaucoma; preferred sleeping position; asymmetric visual field defect

Background

The glaucomatous defect or progression of the two eyes of the same patient was usually unbalanced,[1-3] suggesting different risk factors between the two eyes are taking effect. It is well known that intraocular pressure (IOP) changes with the body position. For example, the IOP is higher in the supine position compares to the sitting and standing position in both normal subjects and primary open-angle glaucoma (POAG) patients.[4-8] Moreover, this change is more apparent in POAG and normal tension glaucoma (NTG) patients.[9, 10] Hence, one of the possible risk factors, i.e. the lateral decubitus sleeping position (LDSP), which would cause height difference between the two eyes, may associate with the unbalanced glaucomatous defect/progression. The IOP of lower eye in the LDSP was reported to be higher than the upper eye in both healthy volunteers and open-angle glaucoma patients.[11-15] Furthermore, the IOP in the lower eye in the LDSP was higher than that in the supine position.[11-15]

People generally spend one-quarter to one-third of their lives sleeping. During sleep, body position varies between the supine position and lateral decubitus position, often one side dominating. Thus, a better understanding of the association between LDSP and asymmetric VF loss is quite important. In a

retrospective study, Kim et al. reported that 89 (67.4%) of 132 open-angle glaucoma patients with both asymmetric VF loss and preferred LDSP preferred the worse eye in the lower decubitus position ($p < 0.001$), similar results for NTG and high-tension glaucoma subgroups, suggesting that the LDSP may be associated with greater VF loss in glaucoma patients.[16] However, conversely, Kaplowitz et al. reported that right-sided sleeping position was preferred and correlated with a lower VF index on the left eye in 29 low pressure glaucoma patients after 2-night continuously sleep record.[17] To date, there is rare data on the LDSP and glaucoma progression. Hence, this study aims to provide data on LDSP and asymmetric VF loss/progression among POAG patients from Wenzhou Glaucoma Screening Program (WGSP).

Methods

This study followed the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the Eye Hospital of Wenzhou Medical University. All participants signed a written and informed consent.

Participants

Briefly, from March 2014 to September 2015, residents in three districts of Wenzhou (Lucheng, Longwan and Ou Hai), Zhejiang, China, aged ≥ 50 years, and having specific risk factors for open-angle glaucoma (i.e. myopia, diabetes and family history of glaucoma) were screened for the WGSP.[18] Glaucoma suspects were invited for further examination, including questionnaires in the Eye Hospital of Wenzhou Medical University. Finally, 161 POAG patients (127, 78.9%, NTG) were consecutively enrolled.

Inclusion criteria

- POAG in at least one eye
- Asymmetric VF loss, i.e. at least 2-dB difference in mean deviation (MD) between the 2 eyes at the baseline[19]
- Patients signed the informed consent

Exclusion criteria

- Spherical diopter < -6.0 diopter
- History of retina photocoagulation, intraocular surgery (except uncomplicated cataract surgery), or penetrating ocular trauma
- Disease that may influence the IOP or VF test
- Unreliability of the VF test ($> 20\%$ fixation loss, $> 15\%$ false-positive, $> 15\%$ false-negative)
- Any of the eyes used anti-glaucoma medication in recent 1 month.

Preferred sleeping position and preferred lateral decubitus

The sleeping position was asked through the question below at baseline, by a single trained doctor (XFP) who masked to the ophthalmic examination results. The patient's preferred sleeping position (PSP) was defined as the sleeping position with the highest percentage. However, we consider there was no PSP if more than one sleeping position with the same high percentage.

The patient was defined as a right preferred decubitus position if he/she had higher percentage of right decubitus position than left decubitus position, even if supine or prone was the PSP. Vice versa for the left preferred decubitus position.

Question: What's your sleeping position in the last one week? Please fulfill the time percentage before the sleeping position, and please be note the total percentage should be 100%

(1)___% right lateral decubitus position (2)___% left lateral decubitus position (3)___% supine position (4)___% prone position

Definition

POAG was defined if the eye met (1) to (3) items plus (4) and/or (5) item. (1) Elevated IOP without treatment; (2) Open anterior chamber angle (not occludable, no goniodysgenesis); (3) No history or signs of other eye disease. (4) Characteristic glaucomatous optic disc damage (such as enlarged vertical CDR >0.65, disc hemorrhage); (5) RNFL defect (localized or diffused) corresponding to glaucomatous VF defects.

NTG was defined as the *POAG* patients with an untreated IOP (Goldmann) ≤ 21 mmHg for any visit during the baseline and follow up.

The better eye was defined as the eye with a higher MD value at baseline, while the contralateral eye was defined as the worse eye.

Progression of POAG was defined according to one of the following criteria: (1) Glaucomatous experts' judgment (YBL, SDZ); (2) The rate of progression (MD) < -1 db/year,[20] calculated by Humphrey Visual Field Analyzer (Zeiss Forum, Carl); (3) The Cirrus OCT GPA software analyzes data yielded upon the use of the optic disc cube200×200 mode. We considered that "Likely Loss" and "Possible Loss" reflected glaucomatous progression.

Statistical

Statistical analyses were performed using SPSS version 23.0 (SPSS Inc, Chicago, Illinois, USA). Data with normal distribution was presented as the mean $\pm$ 1 standard deviation. The parameters, such as baseline IOP, spherical equivalent, axial length, and result of VF and OCT testing using independent t tests between better eye and worse eye. χ^2 tests were used to analyze the count variables, such as number of preferred LDSP. A P value < 0.05 was considered to be significant difference.

Results

Baseline

In the baseline, 68 out of 161 POAG patients (42.2%) had asymmetric VF loss. Among the 127 NTG patients, 53 (41.7%) had asymmetric VF loss. The mean age of the 68 (31 male, 45.6%) POAG and 53 NTG (23 male, 43.4%) patients with asymmetric VF loss was 64.8 ± 8.1 and 64.2 ± 8.3 years old, respectively. The parameters between the better eye and the worse eye among POAG and NTG patients with asymmetric VF loss were compared and presented in Table 1. The spherical equivalent of better eyes of NTG patients was slightly hyperopic than that of worse eyes ($p=0.04$). The spherical equivalent (in POAG), axial length, central corneal thickness, baseline IOP, and nasal retinal nerve fiber layer were not significantly different.

Among the 68 POAG patients with asymmetric VF loss, 53 (77.9%) had PSP. Forty-five (66.2%) patients had LDSP, including 8 patients with supine PSP. Among the 53 NTG patients with asymmetric VF loss, 42 (79.2%) had PSP. Thirty-four (64.2%) patients had LDSP, including 12 patients with supine PSP. For patients with LDSP, both POAG and NTG patients preferred right-side sleeping position (66.7%, $p=0.025$, and 70.6%, $p=0.016$, respectively). However, no significant difference between worse-eye and better-eye LDSP among POAG (53.3% vs. 46.7%, $p=0.66$) and NTG (47.1% vs. 52.9%, $p=0.73$) patients was found (Table 2).

The parameters between the better eye and the worse eye among POAG and NTG with both asymmetric VF loss and preferred LDSP were compared and presented in Table 3. The spherical equivalent, axial length, central corneal thickness, and nasal retinal nerve fiber layer were not significantly different. Baseline IOP was slightly higher in the worse eye than that in better eye. VF parameters and OCT parameter were significantly different (Table 3).

Follow-up

Thirty-nine (86.7%) of the 45 POAG patients with both asymmetric VF loss and LDSP were followed for at least twice (6.3 ± 3.0 , range 2 to 11). The mean follow-up time was 24.7 ± 9.5 months (range 9.1 to 44.6 months). Among the 39 patients, 26 eyes (26/78, 33.3%) of 21 patients (5 patients with both eyes and 16 patients with single eye) were judged as progression until the last follow-up. Among the 26 progression eyes, 12 (46.2%) eyes with LDSP and 14 (53.8%) fellow eyes of LDSP ($p=0.70$). The parameters changes between these two groups were compared and presented in Table 4. None of them were significantly different.

Discussion

The patients enrolled from the WGSP, a community-based study, had significantly less severe glaucomatous damage compared to those from the clinic (mean MD -9.7 ± 7.3 dB vs. -19.8 ± 9.5 dB). Furthermore, the patients enrolled at the baseline were untreated. These suggested an early stage and

natural characteristics (i.e. avoid certain influence of the anti-glaucoma eye drops at night) of the subjects.

To our knowledge, this is the first longitudinal observation on preferred LDSP and glaucoma progression. There were several important findings. *Firstly*, this study found that near two thirds of both POAG and NTG patients with asymmetric visual field loss preferred LDSP during sleep, which was very close with Kim et al's report (also two thirds).[16, 17] However, it should be noted that we further enrolled patients with preferred supine position (highest proportion of sleeping position) and lateral decubitus position (second high proportion), since we assumed that the supine position had negligible effect on asymmetric visual field loss. Furthermore, more than two thirds of both the POAG and NTG patients preferred to the right-side decubitus position. This was similar with Kaplowitz et al's report observed by means of continuously sleep record.[17] *Secondly*, this study found that the percentage of better-eye and the worse-eye LDSP was close (approximately 50%), thus without significant difference. By means of monitoring the continuous sleep record, a more accurate method to assess the sleeping position, Kaplowitz et al. also found that the lateral decubitus sleeping position was not correlated with visual field defect in low pressure glaucoma patients.[17] Conversely, in a retrospective study, Kim et al. found that approximately two thirds of patients with open-angle glaucoma, NTG or high-tension glaucoma preferred the worse eye decubitus position, on the basis of questionnaire data. *Thirdly*, and the most importantly, in a two-year longitudinal observation, the percentage of progressive eyes between eyes with LDSP and fellow eyes of LDSP was also not significantly different. Similar negative results for the changes of anatomy parameters (e.g. RNFL thickness, rim area) and functional parameters (e.g. MD, PSD) between these two subgroups were found. These suggested, at least in this study sample, the LDSP was not associated with asymmetric visual field defect or its progression.

We speculate that there were several reasons for the inconsistency among different studies. *Firstly*, the exact time distribution among sleeping positions could not be ascertained from the questionnaire. *Secondly*, frequent turning during the sleep may weaken the effect of lateral decubitus on elevation of IOP. Although the present study and previous studies found the majority of glaucoma patients preferred one side when the sleeping,[16, 17] it seems that turning was inevitable. The IOP of the eye with lateral decubitus was approximately 1 mmHg higher than the fellow eye in POAG patients.[17, 21] Hence, the frequent turning during the sleep may weaken the significant but not apparent effect on evaluation of IOP. *Thirdly*, the oppression of the pillow onto the eye may elevate the IOP. Kim et al. found that this effect of the pillow against the eye when in lateral decubitus position, would apparently (and significantly) elevate the IOP (3-4 mmHg), compared to fellow eye.[22] However, at present it is difficult to measure this effect during the entire sleeping process. *Fourthly*, inconsistency of the body posture and the head posture during sleeping. Malihi et al. reported that the effect of change of head posture on IOP may be different from that of body posture.[11] Sleeping positions, mainly referring to the body posture were assessed by questionnaire in several studies, including this study. However, it was difficult for this assessment to obtain the variety of changes to the head posture (e.g. the head turning left when in supine position), which may be more directly associated with the ocular IOP. *Fifthly*, systemic diseases, especially hypertension and cardiovascular disease, may induce an unbalanced distribution of the ocular perfusion

pressure, and further influence the bilateral IOPs. *Finally*, a difference in ethnicity may influence the results.

Limitations of this study remained even with the advantage of longitudinal observation. *Firstly*, the patients' LDSP were obtained by questionnaire at baseline. Certain recall bias and inaccuracy were inevitable, though Kaplowitz et al reported the sleep position monitored by video matched the self-reported one by questionnaire in 77% of participants.[17] Furthermore, we assume that the sleeping habit was relatively stable in adults. *Secondly*, the sample size was relatively small. *Thirdly*, the follow up time was relatively short. Hence, longer term longitudinal studies with large samples and more accurate data collection methods are warranted.

Abbreviations

LDSP: lateral decubitus sleeping position

VF: visual field

POAG: primary open-angle glaucoma

NTG: normal tension glaucoma

WGSP: Wenzhou Glaucoma Screening Program

MD: mean deviation

IOP: intraocular pressure

Declarations

Ethics approval and consent to participate

The study followed the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the Eye Hospital of Wenzhou Medical University. Written, informed-consent of patients was obtained.

Consent for publication

Not Applicable

Availability of data and materials

The datasets used and analysed during the current study available from the additional file 1.

Additional files

Additional file 1: raw data used and analysed in this study (XLSX. 114kb)

Competing interests

The authors declare that they have no competing interests.

Funding

None

Authors' contributions

YBL and JC designed the study protocol and conducted the study as a supervisor. ZL, XFP, XW, SDZ, and KZ participated in the study design. ZL, XFP and CY conducted statistical analysis, and drafted the manuscript. SDZ, YBL and JC revised the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1 The parameters between the better eye and the worse eye among primary open-angle glaucoma (POAG) patients and normal tension glaucoma (NTG) patients with asymmetric visual field loss

	POAG (n=68)			NTG (n=53)		
	Better Eye (mean ± SD)	Worse Eye (mean ± SD)	P value	Better Eye (mean ± SD)	Worse Eye (mean ± SD)	P value
SE	0.58 ± 2.46	0.42 ± 2.50	0.34	0.88 ± 2.33	0.51 ± 2.37	0.04
AL	23.81 ± 1.27	23.87 ± 1.38	0.21	23.74 ± 1.27	23.82 ± 1.43	0.10
CCT	536.57 ± 29.29	537.19 ± 28.96	0.46	536.49 ± 28.88	537.38 ± 27.95	0.26
Baseline IOP	15.40 ± 3.02	15.90 ± 3.69	0.10	14.55 ± 2.31	14.78 ± 2.40	0.32
MD	-3.65 ± 3.48	-9.23 ± 4.87	<0.001	-3.62 ± 3.64	-8.98 ± 4.62	<0.001
PSD	3.68 ± 2.77	8.29 ± 3.50	<0.001	3.71 ± 3.00	8.41 ± 3.54	<0.001
VFI	92.69 ± 8.87	76.87 ± 14.90	<0.001	92.62 ± 9.31	77.36 ± 13.97	<0.001
GCL+IPL	84.57 ± 34.94	76.23 ± 32.29	<0.001	86.62 ± 39.44	78.22 ± 36.38	<0.001
RNFL thickness	83.92 ± 12.55	71.92 ± 12.40	<0.001	83.44 ± 12.76	71.92 ± 12.48	<0.001
Rim area	1.10 ± 0.25	0.98 ± 0.27	<0.001	1.10 ± 0.28	0.98 ± 0.28	<0.001
C/D ratio	0.67 ± 0.15	0.72 ± 0.13	<0.001	0.68 ± 0.15	0.73 ± 0.13	<0.001
VC/D ratio	0.65 ± 0.15	0.72 ± 0.13	<0.001	0.66 ± 0.14	0.73 ± 0.14	<0.001
Vertical cup	0.38 ± 0.26	0.44 ± 0.27	<0.001	0.41 ± 0.27	0.46 ± 0.28	0.005
sRNFL	103.78 ± 20.76	86.88 ± 26.36	<0.001	103.66 ± 21.53	87.08 ± 27.47	<0.001
tRNFL	66.02 ± 11.26	57.71 ± 12.05	<0.001	65.32 ± 10.55	57.68 ± 12.07	<0.001
nRNFL	64.05 ± 9.42	61.71 ± 12.88	0.13	62.36 ± 9.15	61.78 ± 13.20	0.75
iRNFL	102.03 ± 25.92	81.54 ± 24.58	<0.001	102.74 ± 27.13	81.22 ± 25.61	<0.001

SE: spherical equivalent (diopter); AL: axial length (mm); CCT: central corneal thickness (mm); IOP: intraocular pressure (mmHg); MD: mean deviation; PSD: pattern standard deviation; VFI: visual field index; GCL: ganglion cell layer (μm); IPL: inner plexiform layer (μm); RNFL: retinal nerve fiber layer (μm); C/D: cup/disc; VC/DR: vertical cup/disc; sRNFL: superior RNFL (μm); tRNFL: temporal RNFL (μm); nRNFL: nasal RNFL (μm); iRNFL: inferior RNFL (μm).

Table 2 The distribution (n, %) of preferred sleeping position (PSP) and lateral decubitus sleeping position (LDSP) among primary open-angle glaucoma (POAG) patients and normal tension glaucoma (NTG) patients

	POAG (n=68)	NTG (n=53)
PSP		
Right	26 (38.2)	22 (41.5)
Left	11 (16.2)	8 (15.1)
Supine	16 (23.5)	12 (22.6)
Prone	0 (0.0)	0 (0.0)
None	15 (22.1)	11 (20.8)
	POAG (n=45)	NTG (n=34)
LDSP		
Right	30 (66.7)	24 (70.6)
Left	15 (33.3)	10 (29.4)
<i>P value</i> *	0.025	0.016
Worse-eye	24 (53.3)	16 (47.1)
Better-eye	21 (46.7)	18 (52.9)
<i>P value</i> *	0.66	0.73

P value*: tested by chi-square

Table 3 The parameters between the better eye and the worse eye among primary open-angle glaucoma (POAG) patients and normal tension glaucoma (NTG) patients

	POAG (n=45)			NTG (n=34)		
	Better Eye (mean $\pm$ SD)	Worse Eye (mean $\pm$ SD)	P value	Better Eye (mean $\pm$ SD)	Worse Eye (mean $\pm$ SD)	P value
SE	0.65 $\pm$ 2.29	0.60 $\pm$ 2.47	0.74	1.05 $\pm$ 2.14	0.78 $\pm$ 2.24	0.12
AL	23.79 $\pm$ 1.37	23.85 $\pm$ 1.51	0.37	23.69 $\pm$ 1.35	23.78 $\pm$ 1.55	0.15
CCT	539.7 $\pm$ 29.1	540.0 $\pm$ 28.9	0.71	541.9 $\pm$ 28.6	542.6 $\pm$ 28.5	0.50
Baseline IOP	15.4 $\pm$ 3.0	16.1 $\pm$ 3.8	0.02	14.4 $\pm$ 2.0	14.8 $\pm$ 2.1	0.06
MD	-3.67 $\pm$ 3.77	-8.95 $\pm$ 5.02	<0.001	-3.51 $\pm$ 4.00	-8.27 $\pm$ 4.49	<0.001
PSD	3.85 $\pm$ 3.08	8.09 $\pm$ 3.42	<0.001	3.86 $\pm$ 3.40	8.10 $\pm$ 3.57	<0.001
VFI	92.04 $\pm$ 9.74	77.58 $\pm$ 15.61	<0.001	92.18 $\pm$ 10.29	79.32 $\pm$ 13.86	<0.001
GCL+IPL	87.04 $\pm$ 41.53	78.31 $\pm$ 38.43	<0.001	90.21 $\pm$ 47.27	81.29 $\pm$ 43.63	<0.001
RNFL Thickness	84.07 $\pm$ 13.24	73.36 $\pm$ 13.56	<0.001	84.03 $\pm$ 13.28	73.74 $\pm$ 13.48	<0.001
Rim Area	1.12 $\pm$ 0.26	1.02 $\pm$ 0.29	0.002	1.13 $\pm$ 0.29	1.03 $\pm$ 0.31	0.01
C/D Ratio	0.65 $\pm$ 0.16	0.70 $\pm$ 0.14	<0.001	0.65 $\pm$ 0.16	0.70 $\pm$ 0.15	0.002
VC/D Ratio	0.63 $\pm$ 0.16	0.70 $\pm$ 0.15	<0.001	0.63 $\pm$ 0.15	0.71 $\pm$ 0.16	<0.001
Vertical cup	0.32 $\pm$ 0.19	0.39 $\pm$ 0.23	0.001	0.32 $\pm$ 0.17	0.39 $\pm$ 0.22	0.007
sRNFL	103.76 $\pm$ 22.70	90.33 $\pm$ 23.99	0.001	104.26 $\pm$ 23.45	91.18 $\pm$ 24.59	0.008
tRNFL	64.73 $\pm$ 10.20	57.56 $\pm$ 12.09	<0.001	63.79 $\pm$ 8.64	58.35 $\pm$ 12.27	<0.001
nRNFL	64.07 $\pm$ 9.32	61.87 $\pm$ 12.70	0.24	62.00 $\pm$ 8.39	61.26 $\pm$ 12.61	0.75
iRNFL	103.84 $\pm$ 27.75	83.73 $\pm$ 26.13	<0.001	106.44 $\pm$ 28.85	84.15 $\pm$ 27.81	<0.001

SE: spherical equivalent (diopter); AL: axial length (mm); CCT: central corneal thickness (mm); IOP: intraocular pressure (mmHg); MD: mean deviation; PSD: pattern standard deviation; VFI: visual field index; GCL: ganglion cell layer (μm); IPL: inner plexiform layer (μm); RNFL: retinal nerve fiber layer (μm); C/D: cup/disc; VC/DR: vertical cup/disc; sRNFL: superior RNFL (μm); tRNFL: temporal RNFL (μm); nRNFL: nasal RNFL (μm); iRNFL: inferior RNFL (μm).

Table 4 The parameter changes of progressive primary open-angle glaucoma between eyes with lateral decubitus sleeping position (LDSP) and the fellow eyes of LDSP

	Eyes with LDSP (n=12, mean $\pm$ SD)	Fellow eyes of LDSP (n=14, mean $\pm$ SD)	P value
MD	0.77 $\pm$ 2.68	-0.30 $\pm$ 3.40	0.39
PSD	0.15 $\pm$ 1.45	0.53 $\pm$ 2.75	0.63
VFI	0.58 $\pm$ 6.57	-1.79 $\pm$ 8.94	0.46
GCL+IPL	-2.83 $\pm$ 3.16	-1.71 $\pm$ 2.37	0.46
RNFL thickness	-0.92 $\pm$ 3.83	-2.29 $\pm$ 3.91	0.38
Rim area	-0.03 $\pm$ 0.08	-0.04 $\pm$ 0.07	0.67
sRNFL	-3.50 $\pm$ 5.37	-1.36 $\pm$ 9.48	0.90
tRNFL	0.67 $\pm$ 4.31	1.21 $\pm$ 4.98	0.77
nRNFL	0.00 $\pm$ 4.35	0.07 $\pm$ 3.65	0.96
iRNFL	-4.50 $\pm$ 7.74	-3.50 $\pm$ 4.13	0.90

MD: mean deviation; PSD: pattern standard deviation; VFI: visual field index; GCL: ganglion cell layer (μm); IPL: inner plexiform layer (μm); RNFL: retinal nerve fiber layer; sRNFL: superior RNFL (μm); tRNFL: temporal RNFL (μm); nRNFL: nasal RNFL (μm); iRNFL: inferior RNFL (μm).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [supplement1.xls](#)