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Research Article

The Interdictive Tyranny of Dense Cataract Meets Century-Old Maddox Rod in Potential Vision Testing

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ABSTRACT

Cataract surgery is the leading curative surgical intervention globally and a dense cataract impedes adequate preoperative evaluation of structures distal to the opaque lens. An effective potential vision test will have to over-come this 'road block'. The aim of the present study is to assess the ability of Maddox rod to transcend dense cataract in potential vision testing. One hundred and twenty-three (123) eyes of 107 patients booked for elective small-incision cataract surgery were preoperatively assessed with Maddox rod. Eighty-eight (88) eyes were cataract blind. The responses were categorized into grades 1-4 with grade 1 having the best possible response while grade 4 had the poorest response. The mean postoperative visual acuity outcomes of grade 1-4 eyes were 0.441 ± 0.179, 0.440 ± 0.128, 0.432 ± 0.093 and 0.273 ± 0.159 respectively. Grade 3 responding eyes were few (n=5) and were not analyzed further. The mean visual acuity outcome for grade 1 response eyes (0.441 ± 0.179 SD) and grade 2 response eyes (0.440 ± 0.12845) were not significantly different statistically (t=0.240{99}p=0.981). There was a statistically significant difference (t=3.59{101} p=0.001) between the means of the visual outcome of grade 1 response eyes (0.442 ± 0.179 SD) and grade 4 response eyes (0.273 ± 0.159). The over-all sensitivity and specificity of the test were 46.9% and 75.2% respectively. These values were minimally impacted by increased cataract density (sensitivity of 48.3% and specificity of 71.4%).

Maddox rod is a viable alternative in the potential vision testing of cataract-blind eyes that could interdict and make effective even the most advanced posterior segment image-acquisition equipment.

Keywords: Maddox-rod; Dense-cataract; Preoperative; Potential; Test; Postoperative; Surgery; Vision

INTRODUCTION

Opacity of the crystalline lens, otherwise known as cataract, is the single commonest cause of global blindness. Latest statistics from WHO showed that about 45 million people are blind globally of which untreated cataract accounts for 39% or 18 million blind persons [1]. The prevalence of cataract seems to double every ten [10] years from forty years of age and by ninetieth birthday, visually significant cataract is universal [2,3]. Populations in poor and emerging regions of the world bear the brunt of this avoidable cause of blindness. Sub-saharan African has the highest prevalence of cataract blindness of 6.0% in those aged 50 years and above [4]. In Nigeria, cataract is a public health problem [5-9]. The national blindness and visual impairment survey done between 2005 and 2007 showed that cataract was the leading cause of blindness, accounting for 43.0% of 1.13 million blind Nigerians over the age of 40 years with a prevalence of 1.8% [5]. This finding was consistent with other population- and hospital-based studies [6-16]. The increasing life expectancy in parts of Asia and Sub-Saharan Africa will inevitably increase the burden of cataract blindness going forward.

Cataract blindness is reversible after a successful cataract surgery. No effective medical treatment exists for patients with cataract. Cataract surgery is the most cost effective surgical procedure performed worldwide and is responsible for more than one half of all ophthalmic operations in most countries including Nigeria [17-19]. The benefits of cataract extraction in terms of visual rehabilitation and quality of life are immediate, encouraging surgeons to carry out the procedure at increasingly lower levels of visual impairment [20-25]. Expectations from patients for post-operative improvement in visual function have equally become bullish. Litigations can arise when these are not met. Surgeons must therefore devise a means of prognosticating the visual outcome in-order to do a realistic pre-operative counseling of the patient. This is imperative because poor cataract surgery outcome irrespective of

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cause is a major barrier to cataract surgery uptake [26]. Potential Vision Tests (PVT) are ancillary clinical tests that aim to predict the postoperative visual outcome consistent with the state of distal visual function-dependent retino-neural elements. Intact retinal and neural elements are absolute prerequisites for visual improvement after an uneventful cataract surgery [27]. These tests serve to complement the surgeons' judgment which may lack quantitative depth [28]. Current PVTs are on the basis of Psychophysical, electrophysiological and anatomic tests. Pinhole (PH), Potential Acuity Meter (PAM) and retinometer are psychophysical PVTs [29-32]. Light projection and two-point discrimination were earlier PVTs but are hampered by increased scattering of light within the eye in cataract patients [33]. Maddox rod test is another psychophysical test which preferentially evaluates macular function [34]. Maddox rod is composed of linear stack of cylindrical glass rods that converts the image of a point source of light source into a straight light streak that is perpendicular to the axis of the rod in keeping with optics of a cylindrical lens [35]. The red Maddox rod is preferred in PVT protocol because perceived color is an integral part of the test. It is cheap and usually found in a standard trial lens box. Laser Interferometer (LI), blue field entoptic phenomenon, Retinal Acuity Meter (RAM), Optimal Reading Speed (ORS), scanning laser ophthalmometer, ocular B-scan and Critical Flicker Frequency (CFF) have been explored in a bid to achieve a better prediction of surgical outcome [36-39]. Most recently, spectral-domain Optical Coherence Tomography (OCT) has been adjudged as the gold standard with respect to PVT. It can detect early forms of maculopathy that are not clinically apparent [40,41]. It however requires a given degree of media clarity for image acquisition and maybe unsuitable in patients with dense cataract [42]. Moreover, these newer testing algorithms are not readily available in resource-challenged domains such as Nigeria. The aim of the present study is to employ a cheap and handy nineteenth century invention, the Maddox rod, as a PVT in patients with dense cataract. Data is sparse in relation to late cataract presentation and a suitable PVT under such setting.

MATERIALS AND METHODS

Study design

This is a descriptive and observational hospital-based study. The sample size was derived from the findings of Nigerian blindness and visual impairment study which estimated the prevalence of operable cataract in Nigerian adults 40 years and above to be 5.0% (visual acuity of <6/18> perception of light) [5]. The estimated sample size for the study was calculated with Cochran equation for sample size as under:

$$n = \frac{t^2 \times p(1-p)}{m^2}$$

Where n=required sample size

t=confidence level at 95% [1.96]

p=Estimated prevalence of 'operable cataract' at 5.0%

m=margin of error at 5% [0.05]

Substituting the values,

$$n = \frac{1.96^2 \times 0.05(1-0.05)}{0.05^2}$$

=72 Subjects

Correcting for contingencies;

Final sample size is:

[72 × 5/100]+72=76

Rounding up, my sample size was 100 subjects.

Study area/Setting

The study was done at Evangelical Church of West Africa (ECWA) Sabon-Gari Kano, Kano state, Nigeria located in north-western part of Nigeria between August and October 2011. It is a high volume cataract surgery hospital located in the heart of a sprawling cosmopolitan city. The Hausa and Fulani ethnic groups are the predominant populations inhabiting the city and Islam is the dominant religion. It serves as both the commercial and administrative capital of Kano State.

Subjects

Subjects were recruited as consecutive consenting adults with operable cataract and requesting cataract surgery for improved visual performance. They were recruited between August and October 2011.

The following were the inclusion criteria for participation in the study:

- Patients who were 40 years and above.
- Eyes with clear cornea normal anterior segment findings on slit-lamp examination and no history of posterior segment disease.
- Eyes with normal pupillary reactions.
- Patients who were willing to give verbal and written consent to participate in the study
- The following exclusion criteria were enforced:
- Eyes with complicated cataract
- Eyes with sluggish pupillary responses or Relative Afferent Pupillary Reaction(RAPD)
- Eyes with No Perception of Light (NPL).
- Patients who were less than 40 years.
- Patients who had any physical or mental impediment to understanding or responding to the testing parameters.
- Eyes that had intra- or immediate postoperative complication(s).

Materials

The materials used for the study were:

- A KeelerR pen torch of 6 volts rating.
- Illuminated Snellen's optotype illiterate visual acuity chart.
- Red Maddox rod (Gulden, USA).
- millimeter pinhole (Gulden, USA).

Procedure

All the subjects that met the inclusion criteria underwent a complete ocular examination comprising distance visual acuity assessment with Snellen's illiterate optotype visual acuity chart to accommodate illiterate subjects, slit-lamp evaluation, Goldmann applanation tonometry and dilated fundoscopy. The cut-off visual acuity for surgical intervention was a best-corrected preoperative visual acuity of 6/36 to Perception of Light (PL). The visual acuities were recorded in fractions and then converted to their decimal equivalent to make statistical analysis possible. The Maddox rod

test was performed as a dark-room procedure (Supplementary Figure S1).

With the contralateral eye occluded, a red Maddox was placed over the index eye through which the patient viewed a bright point source of light [6-volt torch light] at the patient's preferred reading distance wearing his/her spectacle correction where applicable. The Maddox rod was rotated in three meridia; vertical, horizontal and oblique. The patient's response was then graded as adapted from a study by Dubey et al. as follows [34]:

- Grade 1 response: Patient saw a continuous red line correctly defined the orientation of the line [in all three positions] as the orientation of the Maddox rod is changed.
- Grade 2 response: The orientation of the red line was correctly interpreted as the orientation of the straight line is altered but it appeared interrupted/broken.
- Grade 3 response: The red line was wavy.
- Grade 4 response: The patient can only identify red light.

It took on the average 5 minutes to perform the test including the time spent on explaining the protocol but a few patients did require more time. Only subjects that gave consistent responses were included in the study. The response from each subject to Maddox rod test was entered in Maddox rod response form. Ocular biometry for calculation of Intra Ocular Lens (IOL) power was done for all patients.

For uniformity of surgical procedure, only patients that had Small Incision Cataract Surgery (SICS) were analyzed for the study while those that underwent other forms of cataract surgery (extra-capsular cataract extraction and phacoemulsification) were excluded. The surgeries were done by 2 consultant ophthalmic surgeons and a diplomate in ophthalmology. The decision to proceed with surgery was taken by the surgeon and was independent of the study outcome.

The average postoperative hospital stay was three [3] days with a range of two [2] to six [6] days. The study subjects that stayed longer than 3 days were those that had bilateral cataract surgery [36 patients] which was usually done 2 days after the first-eye surgery. The visual acuity of the subjects was taken with a 1.0 mm pinhole just before discharge. Pinhole visual acuity was chosen over refraction because most of the patients received topical 1% cyclopentolate instilled in the operated eye in the immediate postoperative period and so had dilated pupils. The same illuminated Snellen's optotype visual acuity chart was used for postoperative visual acuity assessment.

Data management

Data collation and cleaning was done prior to analysis. Baye's theorem was used to calculate sensitivity and specificity [43]. Differences between means were processed with SPSS version 23R software and a p-value less than 0.05 was reported as a significant finding. Data presentation was done in prose, tables, charts and figures.

Helsinki declaration regarding the conduct of research involving human Subjects was up-held [44]. Informed verbal and formal signed consent was duly obtained from all participating patients (Supplementary Figure S2) and Ethical clearance was obtained from Health Research Ethics Committee of University of Nigeria Teaching Hospital, Ituku-Ozalla, Enugu.

RESULTS

One hundred and thirty three eyes (133) of one hundred and sixteen (116) consenting adult patients were enrolled for the study in ECWA Eye Hospital Sabon-Gari, Kano, Kano State, Nigeria during the period of the study. One hundred and twenty-six (126) eyes of one hundred and eleven (111) patients underwent Small-Incision Cataract Surgery [SICS] with intra-ocular lens insertion as calculated from biometry. Four eyes of three patients were offered phacoemulsification while three eyes of two patients had Extra Capsular Cataract Extraction (ECCE). These seven eyes of five patients were excluded from further analysis. One eye in the SICS group had intra-operative vitreous loss and two eyes developed postoperative corneal edema and they were equally excluded from the study. Thus, one hundred and twenty-three (123) eyes of one hundred and five (105) patients were finally analyzed for this study. The demographic characteristics of the participants are presented in the Table 1 below:

Eighty-three eyes of Seventy-two male patients (68.6%) were men while the forty eyes thirty-three patients (31.4%) were women. This represented a male to female ratio of 2.2. The right eye was slightly more involved than the left eye. The mean age of the patients was 61.5 years+7.7 Standard Deviation (SD) with a range of 40 to 86 years. Females had a slightly higher mean age (62.4 years) when compared to men (60.8 years).

The pre-operative visual acuity also varied and 88 eyes representing 71.5% were blind (2/60 to perception of light) while 35 eyes (28.5%) had preoperative visual acuity of 3/60 or better (3/60 to 6/36). Details of pre-operative visual acuity in percentages are illustrated in the pie chart below (Figure 1):

From pie chart above, Perception of Light (PL) was the modal entry visual acuity, followed by Hand Movement (HM) and between them accounted for 56% of all eyes.

Eighty six eyes or 69.9% had a grade 1 maddox rod test response, 15 eyes gave a grade 2, 5 eyes had a grade 3 response while 17 eyes was a grade 4 responders. All the 17 eyes with grade-4 response were blind. The tables below summarize the responses obtained from the study subjects (Table 2).

The modal post-operative visual acuity outcome was 6/12 (0.5) which was observed in 46 eyes. According to WHO, a good surgical outcome denotes postoperative visual acuity of 6/18 or better and

Table 1: Demographic characteristics of the study participants.

		Male	Female	%
No. of patients		72	33	
Age (years)				
	Mean	60.8	62.2	
	Range	42-78	40-86	
	40-49	9	2	11%
	50-59	25	10	33%
	60-69	24	11	33%
	70-Above	14	10	23%
Mean		60.8	62.2	
Range		42-78	40-83	
No. of Eyes		83	40	
Eye involvement				
Right eye		44	20	52%
Left eye		39	20	48%

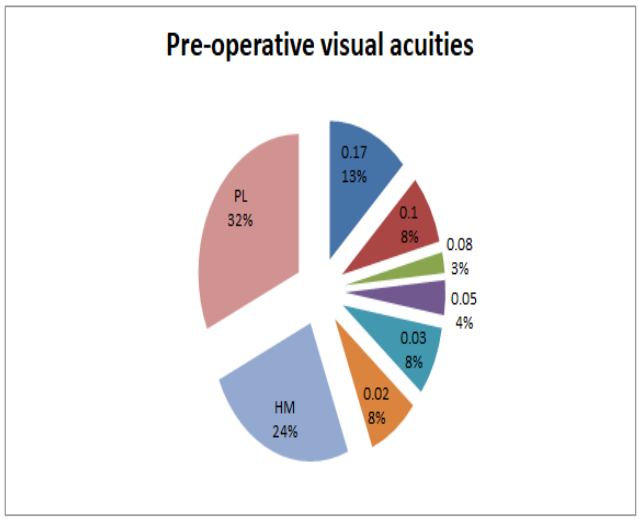

Figure 1: Pie chart showing the pre-operative visual acuity distribution of subjects (in percentages).
Abbrevations: HM: Hand movement; PL: Perception of light

Table 2: Preoperative visual acuity and Maddox rod response in study subjects.

Maddox rod grade	No. of eyes
Grade 1/	86
VA ≥ 6/60	15
VA<6/60	71
Grade 2/	15
VA ≥ 6/60	4
VA<6/60	11
Grade 3/	5
VA ≥ 6/60	1
VA<6/60	4
Grade 4/	17
VA ≥ 6/60	-
VA<6/60	17

visual acuity of 6/24 to 6/60 is a borderline surgical outcome while any visual acuity less than 6/60 is a poor surgical outcome after errors of refraction have been corrected. 91 eyes or 74.8% achieved good post-operative visual outcome while 32 eyes representing 25.2% obtained a borderline visual outcome. No patient had poor visual outcome after excluding subjects that had intraoperative complication. The pie chart below shows the distribution of visual outcomes (Figure 2).

In the Table 3 below, the postoperative visual acuity outcome of the subjects was matched with corresponding preoperative Maddox rod test response (the decimal equivalent of the visual acuity is enclosed in bracket):

Subjects with preoperative severe visual impairment and blindness were isolated to compare their response to the test and their postoperative visual outcome. Values obtained are shown in the Table 4 below.

The sensitivity and specificity of Maddox test was worked out on the basis of its ability to identify subjects with no apparent macular abnormality (grade 1) subsequently had a good visual outcome

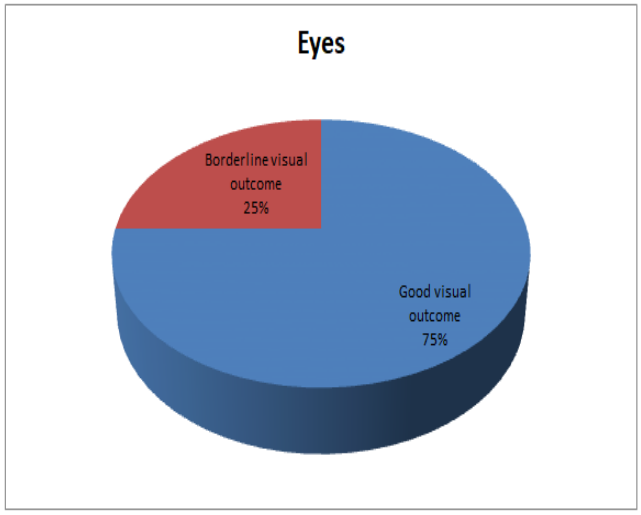

Figure 2: Pie chart representing the visual acuity outcomes in participants (WHO classification).

Table 3: Maddox rod response grade and postoperative visual outcome in study patients.

Maddox rod grade	1	2	3	4
Postoperative VA (No. of eyes)				
6/6 (1.00)	1	-	-	-
6/9 (0.69)	18	-	-	-
6/12 (0.50)	26	12	3	5
6/18 (0.33)	24	-	2	-
6/24 (0.25)	9	2	-	4
6/36(0.17)	8	-	-	5
6/60 (0.10)	-	1	-	3
Mean VA	0.44	0.44	0.43	0.27

Table 4: Postoperative visual outcome of eyes with severe visual impairment or worse and the corresponding Maddox rod responses.

Maddox rod response	1	2	3	4
Visual acuity				
6/6(1.00)	-	-	-	-
6/9(0.69)	11	-	-	-
6/12(0.50)	16	10	3	5
6/18(0.33)	23	-	2	-
6/24(0.25)	8	2	-	4
6/36(0.17)	7	-	-	4
6/60(0.10)	-	1	-	3
Mean VA	0.41	0.37	0.43	0.28

and those with significant macular disease (grade 2-4). In addition, the same parameters were also calculated for subjects whose preoperative visual acuity was less than 6/60 signifying a dense cataract. The obtained values are displayed in the Table 5 below.

The above table suggests that cataract density has minimal impact on the sensitivity and specificity of Maddox rod test.

The means of visual outcome for grade 1 responders were compared to that of grade 2 and grade 4. Only 5 subjects gave grade 3 response and that number cannot be reliably analyzed. A 2-tailed test of significance of mean was done and the outcome is

Table 5: Sensitivity and specificity Maddox rod test for all subjects and subjects with at least severe visual impairment on the basis of good visual outcome.

Grade 1	Sensitivity	Specificity
GLOBAL	46.90%	75.20%
VA<6/60	48.30%	71.40%

Table 6: Group statistics to compare grade 1 and grade 2 response outcomes.

Grade	N	Mean	Std. Deviation	t-test	df	Sig(2-tailed)
acuity 1	86	0.4412	0.17887	0.24	99	0.981
2	15	0.44	0.12845			

Table 7: Group statistics to compare grade 1 and grade 4 response outcomes.

Grade	N	Mean	Std. Deviation	t-test	df	Sig(2-tailed)
acuity 1	86	0.4412	0.17887	0.59	101	0.001
2	4	17	0.2735			

as under (Tables 6 and 7).

DISCUSSION

Cataract surgery is unlikely to be supplanted as the single commonest surgical procedure in orthodox medical practice in the foreseeable future. The essence of PVT is to prognosticate and offer appropriate preoperative counseling in cataract patients. One hundred and twenty–three eyes of one hundred and five patients were analyzed in the study (Table 1). The mean age of the subjects was 61.5 years and females were slightly older than men. Old age remains the single most important risk factor for cataract formation [5-19]. The male to female ratio was 2.2. Poor cataract surgical uptake among the female gender has been reported in previous studies [1,5,18]. Most of the subjects severe visual impairment or worse [80.5%] and light perception was the modal entry visual acuity [32%]. A number of socio-cultural factors have been adduced for late presentation in the study area [7-14]. The surgical outcome in seventy five percent of the operated eyes was good while a borderline outcome was observed in the remaining twenty five percent (Figure 2). The mean postoperative visual acuity outcomes of grade 1-4 eyes were 0.441 ± 0.179, 0.440 ± 0.128, 0.432 ± 0.093 and 0.273 ± 0.159 respectively. The mean visual acuity outcome for grade 1 response eyes (0.441 ± 0.179 SD) and grade 2 response eyes (0.440 ± 0.12845) were similar and was not statistically significant (t=0.240{99}p=0.981). There was a statistically significant difference (t=3.59{101} p=0.001) between the visual outcome of eyes with grade 1 response (mean VA 0.442 ± 0.179 SD) and the visual outcome of eyes with grade 4 response (mean VA 0.273 ± 0.159). Given that only 5 eyes matched a grade 3 response, this group could not be reliably subjected to further statistical analysis.

Considering the preoperative responses to Maddox rod, the overall sensitivity and specificity of the test in this study was 46.9% and 75.2% respectively (Tables 3 and 5). In subjects with at least severe visual impairment (VA<6/60), the sensitivity and specificity of the test were largely unaltered at 48.3% and 71.4% respectively (Tables 4 and 5). It thus appears that cataract density has little influence on the outcome of Maddox rod test.

There is a general paucity of data on the use of Maddox rod as PVT despite the fact that it was invented in the 19th century. Dubey et al. did report an association between a grade 1 response and having a good surgical outcome [34]. The sensitivity of their test was 87.1% and specificity was 100%. These values are higher than the findings in the present study but most of their subjects had mild to moderate cataract pre-operatively unlike in this study. A review of other potential vision tests showed that Scanning Laser Ophthalmometer (SLO) can achieve a sensitivity and specificity of 96.4% and 100% respectively while Potential Acuity Meter (PAM) had a reported sensitivity of 67.0% and specificity of 100% [39]. These studies however were done in patients with non-blinding cataract and their authors acknowledged that a dense-cataract eye will likely be unsuitable for the tests. Vryghem et al. [44,45] devised a macular function test as a PVT for cataract patients and obtained a sensitivity of 92.7% and specificity of 75.0% within 1 line of visual acuity in their study of 396 patients. However, they were also quick to state that presence of dense cataract undermined the outcome of their test. Shankar et al. [37,45] used critical fusion frequency (CFF) to assess a cohort of preoperative cataract patients. It had a sensitivity and specificity of 88% and 90% respectively. They also reported that cataract density had limited effect on the test outcome. However, their definition of dense cataract included preoperative visual acuity of LogMAR>0.5 or 6/24. Cataract-blind eyes predominated the present study and it may be an over-reach to extrapolate their assessment to include such subjects. Ocular B-scan can image structures distal to an opaque lens but only gross abnormalities such as vitreous hemorrhage, chorio-retinal tumors and retinal detachment can be seen. Current opinion among cataract surgeons appears to be in favor of canonizing spectral-domain optical coherence tomography (OCT) as the equipment of choice regarding PVT in cataract patients. OCT has been shown to detect subclinical maculopathies that could torpedo the visual outcome of an otherwise uneventful cataract surgery [40-41]. However, equipment cost and presence of dense cataract will be significant drawbacks for this form of investigation in a practice area such as ours [42,46].

CONCLUSION

An unforeseen posterior segment disease can result in a poor cataract surgery outcome and constitute a barrier to its uptake in populations that most need it. The present study was able to show a significant association between a grade I Maddox test response and a good surgical outcome irrespective of degree of cataract density while a grade 4-responding eye should prompt further investigation(s). Maddox rod is inexpensive and requires no maintenance, readily available, simple to administer and it is easily understood even by illiterate patients. A possible combination of sporadic access to advanced PVT instruments such as OCT and late cataract-blind eye presentation recommends Maddox rod test in our practice area. Further research to interrogate the effect of refractive error, age and cataract type namely cortical, nuclear or posterior sub-capsular on Maddox rod response will improve the usefulness of this simple test in appropriate practice environments.

LIMITATIONS OF THE STUDY

The effect of uncorrected refractive error on Maddox rod response is unknown and might a confounding factor. All the patients were offered manual small incision cataract surgery but the relative short postoperative duration could have effect on the observed visual outcome. A pinhole was used to mitigate this confounding variable.

A larger sample size would permit for a more detailed and definitive study of associations between type of cataract and Maddox rod test response. The effect of patient's age could not be controlled in the study and may be an important variable.

CONFLICT OF INTEREST

The authors hereby declare that there was no conflict of interest regarding this study. No research grant was received by the authors for this study.

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