Original Article

Prescription of near addition and its relation to accommodative reserve in presbyopia - The dichotomy between theory and practice

Susmi Deepu[1,2], Evon Selina Kujur[2], Saban Horo[2], Nancy Priyanka[2,3], Satheesh Solomon T Selvin[2], Thomas Kuriakose[2]

Purpose: To study the relationship between the amplitude of accommodation (AA) measured by the Royal Air Force (RAF) rule and near addition (NA) prescribed in presbyopic patients to assess how far practice is different from theoretical recommendations. **Methods:** Patients, aged 40 to 60 years with best corrected vision of 6/6 N5 were included in this cross sectional observational study. AA was measured using the RAF rule. Refined with near Duochrome chart, the NA was given with the chart at 40 cm. Accommodative reserve was calculated from the measured AA, NA required and the calculated additional accommodation expended by the patient for reading. The percentage of reserve was calculated with and without the correction for depth-of-field. **Results:** A total of 130 patients were studied. In the patients above 50 years of age, the negative correlation of AA with age was -0.298 ($P = 0.065$) and AA and NA was -0.365 ($P = 0.002$) was weak. Among the patients aged between 40 and 50 years, the negative correlation of AA with Age and NA were strong; -0.853 ($P < 0.0001$) and -0.823 ($P < 0.0001$) respectively. When prescribing glasses, 62.01% (CI 58.78 to 65.23) and 90.93% (CI 62.50 to 119.37) of the AA was found to be kept in reserve for patients below and above 50 years of age respectively. **Conclusion:** Accommodative reserve kept in our study patients when prescribing NA was two to three times the theoretical recommendation. High percentage of accommodation kept in reserve suggest that the measured AA is not activated normally and require higher NA and one should not rely on patient's ability to generate accommodative power especially in patients over 50 years.

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Accommodation refers to the process of change in the dioptric power of the human crystalline lens when the point of regard is brought close to the person from infinity. Accommodation increases converging power of the human lens so as to compensate for the divergence of rays from near target and keep the point of focus on the fovea. The accommodative effort, measured as the amplitude of accommodation (AA) represents the maximal voluntary accommodative effort put to see the nearest possible object in an eye that is emmetropic or corrected for distant vision.[1] Ideally, it is measured from infinity to the nearest point of subjective clear vision with maximal accommodation expended, without compensation for the depth-of-field.[2]

Presbyopia refers to the slow, age related, naturally occurring, irreversible reduction in maximal accommodative amplitude sufficient to cause symptoms of blur for near objects.[2] In situations like these, the near point of accommodation (NPA) recedes to a point where it becomes difficult or impossible to accommodate sufficiently for any near work. Near work is considered difficult for most people when the AA drops to less than five diopters.[3] Difficulty with near vision is usually reported by the patients when they reach around 40 to 45 years of age.[4] However it can set-in as early as 38 years or as late as 48 years of age, depending on a variety of factors. From about 52 years onwards, the prevalence of presbyopia is considered to be near 100%.[2] Modulus of the elasticity,[5] sclerotic changes[6] and the volume of the lens[7,8] are the three attributable factors that have been traditionally considered contributing to the age-related loss of accommodation. The defective accommodation is compensated to a certain extent by the depth-of-field of the optical system and the tolerance to the blur by the individual.[9] The onset of symptom varies with the patient's preferred working distance, the duration of the near effort and the nature of near work.

Giving additional convex lens for near vision is the main stay of treatment for presbyopia. In clinical practice the correction for near vision is given after ascertaining and correcting the static refractive error for distance. The "near addition" (NA) of plus power is given with the distance vision correction

[1]Optometrist, Lady Willington Hospital, Manali, Himachal Pradesh, [2]Department of Ophthalmology, Christian Medical College, Vellore, Tamil Nadu, [3]Optometrist, Salins College of Optometry, Bidar, Karnataka, India

Correspondence to: Dr. Satheesh Solomon T Selvin, Schell Eye Hospital, No 1, Arni Road, Vellore - 632 001, Tamil Nadu, India. E-mail: ssts@rediffmail.com

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in place.[10] The NA required depends on both the working distance and the residual power of accommodation in an individual. In theory, it is recommended to keep one third of the patient's accommodative power as reserve so that patient does not over strain for near work.[11,12] However, in routine clinical practice, we noted there was a disconnect between what is being practiced and the theoretical recommendation. To the best of our knowledge there has been no study looking to see the actual amount of accommodation kept in reserve when prescribing presbyopic correction. Our study aimed to measure the AA with the RAF (Royal Air Force) rule and calculate the accommodation kept in reserve when NA was prescribed to our study patients in the clinic and to assess how far practice is different from theoretical recommendations.

Methods

This was a prospective cross sectional observational study conducted in a tertiary eye care center in India. The study was approved by the Institutional Review Board (IRB MIN No: 9784 [OBSERVE] dated 03.12.2016) and was conducted in accordance with the tenets of the Declaration of Helsinki. All patients between 40 and 60 years who were registered for an out-patient consultation and had a best corrected distant vision of 6/6 (Snellen Visual Acuity Chart) and near vision of N5 (with Times New Roman font chart), were invited for the study by the triage optometrist. Patients with diabetes, hypertension, and history of taking systemic medications or had past ocular surgeries identified at the time of triaging were not invited. Patients with refractive error >±3.00D sphere and/or cylinder >±0.75D were excluded. An informed consent was taken from those willing to participate.

The enrollment and collection of demographic data was done by the primary investigator. Right eye was taken as the study eye if the 'screening' best corrected visual acuity (BCVA) was 6/6 for distance and N5 for near. A single optometrist blinded to the age of the patient and screening refraction values reassessed the patient according to the study protocol (retinoscopy followed by subjective refinement) to obtain the distance and near correction. The NA power was assessed at the standard working distance of 40 cm. The NA was refined using the near duochrome testing plate of the self-illuminated near vision drum (VED Enterprise Mumbai, India). The end point was seeing the letters on both the red and green plates equally clear.

Blinded to the value of the spectacle correction needed, the primary investigator measured the NPA of the study-eye. The NPA was measured using the RAF rule keeping the full distance correction in place. With the RAF rule positioned on the cheek as prescribed and kept in a slightly depressed position to the cheek, the reading chart of the rule was pushed in slowly from the end of the rule at 50 cm to the point where the N5 letters started to blur. The reading plate was then slowly pushed back away from the eye till N5 line was just seen clearly. The reading on the scale was noted as the NPA for the patient, reciprocal of which in meters gave the AA in diopters. If the patient could not see the N5 letters even at the end of the scale (50 cm mark) due to an uncorrected NPA beyond that point, a +2.00D sphere was added to the trial frame and the same procedure followed. If a +2.00D lens was added prior to testing, the actual NPA was back calculated mathematically by subtracting two diopters from the AA calculated. Thus if the measured NPA was 20 cm after adding +2.00D, the final AA will be reciprocal 20 cm which is 5D, minus 2D that was added or 3D.[13] After measurements the patients were sent to the ophthalmologists for their routine ophthalmic examination. After the examination, the medical records of the patients were scrutinized to rule out media opacity, presence of cataract, any retinal pathology, strabismus or evidence of past ocular surgeries and were excluded if any of these were present. In our study, emmetrope was defined as anybody with a distant correction of spherical equivalent of less than ± 0.50D sphere. Similarly, hypermetropes and myopes were defined as eyes with a spherical equivalent equal to or more than + 0.50D and -0.50D respectively.

At 40 cm if one cannot read, it means the eye cannot compensate for the divergence of rays coming from that point. The NA given to the patient and the subject's own accommodative effort overcomes the divergence of rays from near and enables them to read. The patients accommodative effort is part of the AA, with the rest kept as reserve. The amount of accommodation reserve kept was calculated by first subtracting the NA required by the patient at 40 cm from +2.50D (the convergence of light required to overcome the divergence of light at 40 cm) and this value is subtracted from the AA to get the reserve. The obtained reserve was then converted into percentage by dividing the accommodation reserve by the AA and multiplying by 100. Thus if the NA given to a patient is + 2.50D and the AA measured was + 3.00D, then the accommodation reserve was calculated as 3.0 - (2.5-2.5) which was equal to 3.00D; this means that 100% of the AA was kept in reserve. Since the measurement of AA by the RAF rule does not exclude the effect of the depth-of-field we also calculated the accommodative reserve after subtracting +1.75D (attributed to the depth-of-field)[10] from the AA measured by the RAF rule. If the measured AA was less than 1.75D then the measured AA was also used as the depth-of-field correction. If NA at 40 cm was more than + 2.50D (the amount required to counter the divergence at 40 cm) only 2.5 was used for calculation of the accommodative reserve. Incorporating the correction for depth-of-field, to calculate the percentage of reserve of accommodation in a patient who has a measured AA of 3.75D and NA of +2.00D, the corrected AA is obtained by reducing the depth-of-field from the measured AA (i.e., 3.75-1.75 = 2.00D). The amount of accommodation generated by the patient would be 2.50-2.00 = 0.50D. The reserve kept would be 2.00-0.50 = 1.50D and the percentage reserve will be 1.50/2.00 x 100 or 75%."

Statistical methods

Categorical variables were summarized using frequencies and percentages. Quantitative variables were summarized using mean and standard deviation for normally distributed variables or median & IQR for skewed-variables. Independent-t-test was used to compare continuous outcome between groups and Spearman's rank correlation test was used to find the relationship between the quantitative variables. All the statistical analysis was done using STATA/IC13.1.

Results

A total of 150 patients were invited for the study and 20 patients who did not fulfill the study criteria were excluded. 130 patients were finally included in the study of which 60 were males. The average age of the subjects was 46.89 yrs.

Table 1 gives the age wise distribution of the patients with their refractive error. Table 2 shows the AA as measured by the RAF rule and the uncorrected accommodation reserves kept while prescribing the NA. This shows a steady rise in the reserves kept from 71% in to the less than 45 years age group to 102% in the 55 to 60 years. Table 3 shows the correlation between age & NA, age & AA and AA & NA in Hypermetropics, Myopics and Emmetropia. There was a strong correlation in all the sub-groups. Table 4 shows the accommodative reserves kept, after correction if the NA was more than +2.50D and by removing the component of AA thought to be due to 'depth-of-field' when an RAF rule is used in patients. Table 4 also shows the Spearman's correlation co-efficient of AA, NA and age among those above and below 50 years of age. It is seen that the negative correlation between age & AA; NA & AA is strong in the younger age group but weak in the group of patients above 50 years of age. Since the number of patients between 55 and 60 years was small a subgroup analysis was not possible. However if one looks at the correlation graph for AA and age in Fig. 1 one can appreciate that data points of the patients above 55 years of age is above the line representing the slope of correlation and seem to be in a straight line.

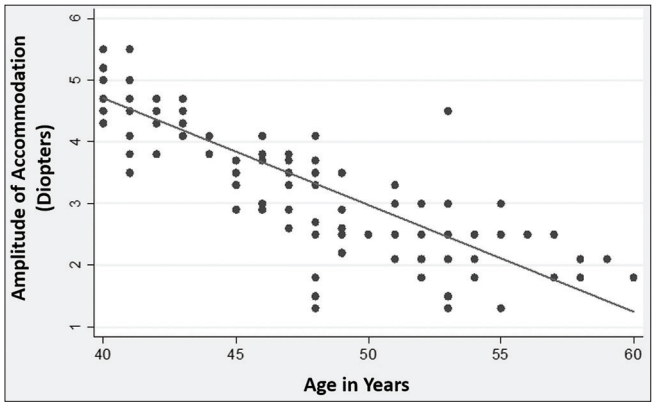

Figure 1: Scatter plot of the correlation between age & amplitude of accommodation (n = 130) showing all data points above the line of slope after 55 years of age

Table 1: Distribution of subjects by age and the type of the refractive error

Age in Years	Number of subjects (Refractive Error)			Total
	Emmetropia	Hypermetropia	Myopia	
40-44	35	10	9	54
45-49	16	14	6	36
50-54	7	18	1	26
55-60	1	9	4	14
Total	59	51	20	130

Discussion

Accommodation and the factors that contribute to help us see near objects is still not fully understood. Changes in the lens curvature, movement of the lens during the accommodative effort, changes in refractive indices of the lens due to changes in lens volume, the photoreceptor density at the fovea, depth-of-field of the optical system and finally the central processing of images all contribute to the end result of accommodative effort. Measuring accommodation is difficult due to the contribution of all these factors and there can be many sources of errors while measuring AA.[14] While newer methods are available that looks at changes in the lens curvature and position[15] we decided to use the RAF as a measure of the entire accommodation process and not to measure only the lens changes that occur during accommodative effort. The depth-of-field inherent in an optical-system also plays a part in near vision and the effect of this is also captured when quantifying the AA with an RAF rule. A depth-of-field of 1.75D has been postulated for the eye which we have used in our study for calculations.[10]

We studied the population between 40 and 60 years because a good number of the patients in our setting present with presbyopia at 40 years itself. By 60 years majority of our population have lens changes that would exclude them from this study. After the sixth decade of life, the amount of accommodative changes of the lens is negligible.[6,16,17] It has been mentioned that between the age of 40 and 60 years about 1.75D of clinical AA is actually caused by the depth-of-field.[10] Therefore we have also used AA values after subtracting 1.75D attributed to the depth-of-field to calculate the percentage of reserves kept while giving the add. If the patient felt the appropriate NA at 40 cm was above + 2.50D only 2.50 was used in the 'corrected' group for analysis of accommodative reserve as that is the only power that should be subtracted from +2.50D required at that distance. If the AA measured by RAF is less than +1.75D it does not make logical sense to subtract more than the measured AA as depth-of-field from the measured value. In these cases what was measured was subtracted as correction for depth-of-field. Here the assumption was that whatever the measured value is, that should be attributed to the depth-of-field and there is no remaining accommodative power present. The corrected AA in these cases were made zero for calculations of the reserve.

The accommodative ability steadily declines starting from the age of five years and a progressive decline in the AA is seen

Table 2: Age wise distribution of the patients with the amplitude of accommodation (AA) and calculated accommodation reserves before correcting for near addition of more than +2.5 D and depth of field less than 1.75 D

Age in years	Mean AA in Diopters (±SD)*	Mean accommodation reserves in Diopters (±SD)	Mean percentage of reserve (CI)**
40-44 (*n*=54)	4.60 (± 0.44)	3.29 (± 0.38)	71.34% (70.58, 72.09)
45-49 (*n*=36)	3.11 (± 1.22)	2.32 (± 0.66)	73.41% (70.28, 76.53)
50-54 (*n*=26)	2.48 (± 1.16)	2.20 (± 0.62)	80.44% (78.29, 82.58)
55-60 (*n*=14)	2.28 (± 1.67)	2.30 (± 0.43)	102.06% (95.86, 108.25)

*SD - Standard Deviation, **CI - Confidence Interval

Table 3: Correlation between age, near addition and the amplitude of accommodation

Spearman's Rank Correlation	Emmetropes (*n*=59)	Myopes (*n*=20)	Hypermetropes (*n*=51)	Combined (*n*=130)
Correlation between Age and NA	0.912 (<0.001)	0.985 (<0.001)	0.961 (<0.001)	0.963 (<0.001)
Correlation between Age and AA	-0.847 (<0.001)	-0.932 (<0.001)	-0.687 (<0.001)	-0.875 (<0.001)
Correlation between NA and AA	-0.824 (<0.001)	-0.939 (<0.001)	-0.824 (<0.001)	-0.865 (<0.001)

AA - Amplitude of accommodation; NA - Near addition

Table 4: Percentage of accommodative reserve after correction for excessive near addition and reducing depth of field in the age categories below and above 50 years, along with respective correlations of age, near addition (NA) and the amplitude of accommodation (AA)

Age Group	40-50 years	51-60 years
Number of subjects	91	39
% of reserve after correction (95% CI)*	72.25% (70.92, 73.58)	91.56% (89.52, 93.59)
% of reserve after correction and deducting 1.75 D** from AA (95% CI)	62.01% (58.78, 65.23)	90.93% (62.50, 119.37)
Correlation between Age and NA	0.914 (<0.001)	0.671 (<0.001)
Correlation between Age and AA	-0.858 (<0.001)	-0.298 (0.065)
Correlation between NA and AA	-0.828 (<0.001)	-0.365 (0.002)

*CI - Confidence Interval, **Depth of Field correction

ranging from approximately 0.2 to 0.45 D/year.[18-23] In our study the AA as measured by RAF rule reduced at an average rate of 0.14 D/year. This is because people above 40 years have very low AA and further reduction in absolute terms will be small. The amount of accommodation kept in reserve for reading increased from 62% for those below 50 years to around 90% for those over 50 years [Table 4]. This would suggest that the eye by default wants to expend minimum accommodative reserve possible and be rather dependent on the power of the glasses. In older people the additional strain of activating the already depleted accommodative reserve can be a factor. The higher adds (above the + 2.50D required to compensate for the –2.50D divergence at 40 cm) used by some of the older patients could also be for the magnification offered by the plus lenses and the greater clarity thereof. Trying to keep 1/3rd AA measured by RAF rule as reserves seems to be an unnecessary exercise and will cause an under correction of the near add especially in the older patients.

In the population we evaluated, the NA given was much more than the theoretical recommendation. The reserves measured by RAF in older patients do not seem contribute to the accommodative effort for routine near work. This could be due to the inherent inertia in the system or the possibility that most of the measured AA in the older patients are compensatory mechanisms like depth-of-field, neural plasticity etc. Accommodation lag could be another factor that was contributing to this difference in what is being practiced and the theoretical recommendation.[9] In clinic testing conditions the patient is often expected to react quickly to the reading comfort offered by the trialed lens and there is not enough time to overcome the accommodation lag which is more pronounced in older patients due to the stiffer lens fibers. Since exercising the accommodative muscles is not known to improve accommodative effort there should be no harm giving the correction the patient is most comfortable with. Though as expected our patients showed a negative correlation between age and AA, what was interesting was the decreasing correlation between the AA and the age, after 50 years. This reduction in correlation seems to become more pronounced after 55 years as seen in the graph [Fig. 1]. Since the number of patients between 55 and 60 were small, a subgroup analysis was not possible. From Fig. 1 one can appreciate however that data points of the patients above 55 years of age is above the line representing the slope of the correlation and the drop seems to have stabilized. Factors other than the contribution from the lens may be responsible. Study by Mordi *et al.* showed that the tonic accommodation and the AA decreased with increasing age, whereas the subjective depth-of-field increased with age.[24] It could be postulated that contribution of the lens related change to the AA has plateaued and the measured AA is due to a combination of the depth-of-field and the limited ability to change the accommodation of the lens quickly. That the AA decreases with age till 50 years and then plateaus, has been mentioned in the literature.[2] In spite of limited numbers our study too shows a similar pattern. AA has been measured in pseudo-phakic patients[25] and in our unpublished observation too we found that we could measure varying amounts of AA with the RAF rule (mean = +2.00D, CI 1.61 to 2.39; Range 0.5 D to 4.55D) in pseudo-phakic patients. This could only be due to the depth-of-field of the eye as an optical system. In our sample, a wide confidence interval for the percentage of accommodation kept in reserve was noted; this is probably a reflection of the variation in the depth-of-field in different people. When studying accommodation, other factors like depth-of-field that improves near vision should not be ignored and efforts can be directed at improving the depth-of-field when designing aids to improve near vision.

Our study has limitations. Authors have questioned the use of RAF rule to study AA.[26] Errors are possible due to the design of the scale of the instrument and the fact that it is a psycho-physical test. RAF rule measures more than the lenticular component of accommodation, it is a measure of the near vision experience. A hospital-based study like this may not reflect the true state in the general population. The number of patients we could recruit above the age of 55 years

was markedly lower than the other age groups. This study excluded the patients with high spherical and cylindrical power to keep the sample more uniform.

Conclusion

In conclusion the accommodation reserves kept while prescribing NA in our practice was more than 60% if AA is measured by the RAF rule. There is a need to study further the whole concept of keeping reserves while prescribing NA. Correlation between the NA given and the age of the patient decreases after 50 years of age.

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Conflicts of interest

There are no conflicts of interest.

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