Preferred Practice

Integrating binocular vision assessment in refractive surgery work-up: Proposition and protocol

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Refractive surgeries are one of most commonly performed surgeries for correcting visual impairment due to refractive errors. With the increase in demand for refractive surgeries, there is an enormous strain on the operating surgeon for delivering ideal outcomes i.e 20/20 visual acuity. Regression, under-correction and ectasia are the most dreaded complications post-refractive correction, for the surgeon as well as the patient. They have significant effects on the quantity of the vision and most importantly on the quality of life of the patient. With the advent of digital era and jobs requiring the eyes being glued to the screen for hours there has been a surge in the patients presenting with complaints of asthenopia, glare, halos, and difficulty in focusing; pointing towards diagnosis of non-strabismic binocular vision anomalies (NSBVA). NSBVA in a postrefractive surgery patient may masquerade as regression or under-correction. However, timely diagnosis of NSBVA in such patients would prevent the greater harm caused by wrongful re-correction. Home- and office-based vision therapy results in improvement in visual acuity in a large majority of these patients. This preferred practice pattern intends to guide the refractive surgeons to diagnose and treat the postrefractive surgery NSBVA following a case-based and algorithmic approach. It also emphasizes the inclusion of the binocular vision assessment as a part of the pre-operative workup for patients undergoing refractive procedures.

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Uncorrected refractive error (URE) is defined as a uncorrected visual acuity (UCVA) of less than 6/12 in the better eye with best corrected refractive error of 6/6 on the Snellen's chart.[1] They are the leading cause for moderate to severe visual morbidity worldwide.[1,2] India and China contribute to the 50% of global vision impairment and blindness attributable to URE.[1,3] A systematic review by Sheeladevi S *et al.* reported a 53% prevalence of at least 0.50 D of spherical equivalent ametropia (myopia 27.7%, hyperopia 22.9%) in India.[4] With the growing impact of URE on ocular morbidity there has been an increase in demand for refractive surgery. The Global demand for refractive surgery is growing at an annual rate of 5.2%. 4.3 million refractive surgeries were performed in 2018 and the number is expected to increase to 5.5 million by the year 2023.[5]

Photorefractive keratectomy (PRK) and Laser-in-situ keratomileusis (LASIK) which make use of excimer laser have revolutionized the field of corneal refractive surgery. Refractive lenticule extraction (ReLEx) of intracorneal tissue, using a femtosecond laser led to the development of 2 novel refractive surgeries- the ReLEx flex (FLEX) and the ReLEx smile (SMILE). Implantable collamer lens implantation is another refractive procedure particularly in high myopes who are not the ideal candidates for LASIK or PRK. PresbyLASIK and monovision LASIK are the refractive procedures for correction of presbyopia. The early postoperative recovery, excellent refractive outcomes, freedom from contact lens and spectacles are responsible for high levels of patient satisfaction and improvements in quality of life post-refractive surgery.[6] Regression is defined as a recurrence of the refractive error following refractive correction.[7] It has significant effects on patient satisfaction posing a challenge to the surgeon. Regression post LASIK has been reported to range from 5.5 to 27.7%.[8,9] Retreatment requirement post PRK regression correction ranged 3.8% to 20.8%.[10,11] The exact mechanism that leads to regression remains unknown.

Patients presenting post-refractive surgery with complaints of diminution of vision, glare, halos, difficulty in focusing, headache and other asthenopic symptoms pose a major challenge to the refractive clinician. A proportion of these can be attributed to accommodative dysfunctions and non-strabismic binocular visual anomalies (NSBVA) arising due to increase in the visual demand due to increasing use of computers and other screen-based devices leading to over-exertion of accommodation and convergence. Adult

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NSBVA is an important differential diagnosis to be considered in a post-refractive surgery unhappy patient, presenting with regression or other symptoms. With the improved understanding that management in refractive surgeries is not only limited to corneal contour reshaping procedures, more efforts are being put forth to evaluate the subtle or obvious binocular vision imbalance that surface after the procedure.[12]

The prevalence of NSBVA in the urban and rural population was 31.5% and 29.6% according to the BAND study.[13] Magdalene *et al.* in their study conducted in North-east India reported the prevalence of NSBVA as 67.35% in the age group of 21-30 years and 50% in the age group of 31-40 years.[14] This age group does but obviously overlap with the patients seeking refractive surgeries. However, there is still a lacuna in the current literature regarding the true prevalence of accommodative and NSBVA which remains largely unknown.[15] Patients complaining of blurring of vision, difficulty in focusing, glare and haloes following refractive surgery may have undiagnosed binocular vision anomaly (BVA) of which convergence related anomaly was seen in 83% of cases.[16] Accommodative lag has also been reported post SMILE for moderate to high myopia correction.[17]

The success of the refractive correction is primarily measured by means of the optimal results achieved and satisfaction of the patient[18] and hence in response to this risk and accepting the fact that the current preoperative evaluation for refractive procedures is not fool proof, this review emphasizes on BVA in cases presenting with regression, glare, haloes and other asthenopic symptoms. It will guide the clinician by giving a step wise approach to diagnosis and management of NSBVA, thus preventing them from causing any potential harm of attempting a re-correction in such patients and in incorporating the BVA in patients seeking any refractive procedure making their pre-operative screening more robust when necessary.

When and How to Consider NSBVA Work Up?

Post refractive surgery NSBVA work-up

All patients, presenting with asthenopia, blurring of vision and glare post-refractive surgery who show no evidence of ectasia on topography, no increase in the axial length, and absence of dysfunctional lens index/dry eye should be subjected to BVA before making a diagnosis of regression and planning a re-correction.

They should be subjected to a complete ophthalmic evaluation including:

- Visual acuity
- Objective and subjective refraction
- Slit lamp examination
- Anterior segment examination
- Posterior segment examination.

In cases of asthenopia, a post-mydriatic test and a comprehensive orthoptic evaluation including the BVA for diagnosis of NSBVA [Fig. 1] should be performed after the third day.

Pre-refractive surgery NSBVA work-up

Because the majority of the young population today have a work profile mandating the use of computer, cell phones, or other visual display devices for long hours. This results in prolonged use of near and intermediate visual activity. Hence, a large number of young adults are being diagnosed with BVA leading to ocular discomfort.[19]

It should alarm the refractive surgeon that these are the kind of individuals who exactly fit the demographic profile of patients seeking a refractive correction as well. Subsequently, one can include the basic examination such as the:

- Near point of convergence (NPC)
- Near point of accommodation (NPA)
- Dominant eye
- Cover test to look for phorias
- Dilated refraction.

Based on the history these examinations should be added to the routine refractive surgerywork-up especially in cases of low myopes. In cases with abnormal NPA, NPC or large phorias a detailed BVA should be carried out for diagnosis of the NSBVA as outlined in Fig. 2. Refractive surgery can be planned after completion of the vision therapy based on the diagnosis. The patients should be counseled in detail regarding the possibility of need for vision therapy post-surgery as well.

Types of NSBVA and their Management

Types of NSBVA and their management is described below with flowcharts and case scenarios [Figs. 2-8].[20,21] NSBVA consist of accommodative and vergence disorders Table 1. Table 2 lists the terms used and Table 3 shows the cut-off values for the cover test and AC/A ratio.[21] Table 4 lists the expected values of binocular single vision assessment[21] Table 5 provides a list of direct and indirect tests performed for the diagnosis of NSBVA/.[21]

Case 1

A 22-year-old-female who underwent an uneventful LASIK surgery presented with chief complaints of difficulty in focusing and glare 18 months post LASIK. Her preoperative refractive error was –5DS/–1.25DCx 170 degrees in the right eye (OD), 6/6; N6 and –5.25DS/–1.00 DC × 10 degrees in the left eye (OS) 6/6; N6. Her pre-operative NPA and NPC with glasses were 7 cm and 6 cm, respectively. Duochrome test was balanced for both eyes. Stereopsis was tested using the Titmus fly test was normal. Pre-operatively her topography showed with the rule astigmatism with no evidence of ectasia. Cycloplegic refraction was performed preoperatively. She underwent uneventful refractive surgery and post-operatively her UCVA was 6/6 with plano in both eyes. Her corneal

Table 1: Classification of NSBVA

Vergence disorders	Accommodative anomalies
Convergence Insufficiency (CI)	Accommodative Insufficiency (AI)
Convergence Excess (CE)	Accommodative Excess (AE)
Divergence Insufficiency (DI)	Accommodative Infacility (AIF)
Divergence Excess (DE),	Ill sustained accommodation
Basic Esophoria (BES),	
Basic Exophoria (BEX),	
Fusional Vergence Dysfunctions (FVD)	
Vertical Deviation	

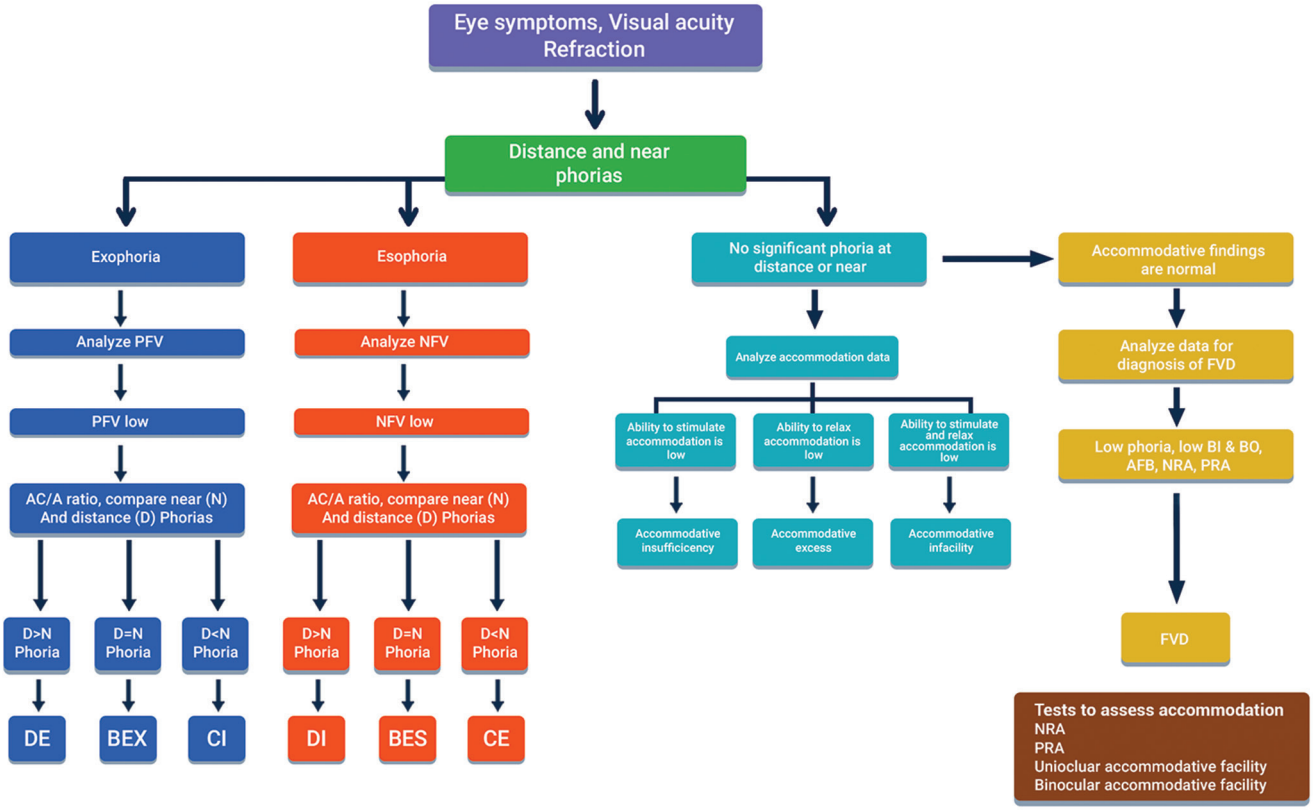

Figure 1: Flowchart summarizing diagnosis of various NSBVA

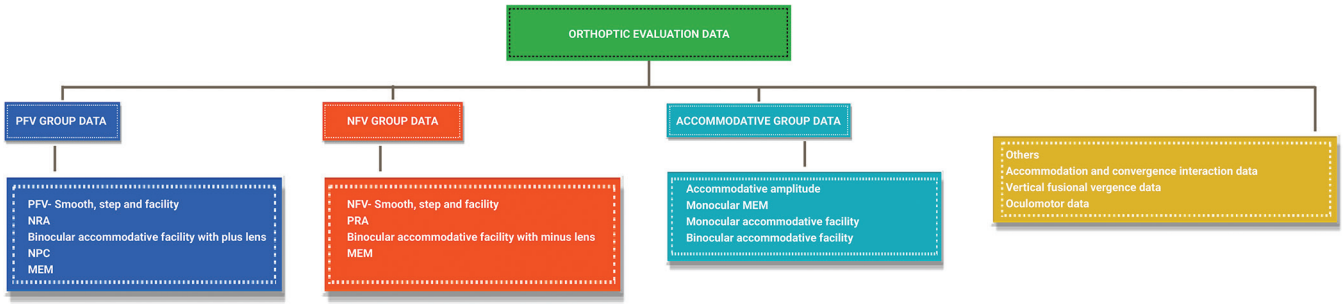

Figure 2: Flowchart orthoptic evaluation data groups

Table 2: Terms used in orthoptic evaluation

ABBREVIATIONS	FULL FORM	UNIT
NPC	Near Point Of Convergence	Cm
NPA	Near Point Of Accommodation	Cm
AA	Amplitude Of Accommodation	Dioptres
NRA	Negative Relative Accommodation	Dioptres
PRA	Positive Relative Accommodation	Dioptres
NFV	Negative Fusion Vergence (Divergence)	Prism Dioptres
PFV	Positive Fusional Vergence (Convergence)	Prism Dioptres
MEM	Monocular Estimation Method Of Dynamic Retinoscopy	Dioptres
AFB	Accommodative facility binocular	Cycles/minute
BO	Base out	Prism Dioptres
BI	Base in	Prism Dioptres
AC/A	Accommodation convergence/accommodation	Ratio

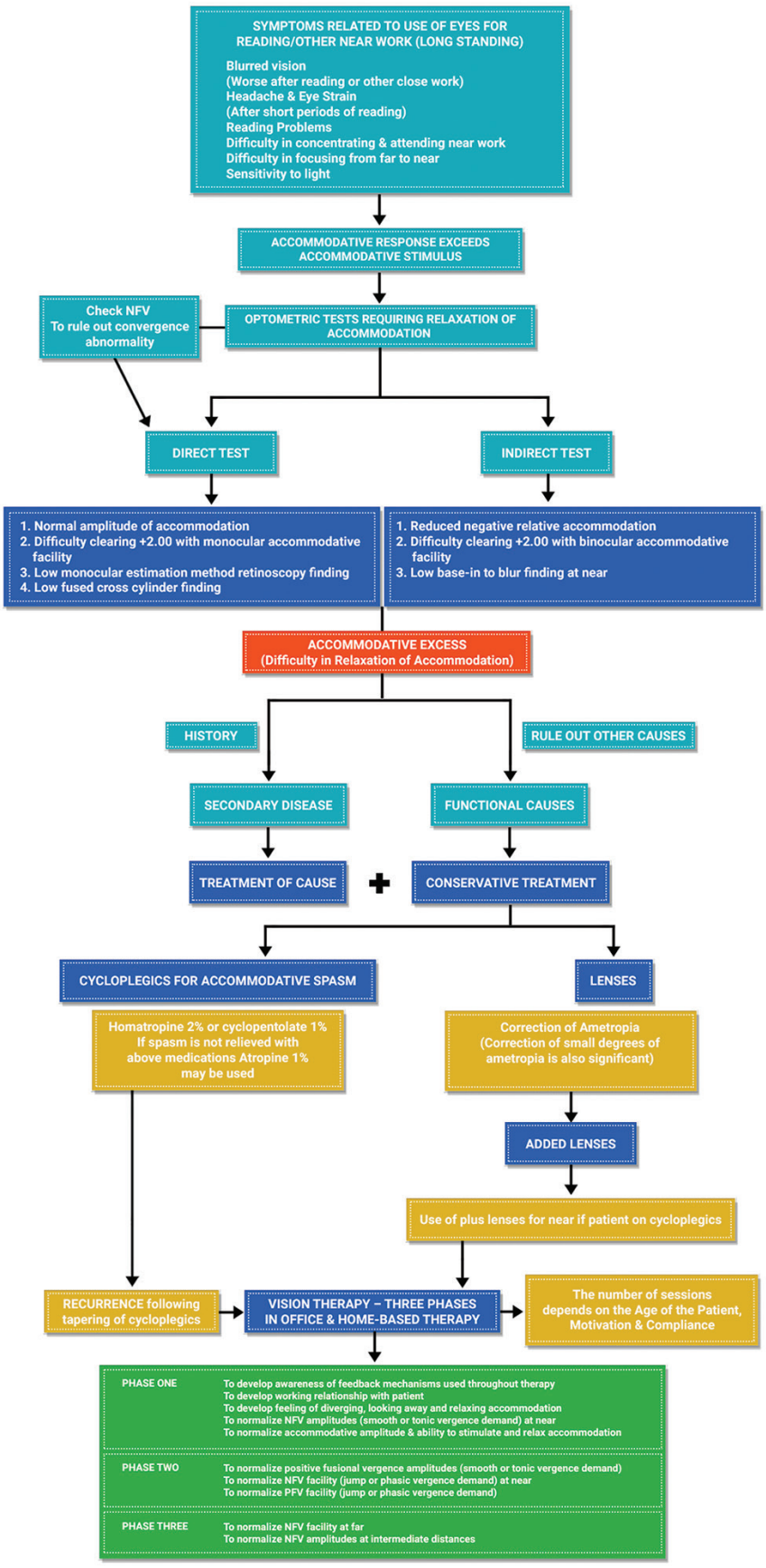

Figure 3: Flowchart showing algorithmic approach to diagnosis and management of accommodative excess

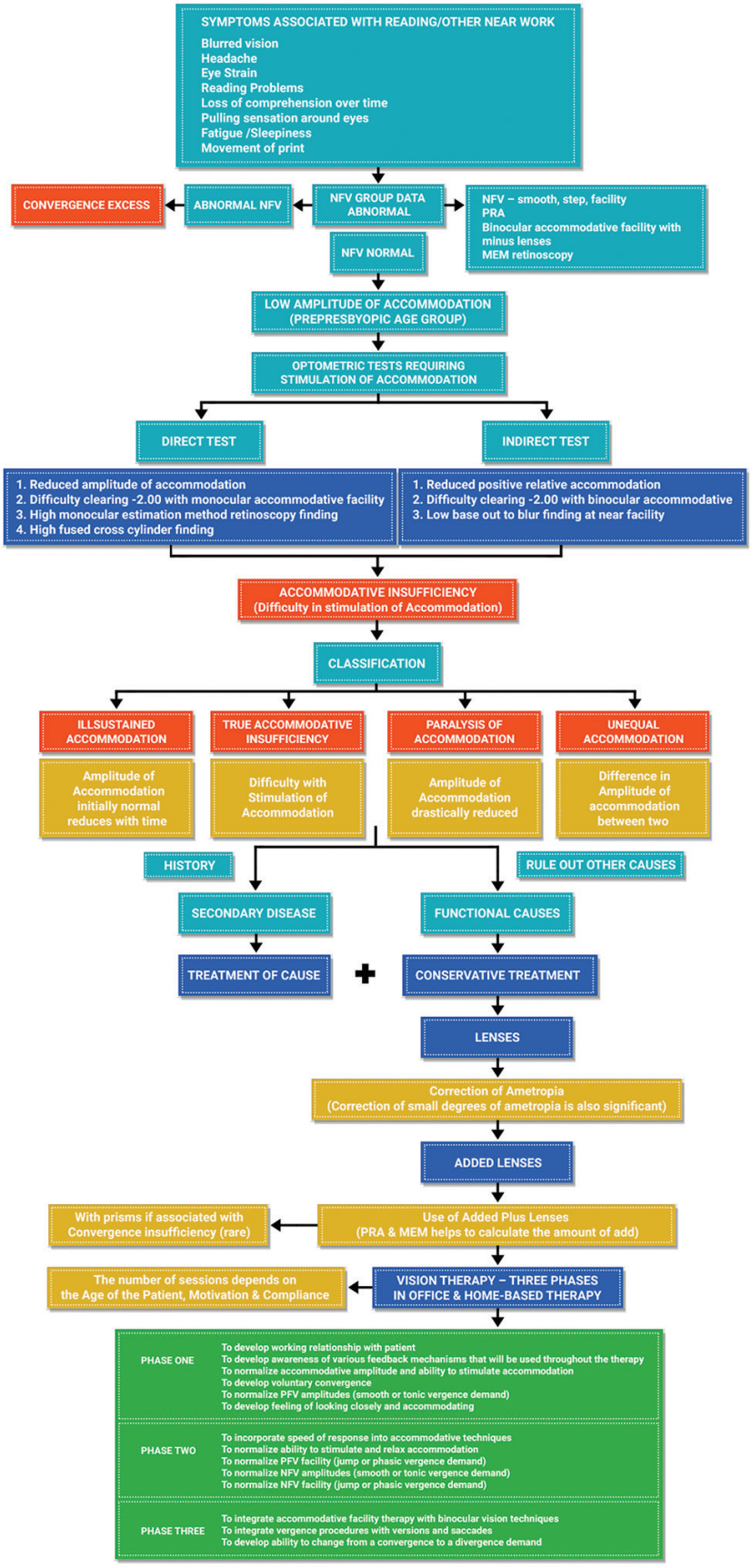

Figure 4: Flowchart showing algorithmic approach to diagnosis and management of accommodative insufficiency

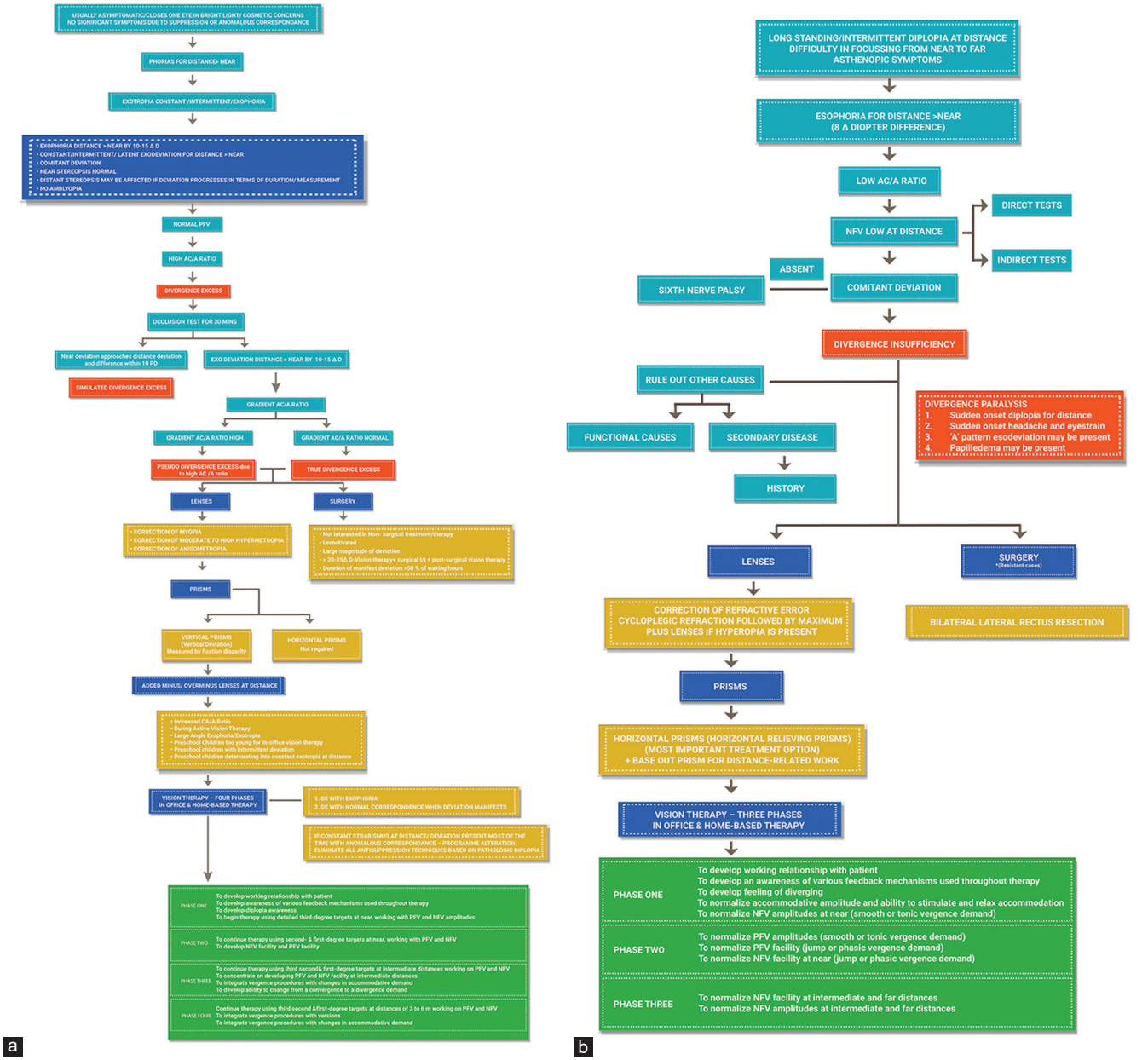

Figure 5: Flowchart showing algorithmic approach to diagnosis and management of divergence excess (a) and divergence insufficiency (b)

topography showed no evidence of ectasia. She was an IT professional with 9 hours of screen time per day. On evaluation at 18 months postrefractive surgery her vision was 6/12 in both eyes improving to 6/6 with –1.25 DS OD and –0.75 DS OS. She was advised cycloplegic refraction and BVA. Cycloplegic refraction revealed emmetropia with no significant refractive error. However, orthoptic evaluation showed high positive relative accommodation (PRA) of-3.5D, low negative relative accommodation (NRA) of + 1.5 D and difficulty with plus lenses on accommodative facility. Monocular estimation method (MEM) retinoscopy finding was –0.5D, suggestive of a lead of accommodation. Thus, the above findings suggest that patient had an accommodative excess. The patient was advised to reduce screen-time and follow visual hygiene practices. With vision therapy as outlined in the flowchart [Fig. 3] her symptoms resolved, and unaided vision returned to 6/6 in both eyes in 8 weeks.

Note: Accommodative excess can be an important cause of post-refractive surgerypseudo-regression. Cycloplegic refraction and detailed orthoptic evaluation can help clinch the diagnosis and administer treatment on time.

Vision therapy is preferred over the use of cycloplegics in the treatment of accommodative excess to keep accommodation flexible. However, in resistant cases, cycloplegics must be used initially and gradually tapered off.

Case 2

27-year-old-male visited the refractive clinic 1 year after uneventful Trans-epithelial PRK (Trans-PRK) with complaints of blurring of vision after prolonged screen use or reading and halos. The patient had difficulty with near activities and complained of discomfort and eyestrain associated with reading. His pre-operative refractive error was –3.00

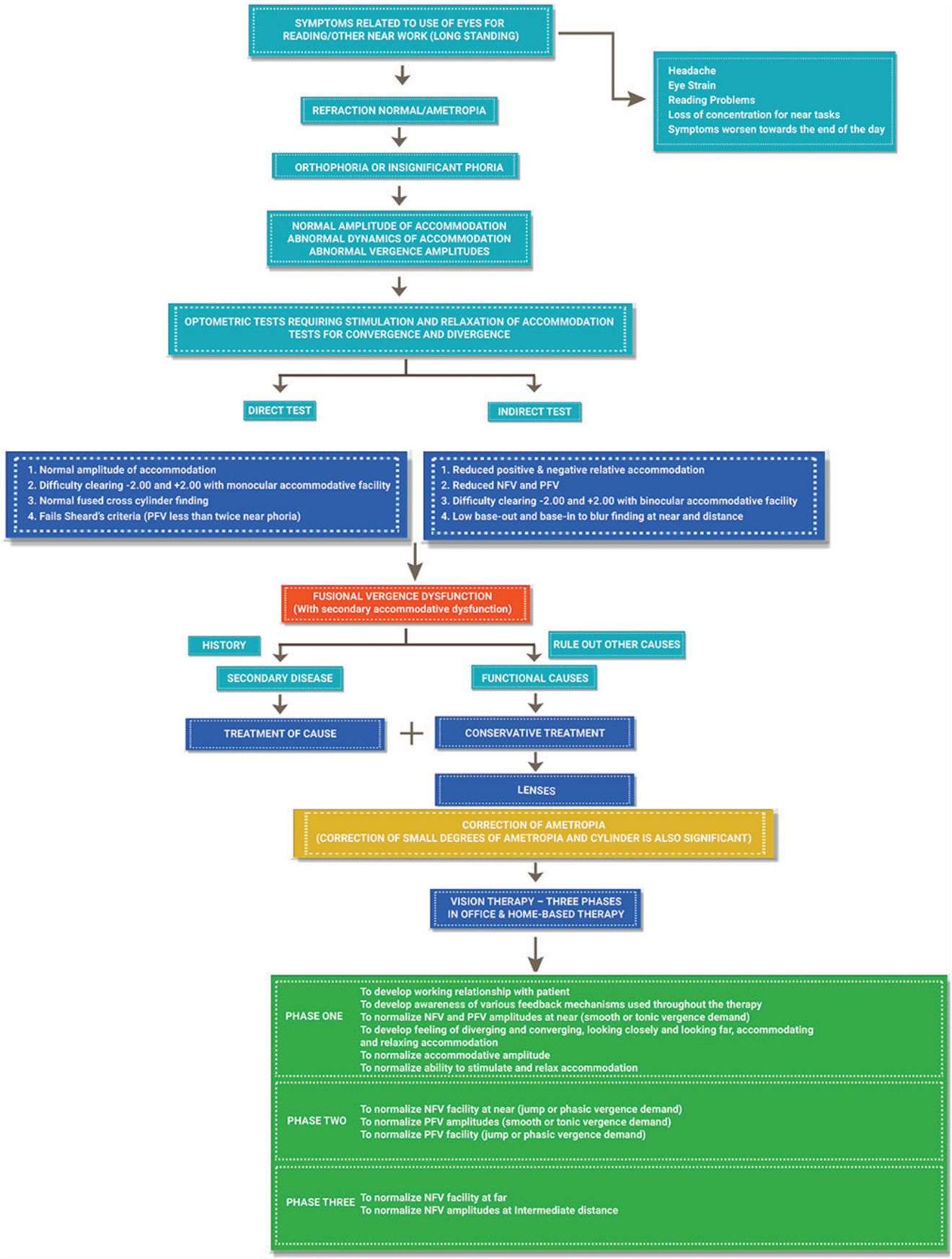

Figure 6: Flowchart showing algorithmic approach to diagnosis and management of fusional vergence dysfunction

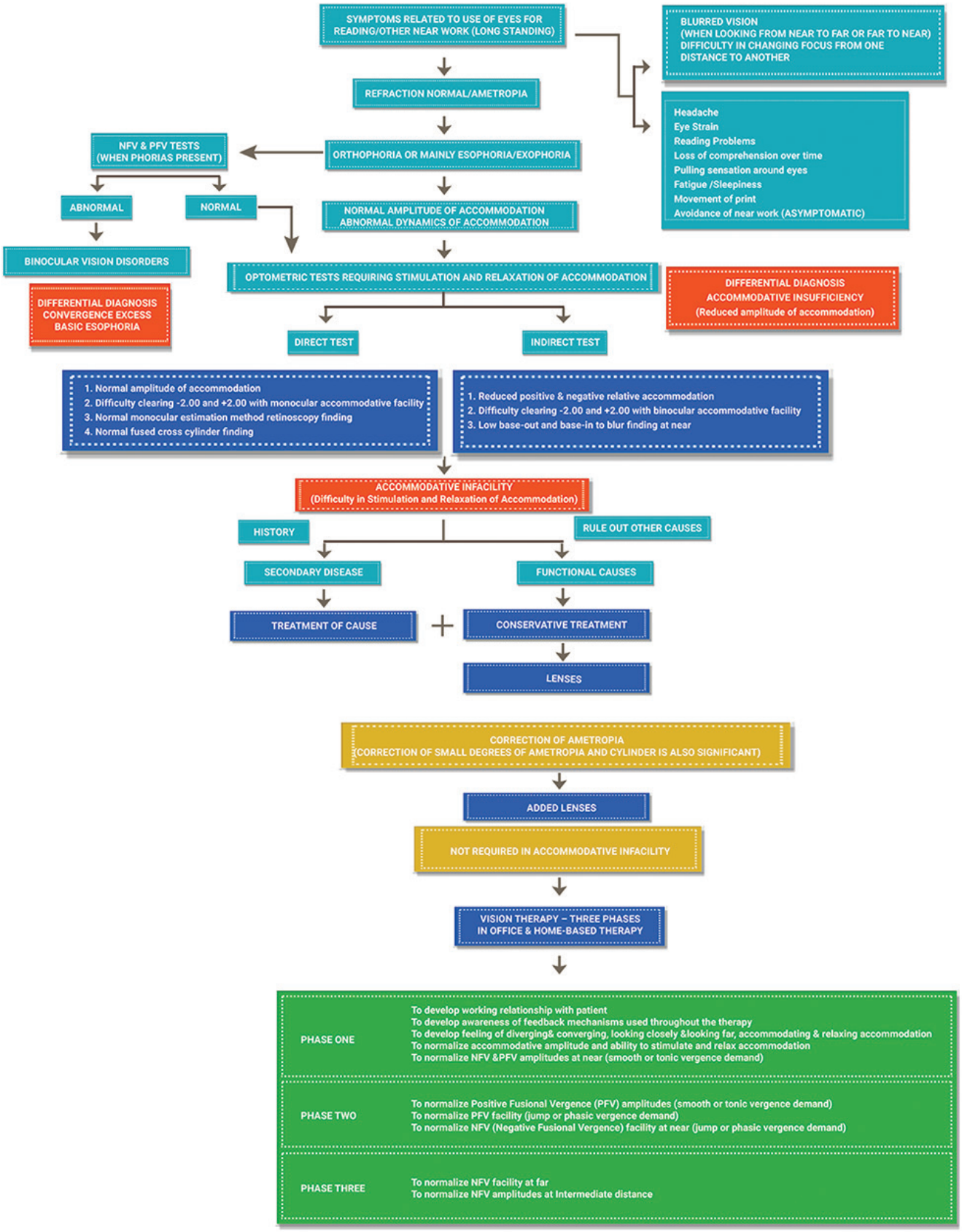

Figure 7: Flowchart showing algorithmic approach to diagnosis and management of accommodative infacility

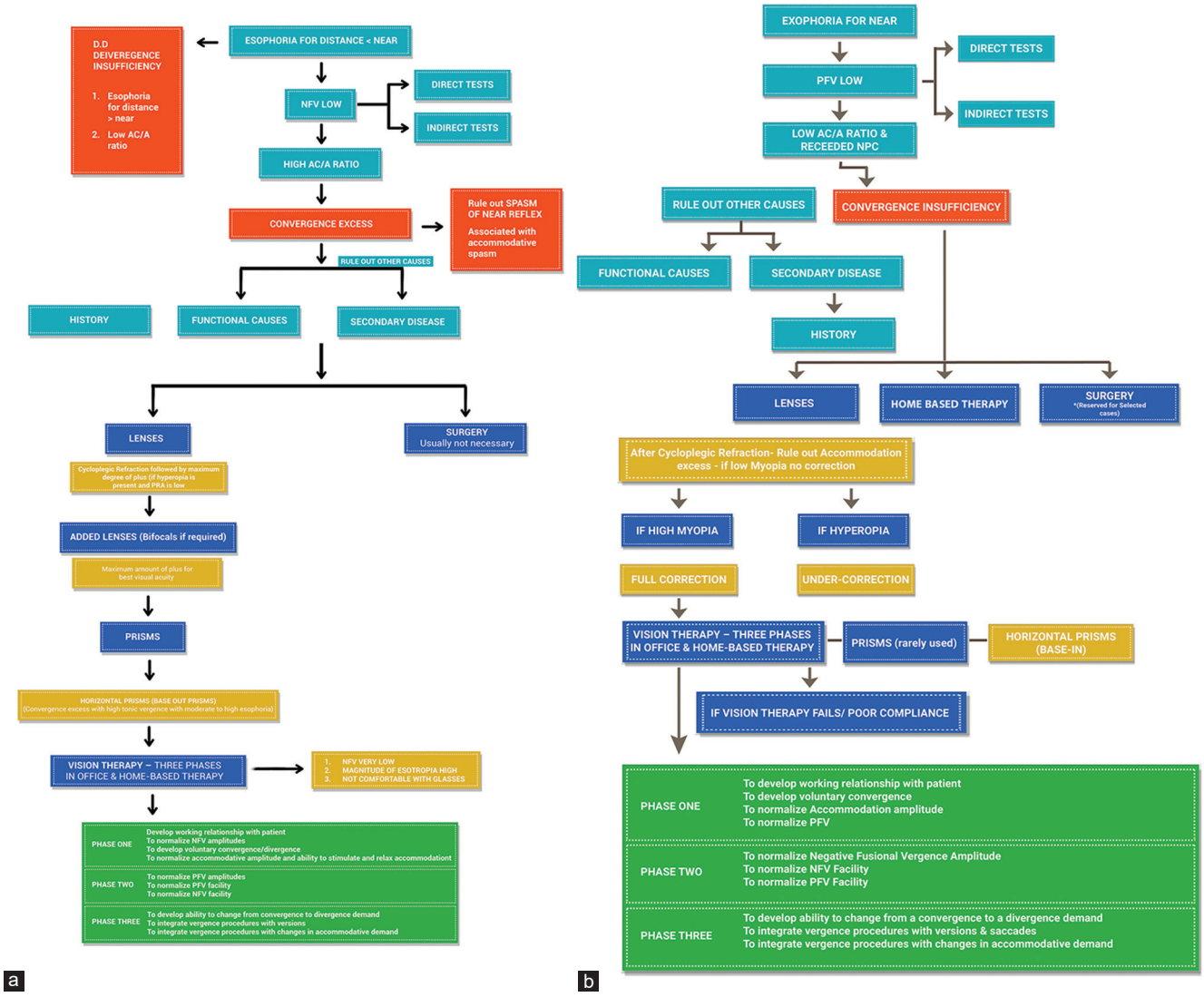

Figure 8: Flowchart showing algorithmic approach to diagnosis and management of convergence excess (a) and convergence insufficiency (b).

Table 3: Table of cut off values for cover test and AC/A ratio

Test	Mean Value	Standard Deviation
Cover test		
Distance	1 exophoria	± 2 Δ
Near	3 exophoria	± 3 Δ
Distance lateral phoria	1 exophoria	± 2 Δ
Near lateral phoria	3 exophoria	± 3 Δ
AC/A ratio	4:1	± 2 Δ

DS (OD) and –2.75 DS (OS). Pre-operatively, he underwent cycloplegic refraction and orthoptic evaluation (including NPA, NPC and duochrome balance test with glasses) was within normal limits. Stereopsis tested using the Titmus fly test was within normal limits OU. His pre-operative corneal topography showed a thinnest corneal thickness of 486 microns in both eyes (OU) so Trans- PRK was planned. On examination, his UCVA in OD was 6/9P and OS was 6/6P whereas the BCVA OU was 6/6 with +1.0DS OD and +0.75 DC OS. Near vision was 6/6 but the patient complained of intermittent blurring while reading. On orthoptic evaluation patient had a receded NPA (16 cm), reduced amplitude of accommodation for age, low PRA -1.25 D, high NRA of +3D. MEM retinoscopy revealed a lag of accommodation (+2D). Thus, the patient was diagnosed with accommodative insufficiency and underwent vision therapy. After 12 weeks of vision therapy [Fig. 4], his UCVA in both eyes was 6/4.5. There was a significant improvement in symptoms as well as accommodative amplitude.

Case 3

A 29-year-old-man reported to our clinic with chief complaints of starburst appearance, glare and halos 8 months post successful SMILE surgery. He also complained of intermittent blurring with occasional doubling and difficulty with driving at night. His preoperative BCVA was 6/6 with -4.5DS OU. His corneal topography showed no evidence of ectatic corneal disorders. Pre-operative cycloplegic refraction was performed and orthoptic evaluation (including NPA, NPC and duochrome balance test

Table 4: Table of expected values for Binocular single vision assessment

Test		Mean Value	Standard Deviation
Smooth vergence testing			
Base-out (distance)	Blur:	9	± 4
	Break:	19	± 8
	Recovery:	10	± 4
Base-in (distance)	Blur:	7	± 3
	Recovery:	4	± 2
Base-out (near)	Blur:	17	± 5
	Break:	21	± 6
	Recovery:	11	± 7
Base-in (near)	Blur:	13	± 4
	Break:	21	± 4
	Recovery:	13	± 5

Test		Mean Value	Standard Deviation
Step vergence testing			
Children 7–12 year old			
Base-out (near)	Break:	23	± 8
	Recovery:	16	± 6
Base-in (near)	Break:	12	± 5
	Recovery:	7	± 4
Adults			
Base-out (distance)	Break:	11	± 7
	Recovery:	7	± 2
Base-in (distance)	Break:	7	± 3
	Recovery:	4	± 2
Base-out (near)	Break:	19	± 9
	Recovery:	14	± 7
Base-in (near)	Break:	13	± 6
	Recovery:	10	± 5

Test	Mean Value	Standard Deviation
Vergence facility testing		
(12 base-out/3 base-in)	15.0 cpm	± 3

Test		Mean Value	Standard Deviation
Near point of convergence			
Accommodative target	Break:	2.5 cm	± 2.5
	Recovery:	4.5 cm	± 3.0
Penlight and red/green glasses	Break:	2.5 cm	± 4.0
	Recovery:	4.5 cm	± 5.0

Table 5: Table of direct and indirect tests performed for diagnosis of NSBVA

Convergence insufficiency	Direct tests for PFV	Smooth vergence Step vergence Vergence facility
	Indirect tests PFV	NRA Plus lenses in binocular accommodative facility Low mem retinoscopy
Accommodative excess	Direct tests	Low NRA High PRA Low mem retinoscopy Plus lenses in monocular and bionocular accommodative facility
	Indirect tests	Vergence facility
Accommodative insufficiency	Direct tests	Low PRA High NRA High mem retinoscopy Minus lenses in monocular and bionocular accommodative facility
	Indirect tests	Vergence facility
Accommodative infacility	Not applicable	
Divergence insufficiency	Direct tests NFV	Smooth vergence Step vergence Vergence facility
	Indirect tests for NFV	NRA Plus lenses in binocular accommodative facility Low mem retinoscopy
FVD	Not applicable	
Convergence excess	Direct tests for NFV	Smooth vergence Step vergence Vergence facility
	Indirect tests for NFV	PRA Minus lenses in binocular accommodative facility High mem retinoscopy

with glasses) was normal. Stereopsis was tested using the Titmus fly test was normal. Post-operatively, on visual acuity testing with Snellen's chart his UCVA was 6/6. Aberrometry and topography were within normal limits. Cycloplegic refraction and orthoptic evaluation were repeated. Cycloplegic refraction revealed no significant refractive error. On orthoptic evaluation patient had an exophoria for near and intermittent exodeviation for distance. Exodeviation for distance was 20 PD and greater than that for near, by 12 PD. Patient had normal amplitude of accommodation and high AC/A ratio of 8:1. PFV was low for distance and borderline for near. NFV was within normal limits. With office and home-based exercises for Divergence excess as outlined in flowchart [Fig. 5a], and exercises to improve binocular fusion and stereopsis, his PFV and control over exodeviation improved, and the visual disturbances gradually resolved.

Case 4: Special Situations

A 24-year-old female presented with chief complaints of intermittent blurring of vision for distance and near, asthenopia OD 9 months post an uneventful transepithelial PRK. Her pre-operative examination record showed her BCVA was 6/6, N6 OU with -1.25DS/-0.75DC at 80 degrees OD and -1.25DS OS. Her NPA and NPC with glasses were within normal limits and the Duochrome test was balanced. Her stereopsis was tested using the Titmus fly test and was normal. She was

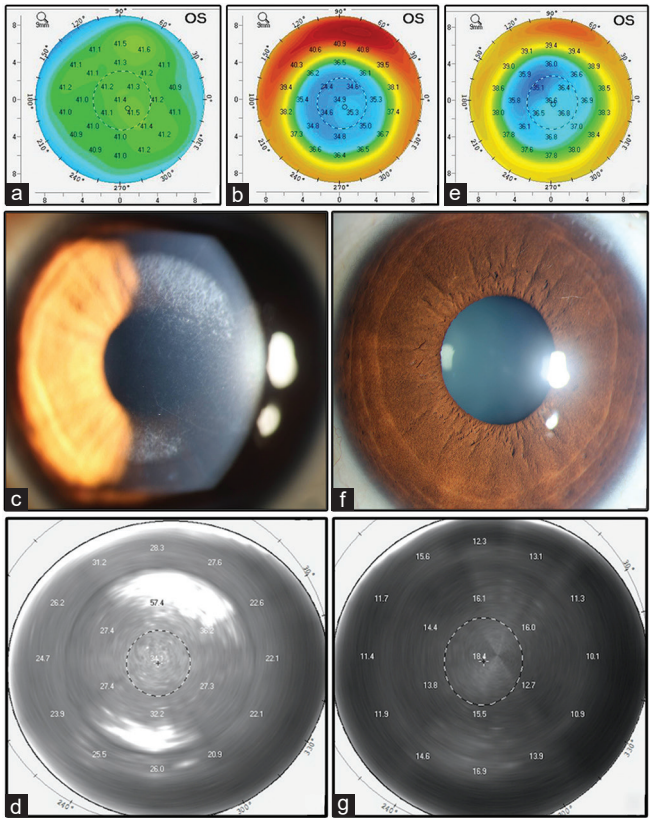

Figure 9: (a) A normal pre-operative axial/sagittal map of OD. (b-g): Axial/sagittal map, slit lamp photograph and corneal densitometry map OD at 9 months post Trans – PRK and 12 weeks post treatment

advised Trans-PRK in both eyes, since here thinnest corneal thickness (TCT) was 483 µm OD and 498 µm OS respectively on Pentacam pachymetry map [Fig. 9a]. She underwent uneventful OD Trans-PRK followed by OS Trans-PRK 2 days later on Schwind Amaris 1050 (Peramis; SCHWIND eye-tech-solutions, Kleinostheim, Germany). Her UCVA on postoperative day 1 was 6/6 OU. Her immediate post-operative period was uneventful. She was a teacher and an avid computer user, spending approximately nine hours a day using computers. On examination at 9 months post trans- PRK her BCVA was 6/24 with +3.75DS/-3.00DC at 90-degree N10 OD and 6/6; N6 with plano OS. Slit-lamp biomicroscopic examination revealed the presence of clinical grade 2 haze OD which corresponded to the corneal densitometry map on the Pentacam showing evidence of post-PRK scaring [Fig. 9b-d]. The rest of the anterior and posterior segment examination was within normal limits in both eyes. Hence, a diagnosis of late-onset post-PRK haze was made and she was prescribed a tapering dose of eye drop prednisolone along with eye ointment tacrolimus 0.03% at bedtime and tablet vitamin C 500 mg three times a day for 12 weeks. At 12 weeks follow up, the slit lamp examination showed minimal haze OD with corresponding reduction of the same on corneal densitometry map OD [Fig. 9e-g]; nevertheless, the complaints of eye strain and blurring of vison persisted OD. Her BCVA OD was 6/6 with +1.25 D/-0.75 DC at 90 degrees; however, the clinical picture did not correlate with the magnitude of the hyperopic shift, so she was advised to undergo a detailed orthoptic evaluation which revealed esophoria for distance on cover test and Maddox rod test. She also had low near point of accommodation, low positive fusional vergence (PFV) at distance and near, low negative fusional vergence (NFV) at distance and near and low binocular accommodative facility (BAF), reduced cycles per minute on monocular accommodative facilities (MAF). Based on these findings a diagnosis of fusional vergence dysfunction was made and she was prescribed +1.25 DS/-0.75DC at 90 OD glasses and was started on orthoptic exercise initially at the clinic which was then subsequently shifted to home-based exercises [Fig. 6] She was re-evaluated 8 weeks post orthoptic exercises, her BCVA improved to 6/6 with +0.25DS OD and her symptoms had significantly resolved.

Vision therapy is the mainstay of treatment in convergence insufficiency. However, correction of refractive error, as with any other NSBVA is important. Low myopia perhaps may be corrected after starting vision therapy. Pencil push-ups are one of the most common exercises prescribed for CI. Convergence insufficiency treatment trail (CITT) evaluated efficacy of office-based vision therapy, office-based placebo therapy, home-based pencil push-up (HBPP) and home-based computer vision therapy + pencil push up. 73% improved in officed based vision therapy group as compared to 43% in HBPP group and 33% in homed based computer vision therapy plus pencil push up group.[22] Hence whenever possible office-based vision therapy must be insisted upon as monitoring of techniques performed by the patient with feedback and correction is very important

Home-based vision therapy can be advised for patients who cannot attend office-based vision therapy: Pencil push-ups, Brock string, lifesaver cards, and eccentric circles are the various options. Office-based vision therapy is outlined in Fig. 8.

Key Take-Home Points

- It is important to identify the dominant eye since any inadvertent under-correction in dominant eye will derange the binocular balance.
- Monovision should be performed only in patients with equal visual acuity in both the eyes and normal BVA with good fusion capacity. Distance correction should be performed in the dominant eye
- Overcorrections in myopic patients cause a decrease in convergence.[12] Hence a dilated refraction should be performed to assess the true refractive error
- NSBVA is an important differential diagnosis in patients presenting as regression
- Any patient presenting with complaints of glare and halos post-refractive surgery must undergo a complete binocular vision assessment as NSBVA is an important differential diagnosis other than the dry eye and flap related complications
- Pre-operative BVA will help in improving post-refractive surgery outcomes in patients with an undiagnosed NSBVA.

Conclusion

In conclusion, the authors would like to emphasize the importance of including binocular vision assessment and orthoptics evaluation in the routine pre-operative refractive surgery work-up. Also, the surgeons must keep in mind a differential diagnosis of NSBVA while evaluating a patient presenting with visual complaints resembling regression, overcorrection or asthenopic symptoms before planning any surgical intervention for re-correction or enhancement.

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Conflicts of interest

There are no conflicts of interest.

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