Macular Thickness in Glaucoma

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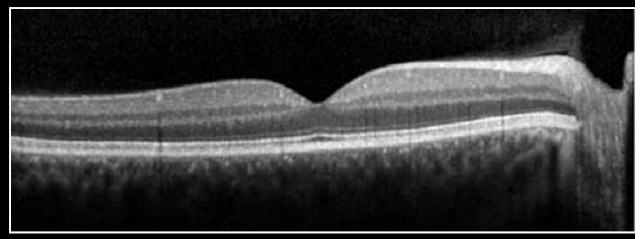
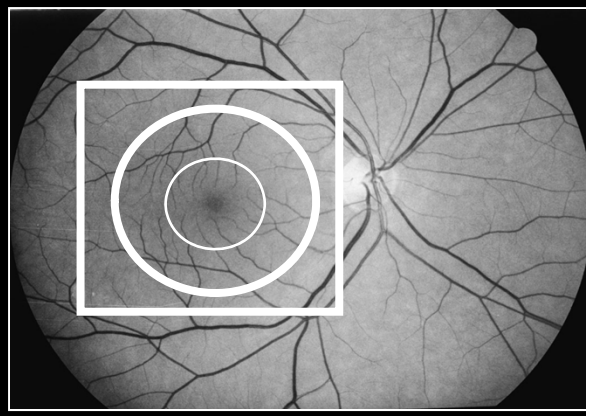
Financial Disclosure

- I have received lecture honoraria from Heidelberg Engineering

Why should we be interested in the retinal thickness in glaucoma?

- The ganglion cell layer is multi-layered in the macular region – with RNFL, 40% of total retinal thickness
- The majority (> 50%) of the entire retinal ganglion cell population is in the macular region
- Variation in macular ganglion cell numbers is small



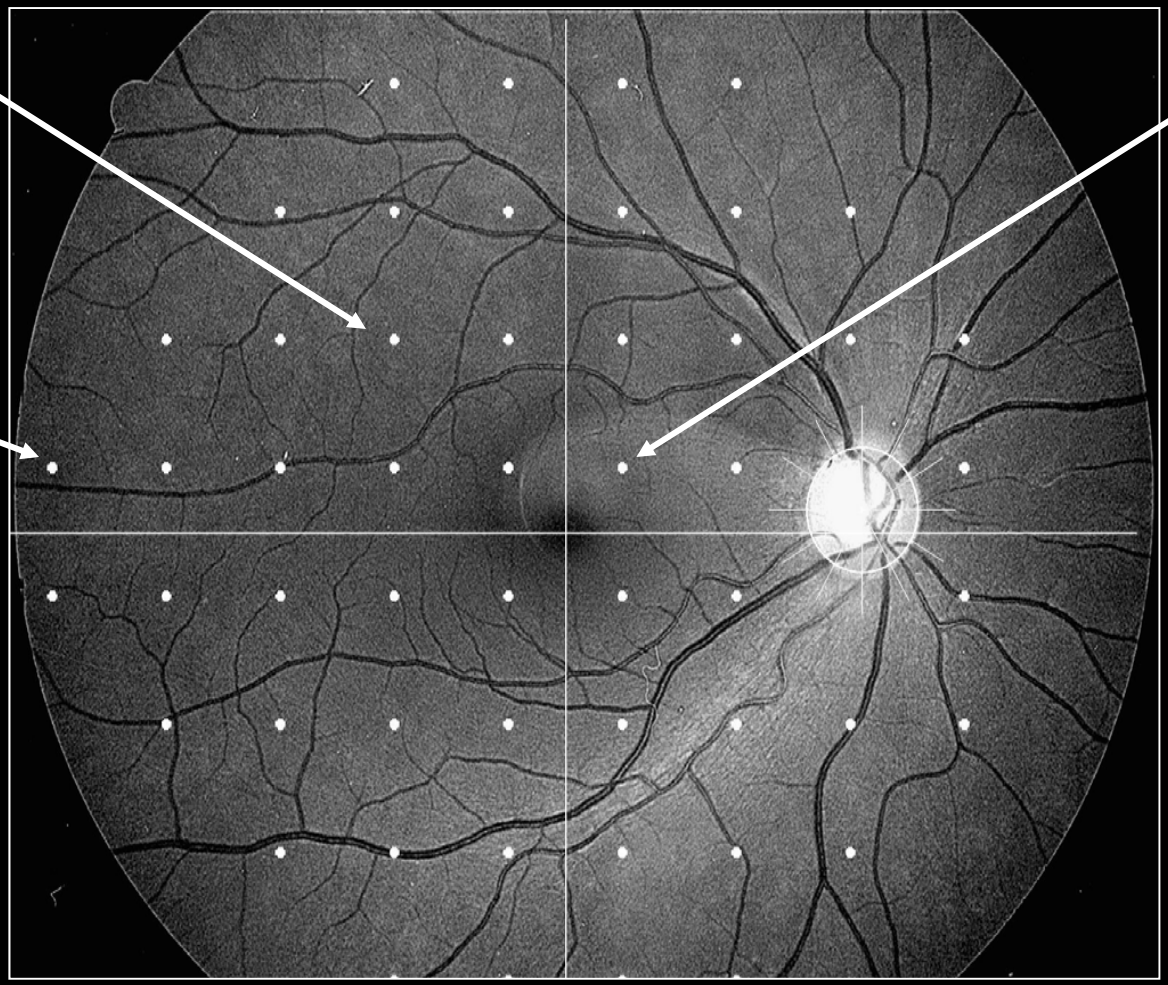


Curcio CA, Allen KA. J Comp Neurol 1990;300(1):5-25

The visual field relatively under-samples the macula

35 ganglion cells per size III target

10 ganglion cells per size III target



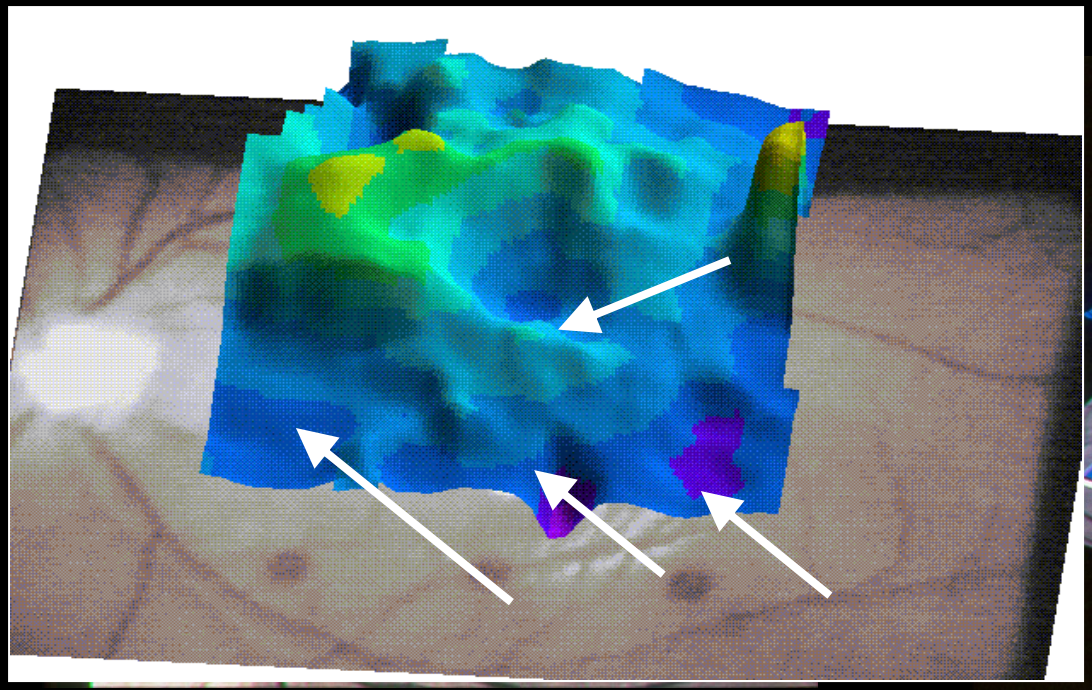
230 ganglion cells per size III target

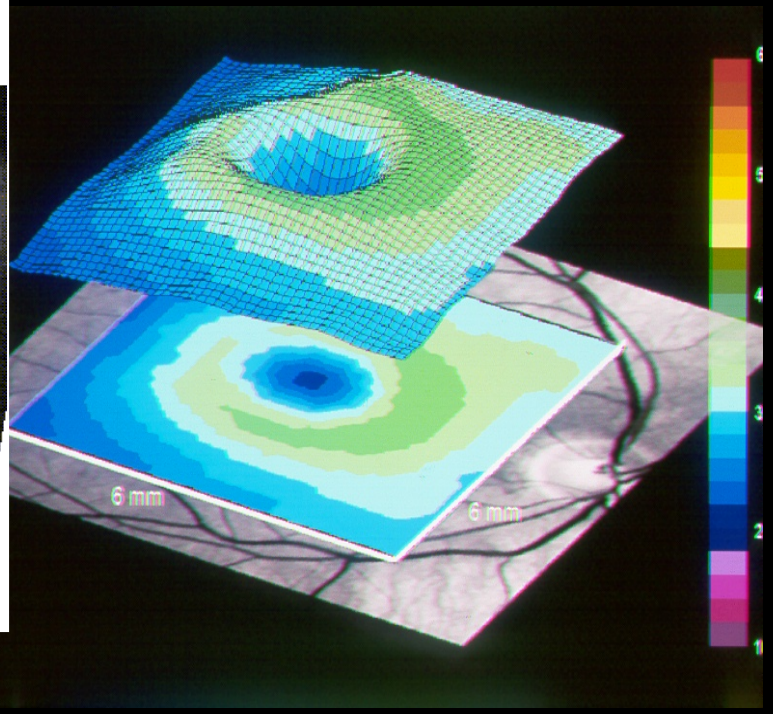
Percentage of ganglion cell loss for 3db field loss

				32					
			44						
		49		55					
			62	67					
44				69					
44				70					
			63	62					
		54		57					
			52						
				45					

Garway-Heath DF et al. Scaling the hill of vision: The physiological relationship between ganglion cell numbers and light sensitivity. *Invest Ophthalmol Vis Sci* 2000;41:1774-1782

Macular thickness in normals and glaucoma





Asrani S, Zou S, D' Anna S, Vitale S, Zeimer R. Noninvasive mapping of the normal retinal thickness at the posterior pole. *Ophthalmology* 1999;106:269-273

Zeimer R, Asrani S, Zou S, Quigley H, Jampel H. Quantitative Detection of glaucomatous damage at the posterior pole by Retinal thickness mapping. *Ophthalmology 105(2):224-31, 1998*

Asrani S, Challa P, Herndon L et al Correlation between retinal thickness analysis, optic nerve and visual fields in glaucoma patients and suspects. J Glaucoma 2003; 12(2):119-28

Various macular thickness parameters have been used:

- Asymmetry of Macular thickness
- Segmented macular ganglion cell complex (GCC)
- Increased area of the GCC measured
- Ratio of GCC and total retinal thickness
- Hemifield thickness

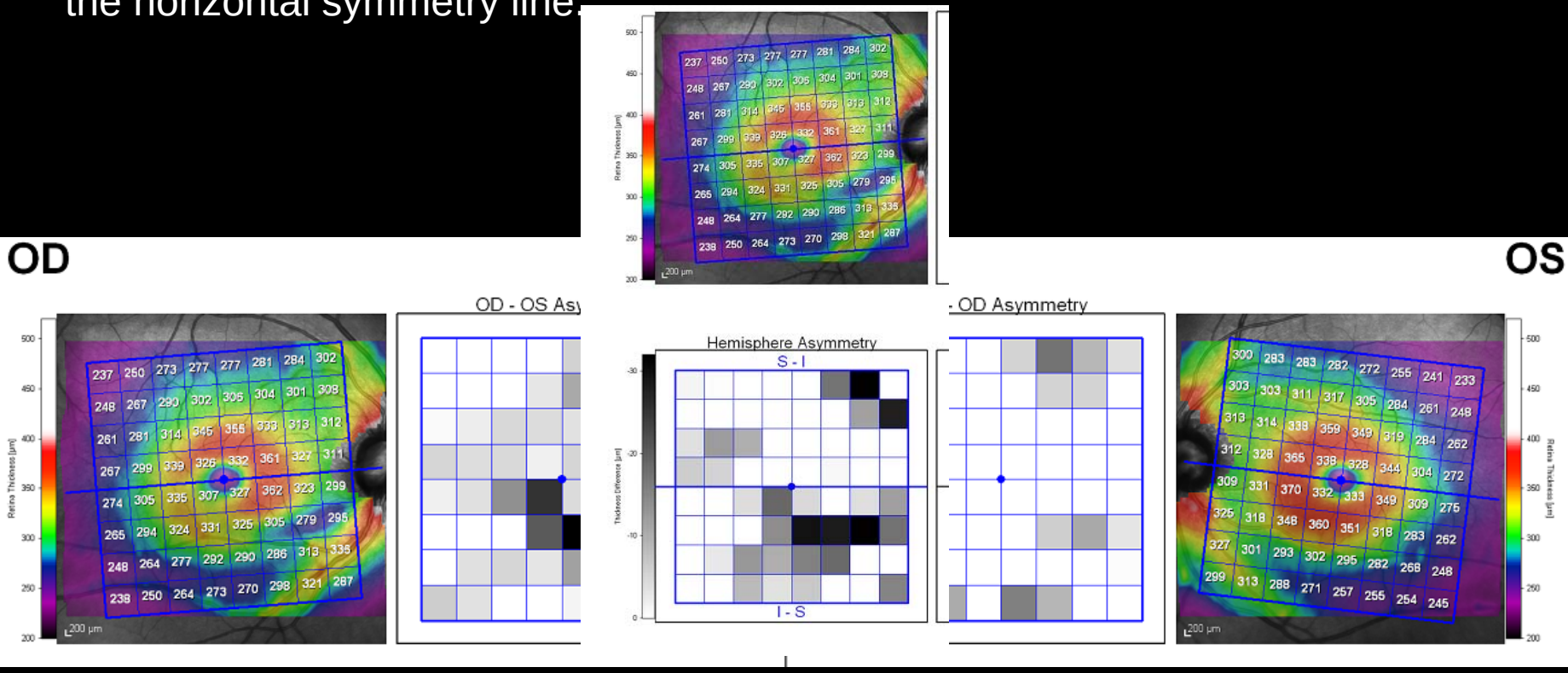
- Asrani S, Rosdahl JA, Allingham RR. Novel Strategy for Glaucoma Diagnosis. Arch Ophthalmol 2011;129(9);1205-11
- Mwanza JC, Durbin MK, Budenz DL et al. Glaucoma diagnostic accuracy of ganglion cell-inner plexiform layer thickness: comparison with nerve fiber layer and optic nerve head. Ophthalmology. 2012 Jun;119(6):1151-8.
- Morooka S, Hangai M, Nukada M et al. Wide 3-dimensional macular ganglion cell complex imaging with spectral-domain optical coherence tomography in glaucoma. Invest Ophthalmol Vis Sci. 2012 Jul 20;53(8):4805-12
- Kita Y, Kita R, Takeyama A, et al Ability of Optical Coherence Tomography-determined Ganglion Cell Complex Thickness to Total Retinal Thickness Ratio to Diagnose Glaucoma. J Glaucoma. 2012 Jun 4
- Um TW, Sung KR, Wollstein G, et al. Asymmetry in hemifield macular thickness as an early indicator of glaucomatous change. Invest Ophthalmol Vis Sci. 2012 Mar 2;53(3):1139-44.

Asymmetry Analysis: compare retinal thickness measurements between eyes and between hemispheres of each eye

Asymmetry display: As gray scale of difference in thickness from 0 to - 30 microns

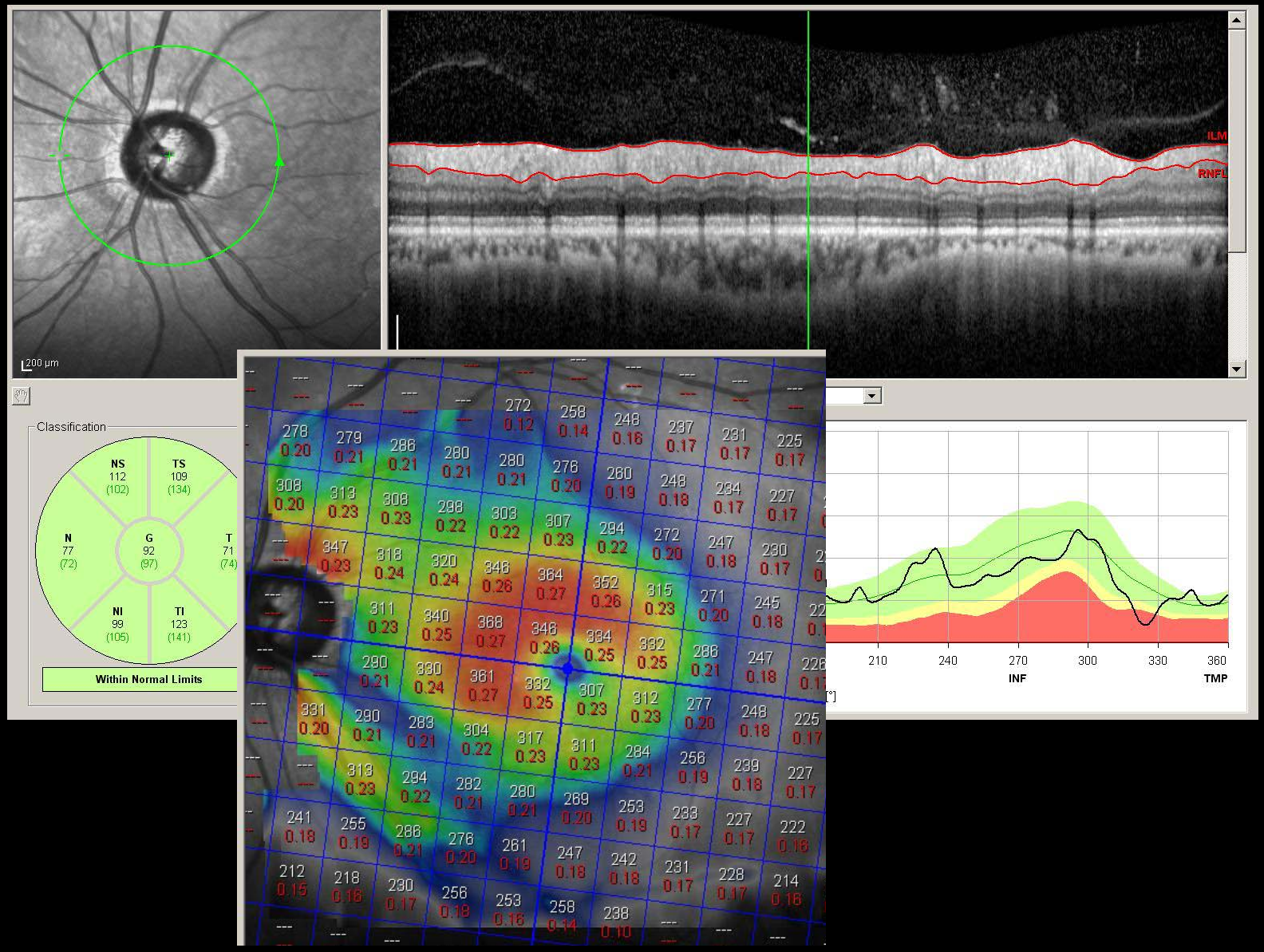
Asymmetry between eyes: For each small 3° x 3° area of one eye, the mean thickness is compared to the value in the corresponding area of the other eye

Hemisphere Asymmetry: Each small area in the lower hemisphere is compared to the corresponding area in the superior hemisphere. The fovea-to-disc axis is the horizontal symmetry line.

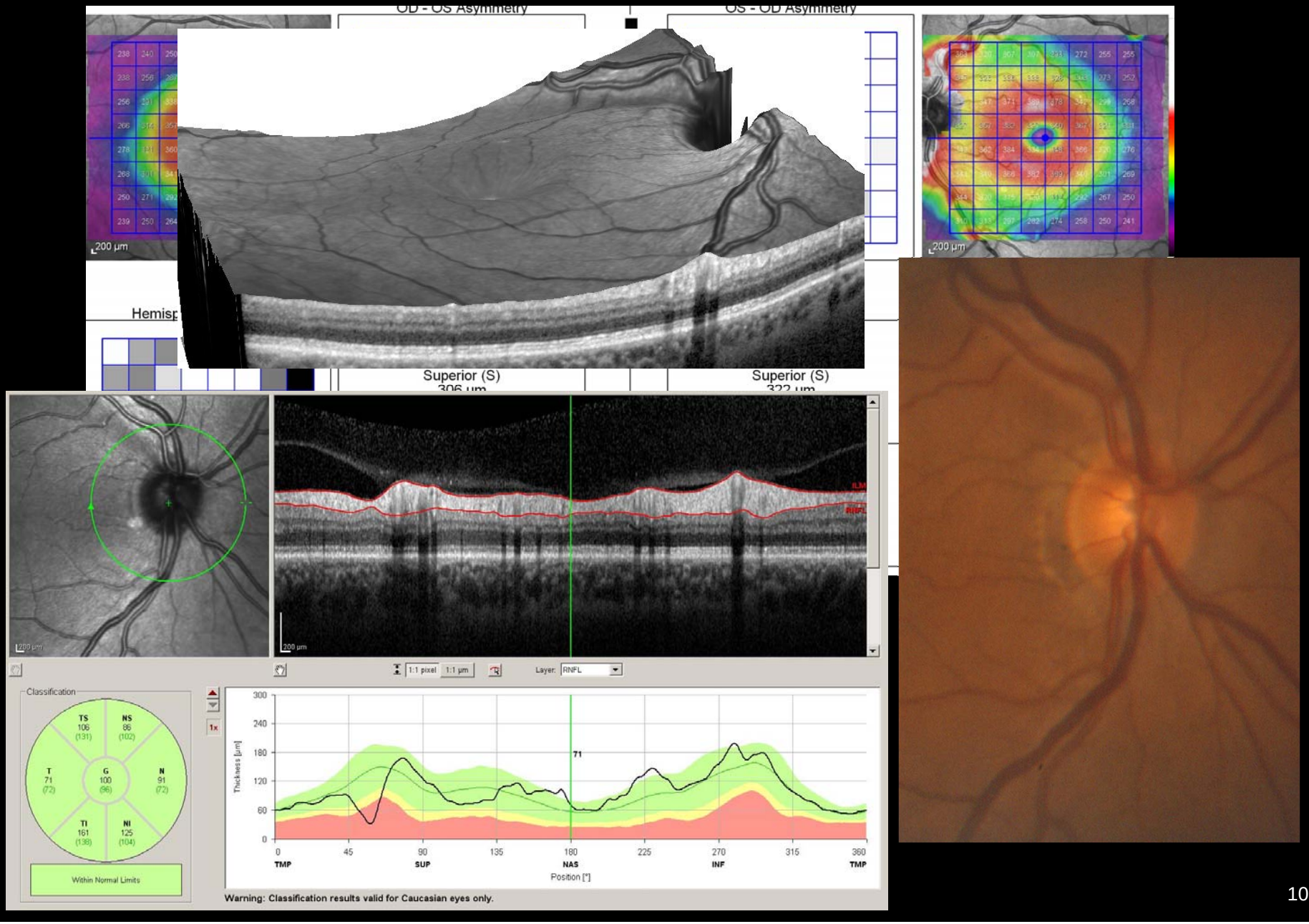


Asrani S, Rosdahl JA, Allingham RR. Novel Strategy for Glaucoma Diagnosis. Arch Ophthalmol 2011;129(9);1205-11

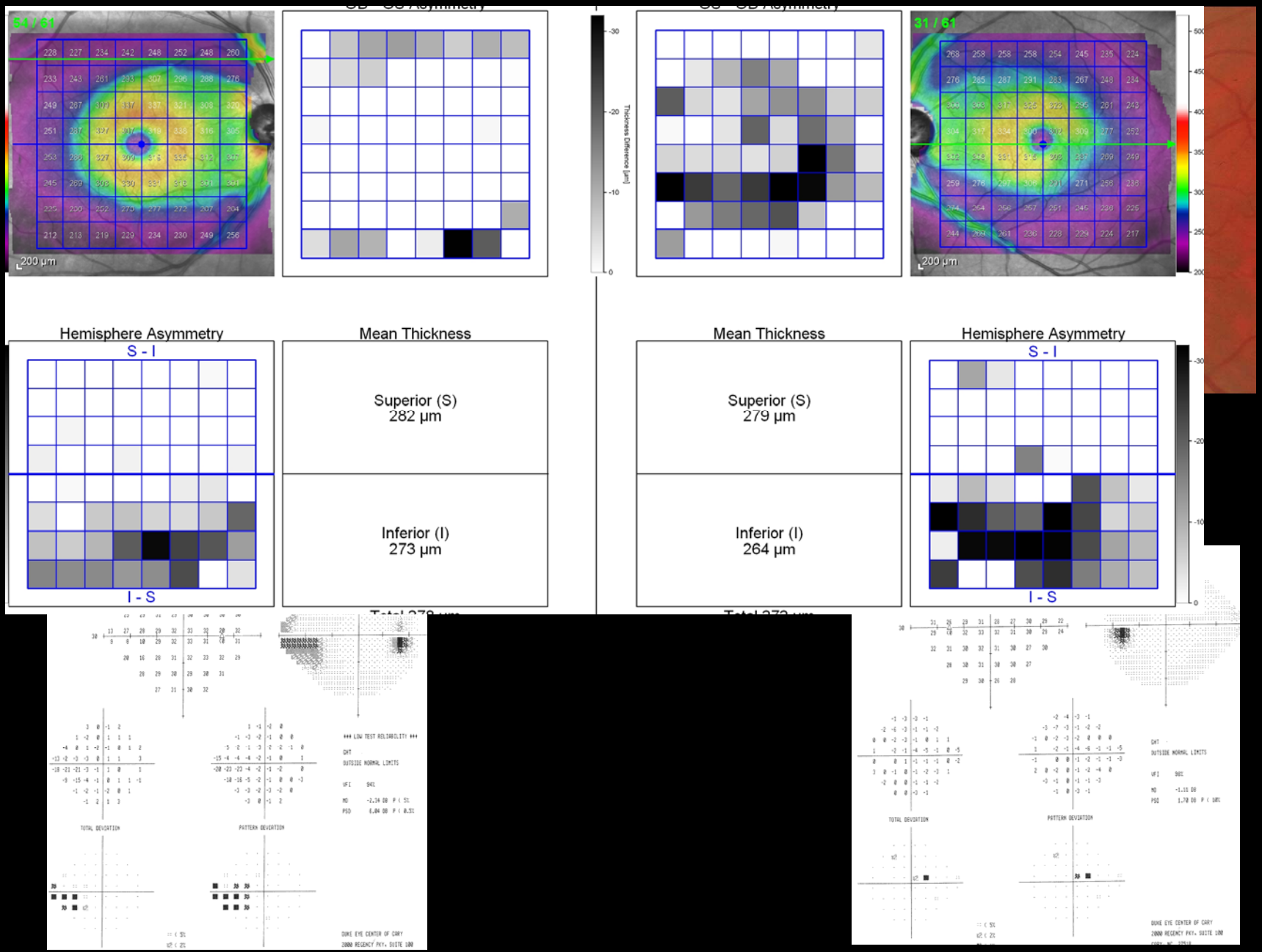
RNFL circle scan considers the peripapillary region



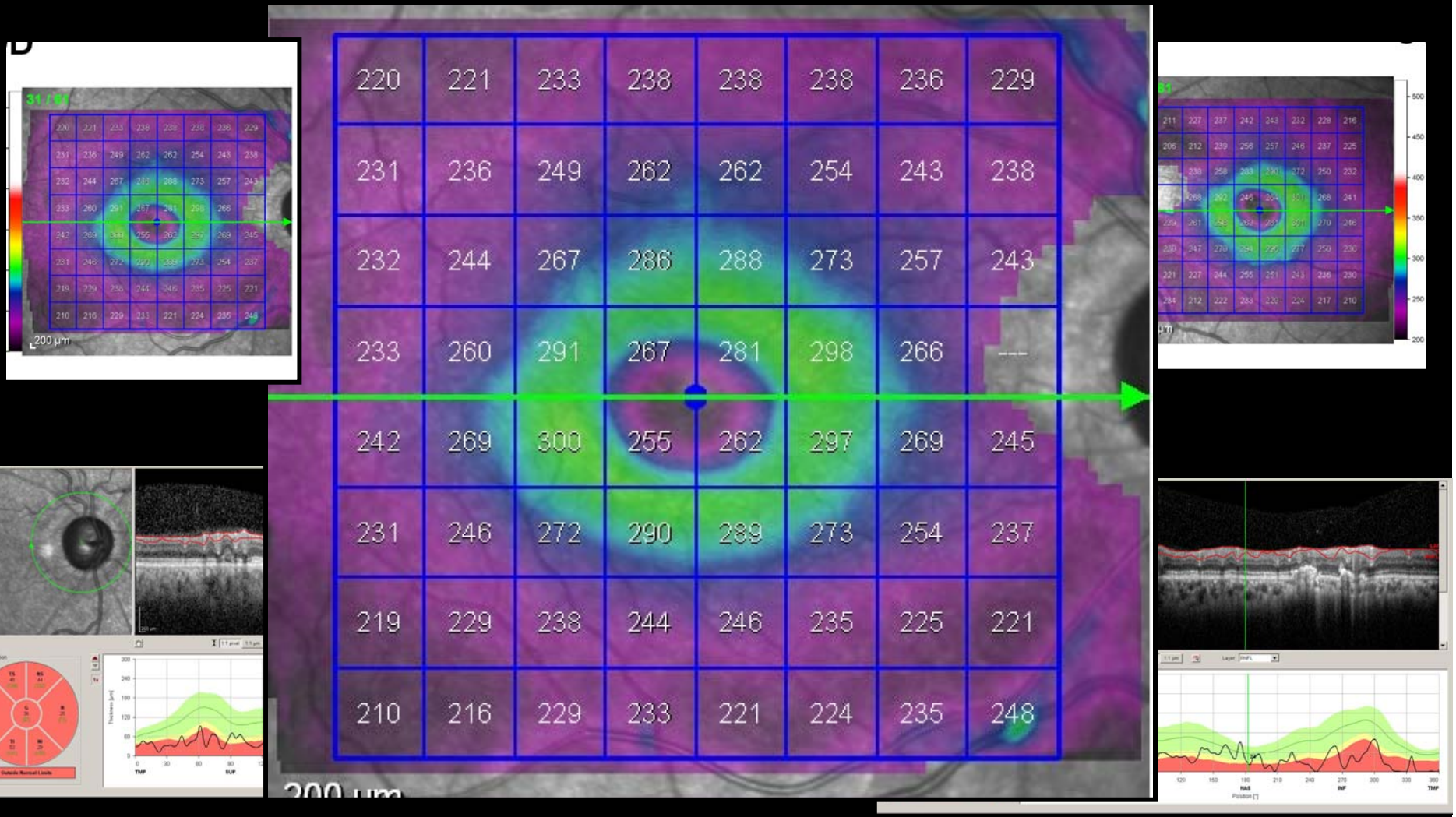
Glaucoma suspect with normal visual field



Paracentral VF depression OS



End stage glaucoma



Macular vs Average RNFL Reproducibility

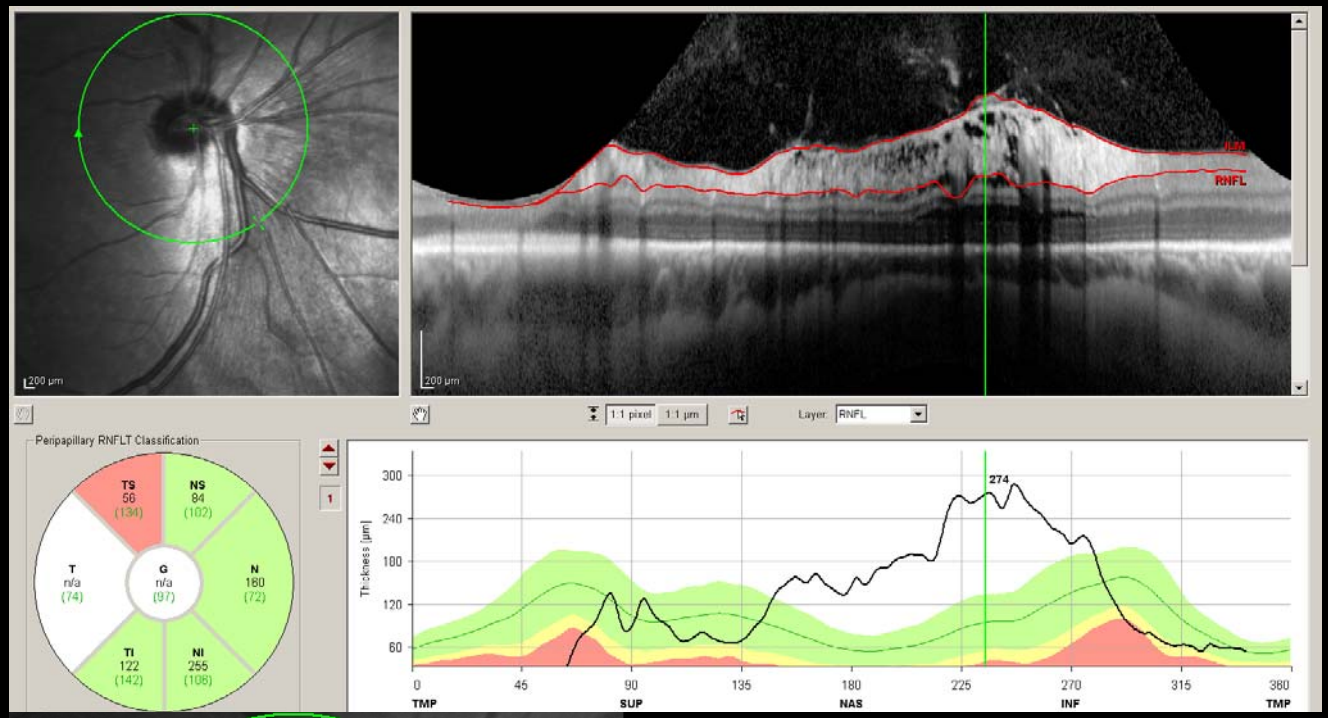
Inter-visit Coefficient of variation

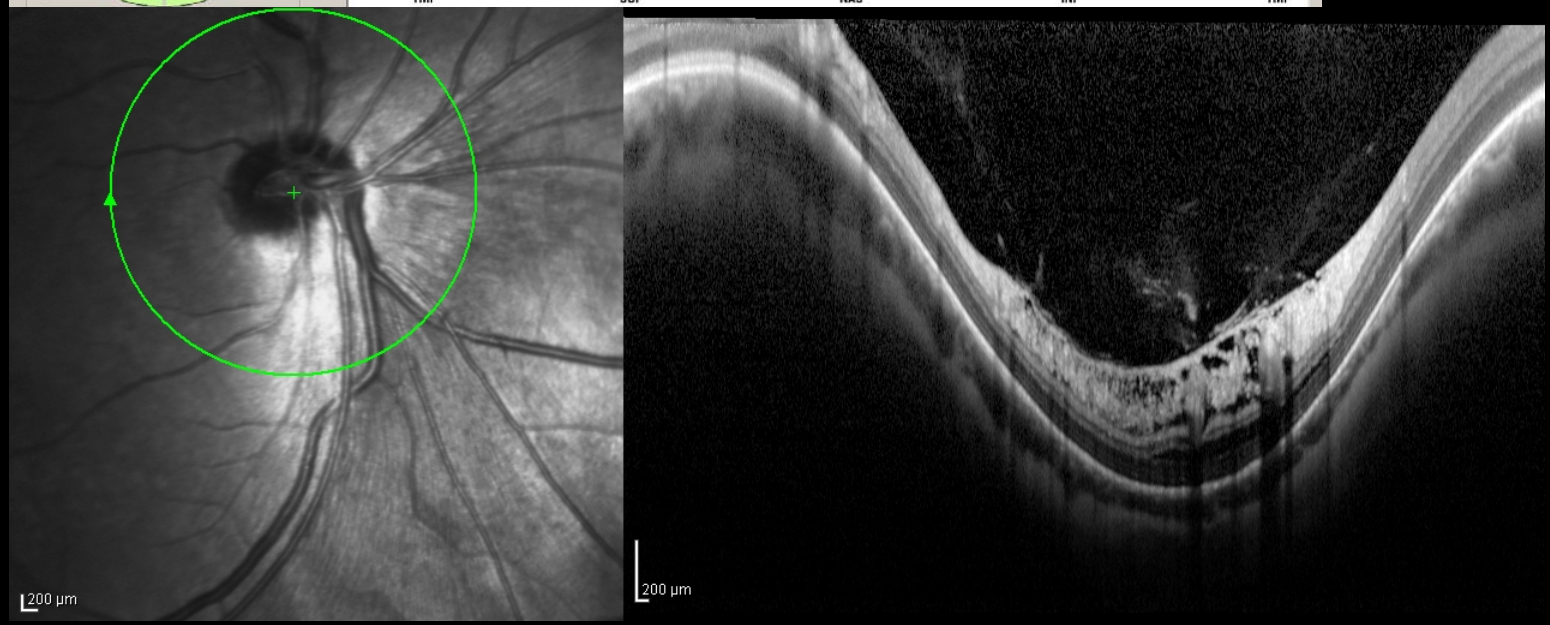
OCT Parameters	Normal	glaucoma suspect	mild glaucoma	mod/severe glaucoma
Cen-Macula	0.98%	0.77%	0.76%	0.84%
Peri-macula	0.96%	0.84%	0.72%	1.03%
Average RNFL	1.93%	1.84%	1.95%	1.62%

Intra-visit Coefficient of variation

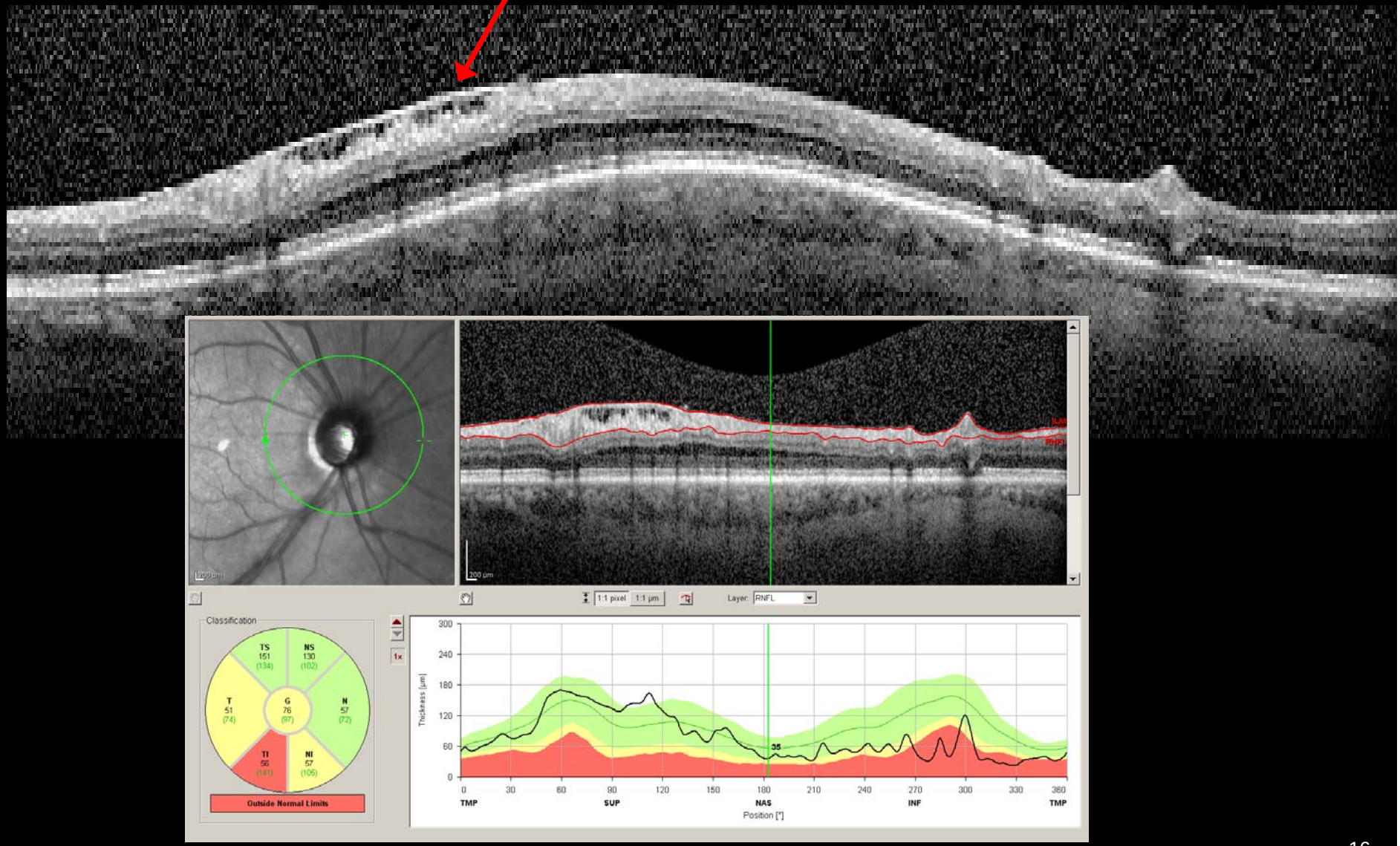
Cen-Macula	0.60%	0.47%	0.70%	0.60%
Peri-macula	0.56%	0.62%	0.75%	0.67%
Average RNFL	1.13%	1.33%	2.81%	1.36%

Artifacts affecting RNFL and Macular Scans

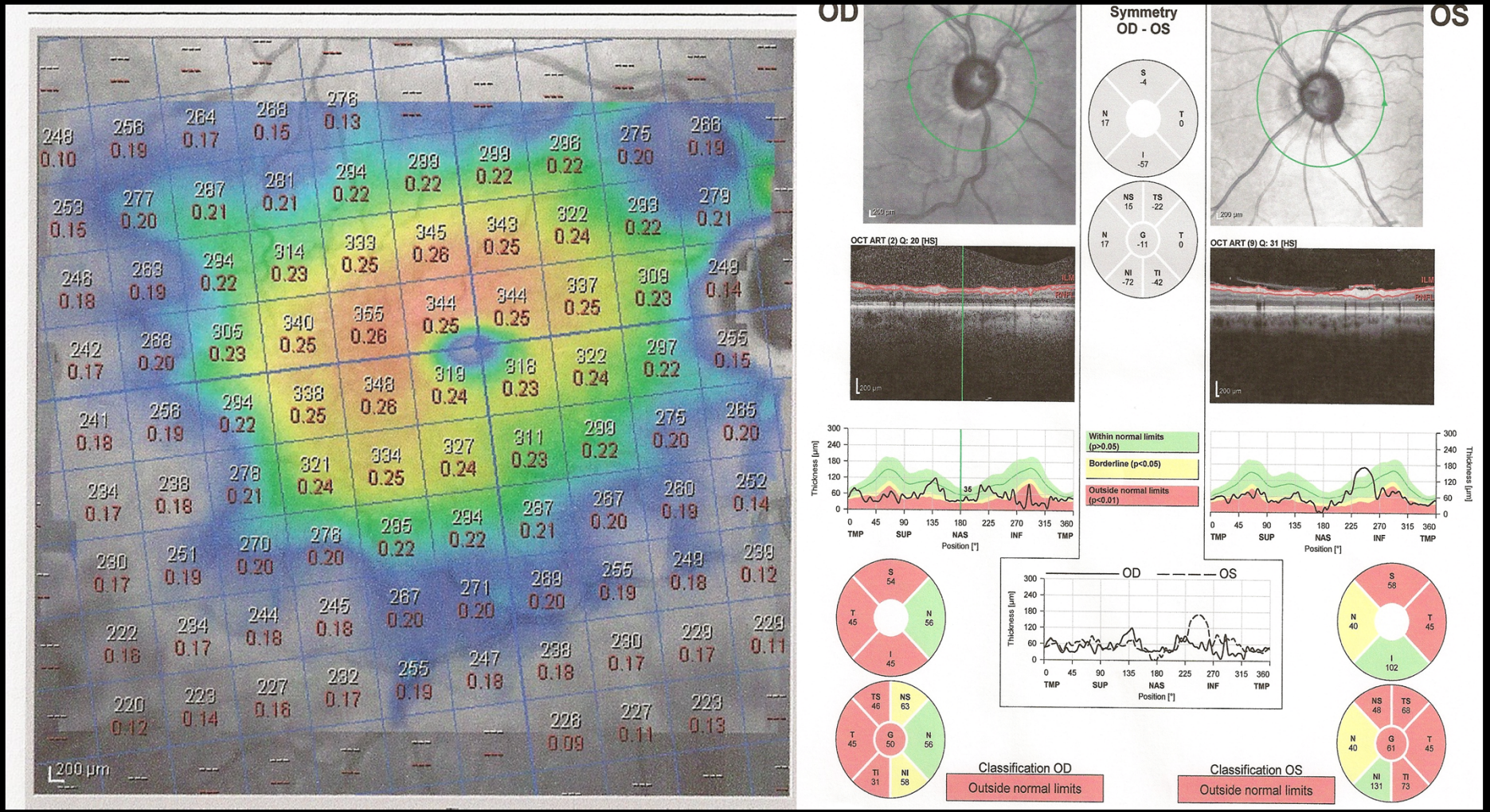

200 µm
ILM
RNFL
200 µm
1:1 pixel
1:1 µm
Layer: RNFL
Peripapillary RNFLT Classification
TS
56
(134)
NS
84
(102)
T
n/a
(74)
G
n/a
(97)
N
180
(72)
TI
122
(142)
NI
255
(108)
Thickness [µm]
300
240
180
120
60
274
0
45
90
135
180
225
270
315
360
TMP
SUP
NAS
INF
TMP


200 µm
200 µm

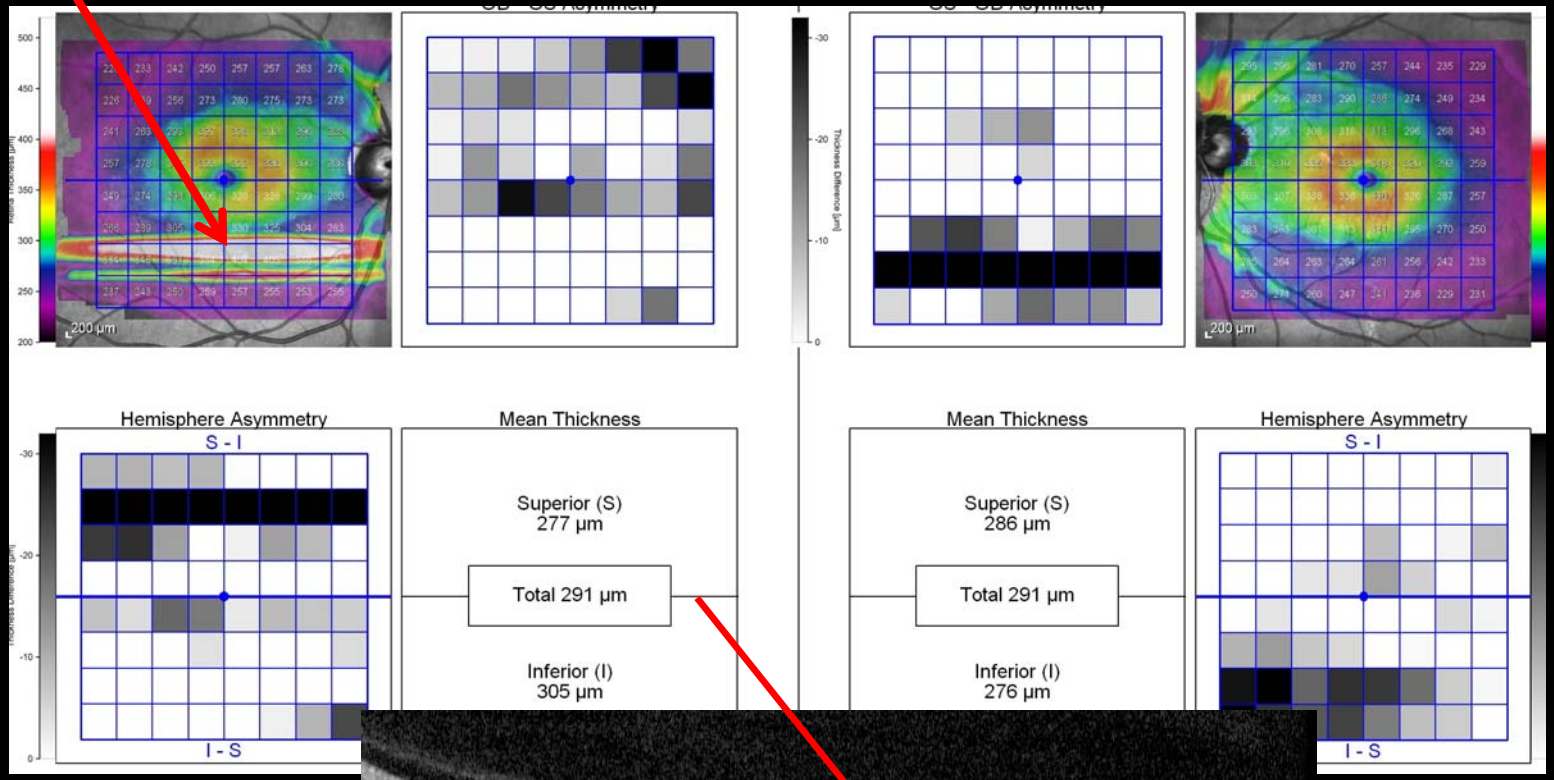
Artificially thick RNFL due to epiretinal membrane

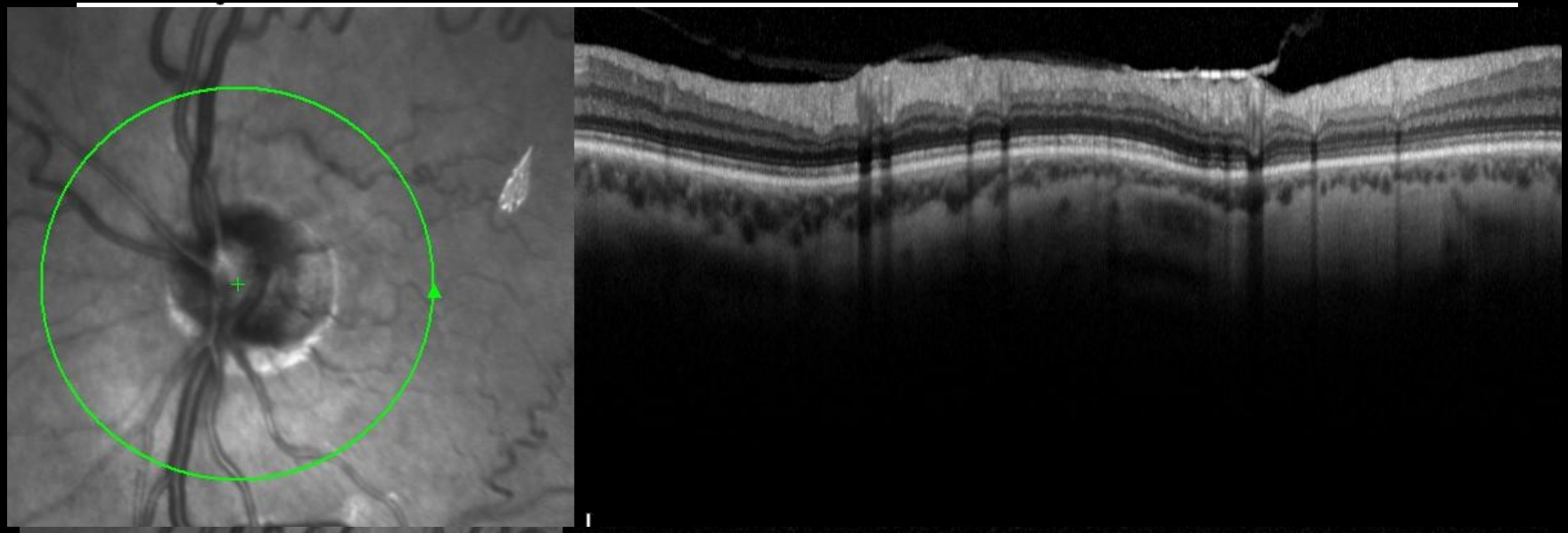


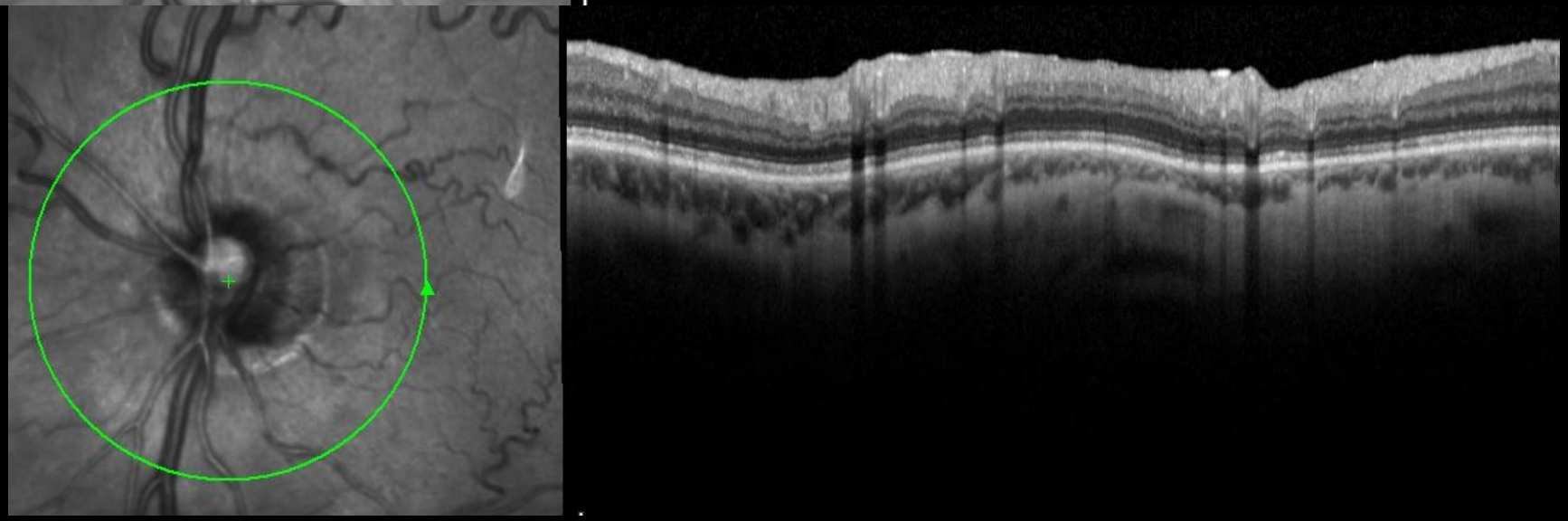
Artificially thick macula due to epiretinal membrane



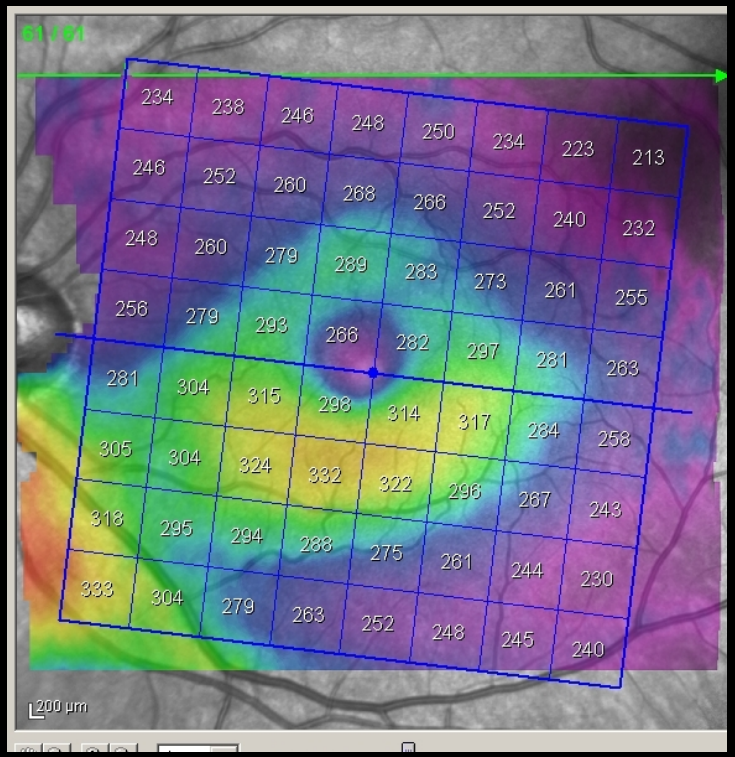
Artifact due to prominent posterior vitreous

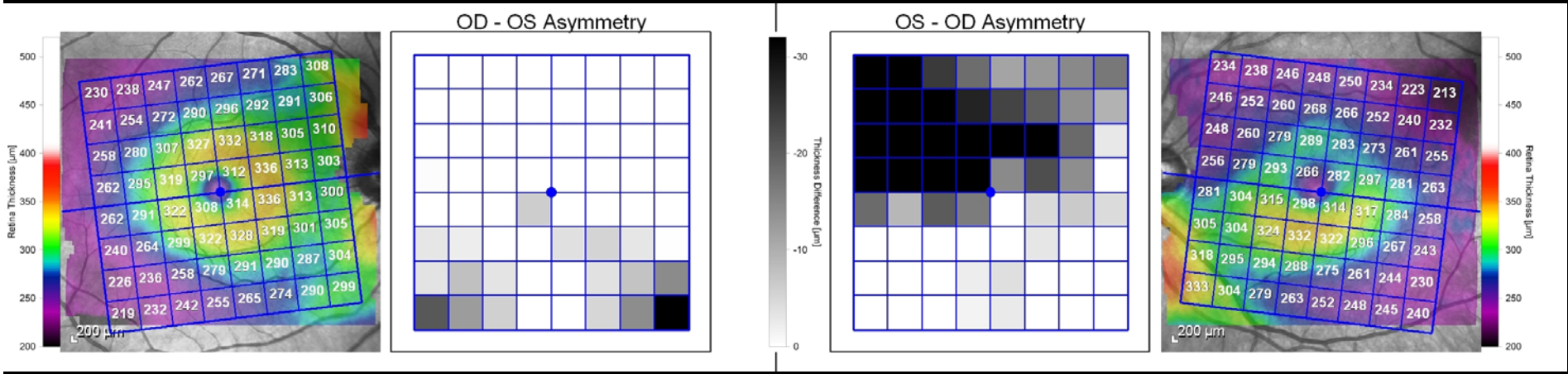


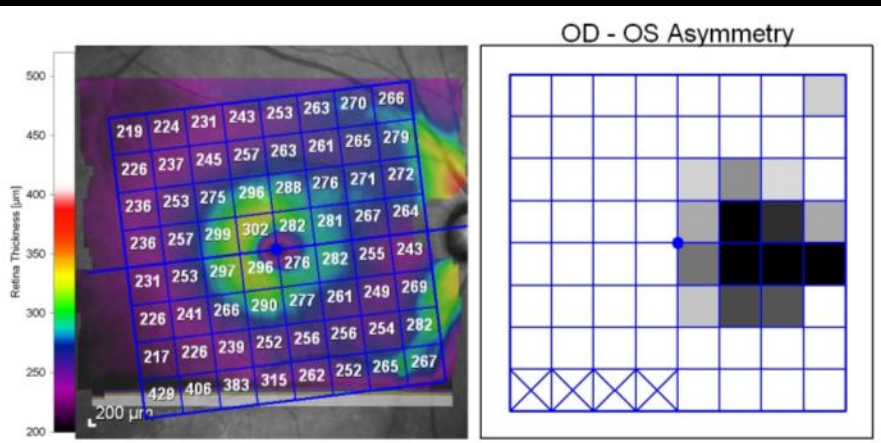


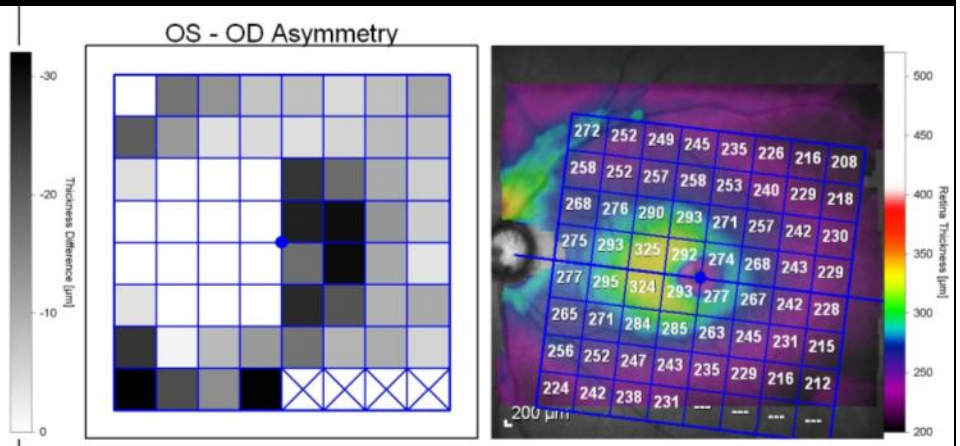


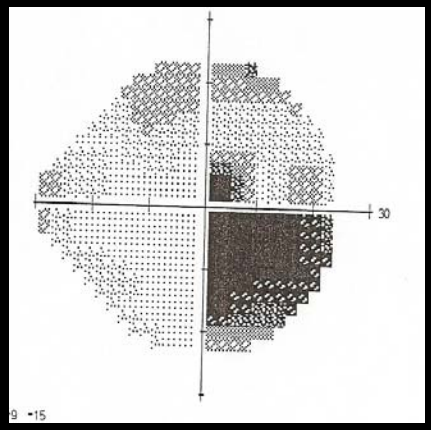
Peripapillary RNFLT Classification
NS 66 (102)
TS 39 (131)
N 107 (72)
G 92 (96)
T 42 (72)
NI 179 (104)
TI 151 (136)
Outside Normal Limits
Layer: RNFL
Thickness [µm]
TMP
SUP
NAS
INF
TMP
Position [°]
Warning: Classification results valid for Caucasian eyes only.

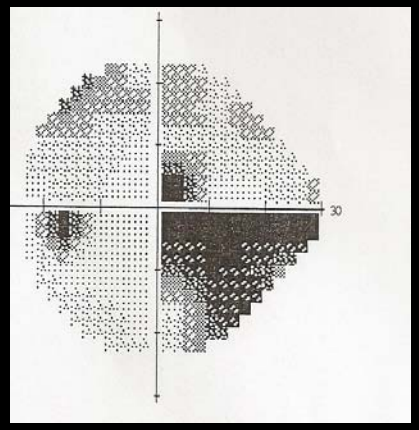

61 / 61
234 238 246 248 250 234 223 213
246 252 260 268 266 252 240 232
248 260 279 289 283 273 261 255
256 279 293 266 282 297 281 263
281 304 315 298 314 317 284 258
305 304 324 332 322 296 267 243
313 295 294 288 275 261 244 230
333 304 279 263 252 248 245 240
200 µm


Retina Thickness [µm]
230 238 247 262 267 271 283 308
241 254 272 290 296 292 291 306
258 280 307 327 332 318 305 310
262 295 319 297 312 336 313 303
262 291 322 308 314 336 313 300
240 264 299 322 328 319 301 305
226 236 258 279 291 290 287 304
219 232 242 255 265 274 290 299
200 µm
OD - OS Asymmetry
OS - OD Asymmetry
Thickness Difference [µm]
234 238 246 248 250 234 223 213
246 252 260 268 266 252 240 232
248 260 279 289 283 273 261 255
256 279 293 266 282 297 281 263
281 304 315 298 314 317 284 258
305 304 324 332 322 296 267 243
318 295 294 288 275 261 244 230
333 304 279 263 252 248 245 240
200 µm
Retina Thickness [µm]

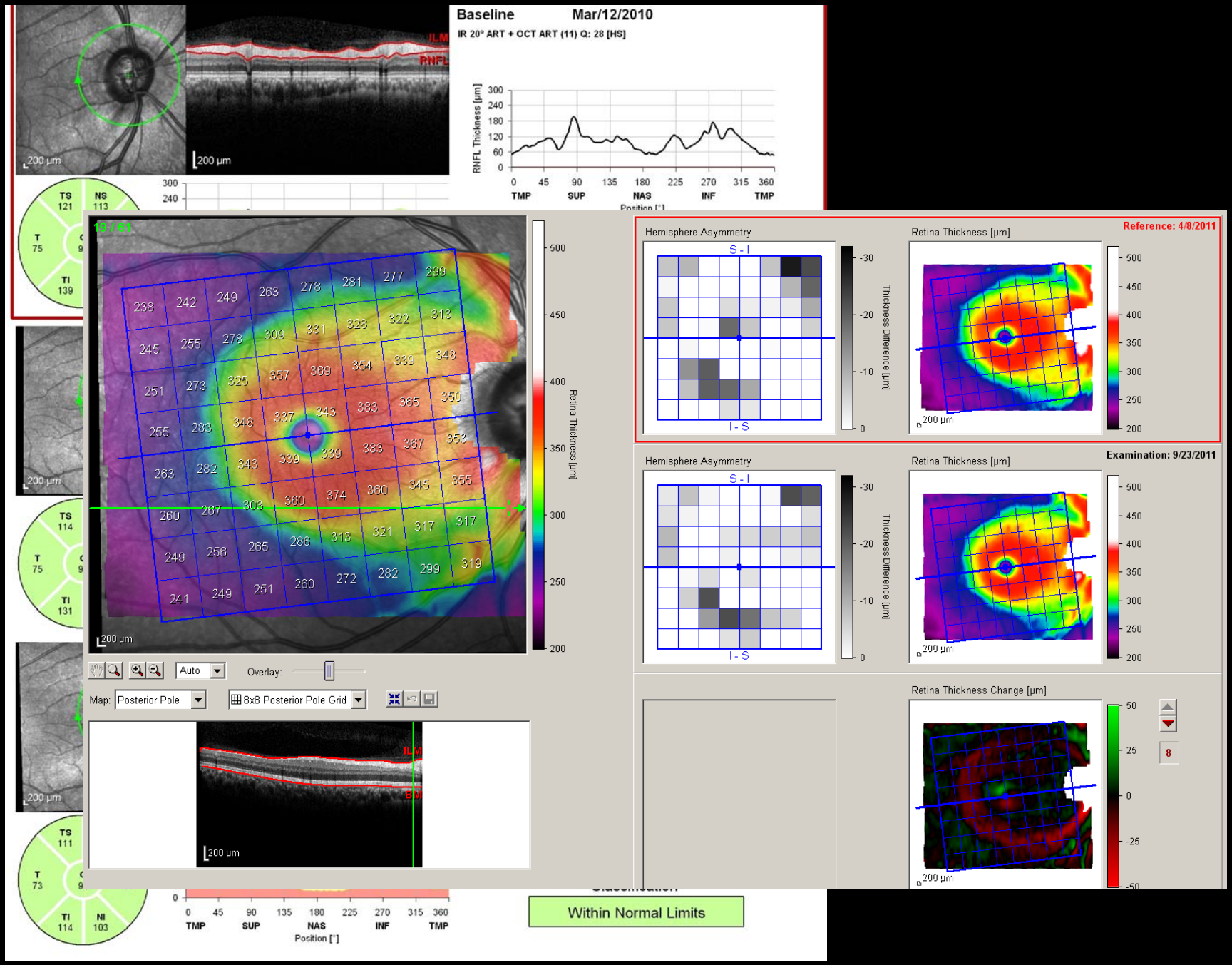

OD - OS Asymmetry
Retina Thickness [µm]
500
450
400
350
300
250
200
219 224 231 243 253 263 270 266
226 237 245 257 263 261 265 279
236 253 275 296 288 276 271 272
236 257 299 302 282 281 267 264
231 253 297 296 276 282 255 243
226 241 266 290 277 261 249 269
217 226 239 252 256 256 254 282
429 406 383 315 262 252 265 267
200 µm

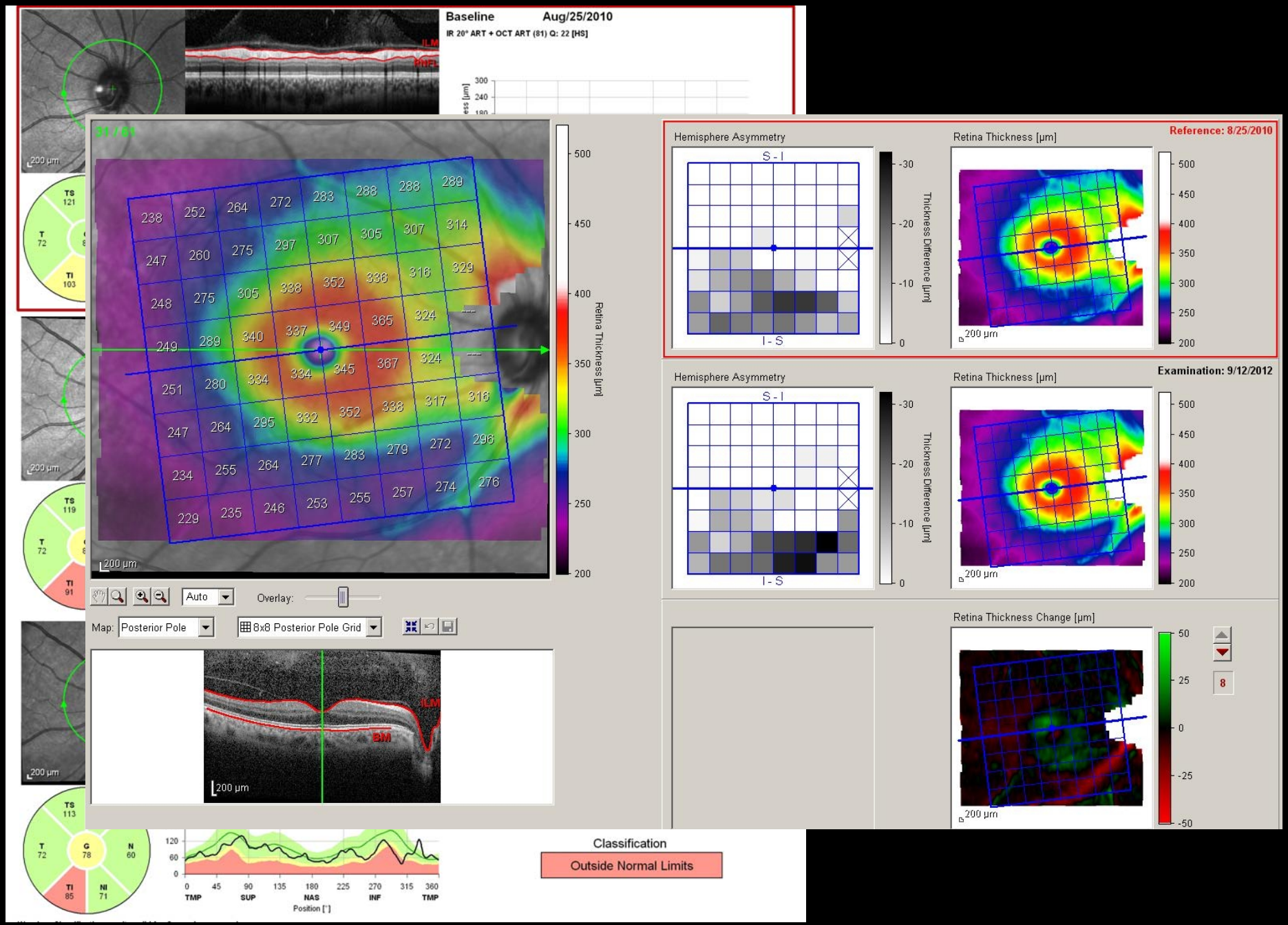

OS - OD Asymmetry
Thickness Difference [µm]
-30
-20
-10
0
Retina Thickness [µm]
500
450
400
350
300
250
200
272 252 249 245 235 226 216 208
258 252 257 258 253 240 229 218
268 276 290 293 271 257 242 230
275 293 325 292 274 268 243 229
277 295 324 293 277 267 242 228
265 271 284 285 263 245 231 215
256 252 247 243 235 229 216 212
224 242 238 231 --- --- --- ---
200 µm

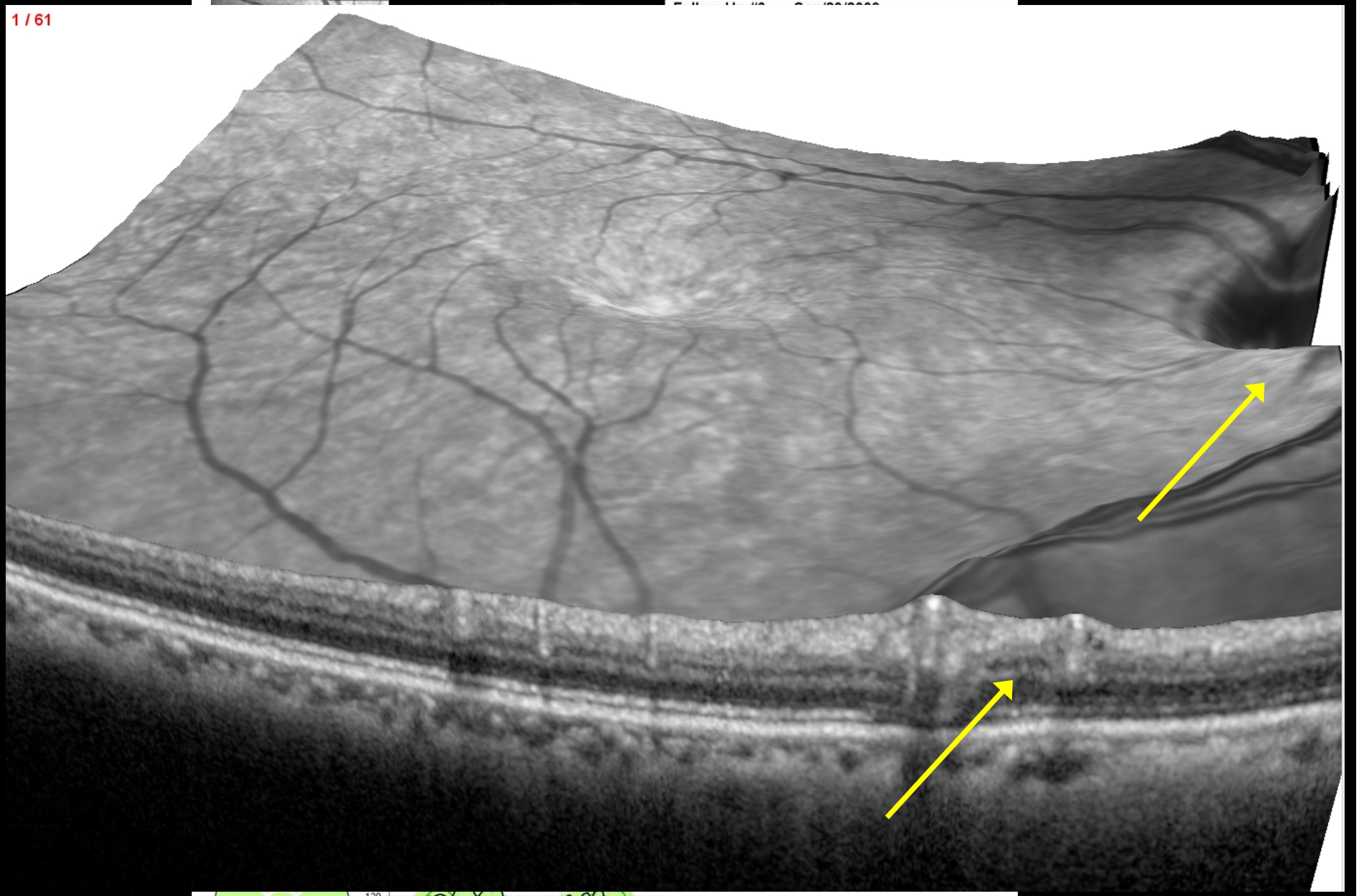

30
-15

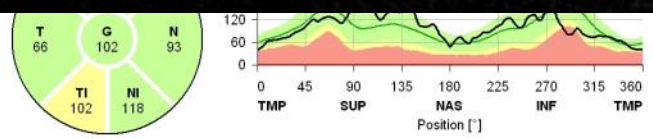

30

Detecting Progression


Baseline
Mar/12/2010
IR 20° ART + OCT ART (11) Q: 28 [HS]
RNFL Thickness [µm]
TMP
SUP
NAS
INF
TMP
Position [°]
Reference: 4/8/2011
Examination: 9/23/2011
Hemisphere Asymmetry
S - I
I - S
Thickness Difference [µm]
Retina Thickness [µm]
Retina Thickness Change [µm]
Auto
Overlay:
Map:
Posterior Pole
8x8 Posterior Pole Grid
ILM
BM
200 µm
Within Normal Limits


Baseline
Aug/25/2010
IR 20° ART + OCT ART (81) Q: 22 [HS]
ILM
RPE
31 / 61
238 252 264 272 283 288 288 289
247 260 275 297 307 305 307 314
248 275 305 338 352 336 316 329
249 289 340 337 349 365 324 ---
251 280 334 334 345 367 324 ---
247 264 295 332 352 338 317 316
234 255 264 277 283 279 272 296
229 235 246 253 255 257 274 276
200 µm
Retina Thickness [µm]
Auto
Overlay:
Map: Posterior Pole
8x8 Posterior Pole Grid
ILM
BM
200 µm
Hemisphere Asymmetry
S - I
I - S
Thickness Difference [µm]
Retina Thickness [µm]
Reference: 8/25/2010
Examination: 9/12/2012
Retina Thickness Change [µm]
TS 121
T 72
TI 103
TS 119
TI 91
TS 113
G 78
N 60
NI 71
TI 85
TMP
SUP
NAS
INF
Position [°]
Classification
Outside Normal Limits





Classification

Borderline

Warning: Classification results valid for Caucasian eyes only.

Findings from Recent Studies

- Macular GCC parameters were found to be superior to RNFL in detecting early glaucoma especially in high myopes
- Both retinal thickness measurements as well as GCC are highly reproducible
- Both total retinal thickness and macular GCC showed similar levels of sensitivity in progression detection and were better than RNFL parameters, especially for advanced glaucoma

- Moreno PA, Konno B, Lima VC et al. Spectral-domain optical coherence tomography for early glaucoma assessment: analysis of macular ganglion cell complex versus peripapillary retinal nerve fiber layer. Can J Ophthalmol. 2011 Dec;46(6):543-7
- Sung KR, Sun JH, Na JH, Lee JY, Lee Y. Progression detection capability of macular thickness in advanced glaucomatous eyes. Ophthalmology. 2012 Feb;119(2):308-13
- Mwanza JC, Oakley JD, Budenz DL et al. Macular ganglion cell-inner plexiform layer: automated detection and thickness reproducibility with spectral domain-optical coherence tomography in glaucoma. Invest Ophthalmol Vis Sci. 2011 Oct 21;52(11):8323-9.
- Na JH, Sung KR, Baek S, Kim YJ, Durbin MK, Lee HJ, Kim HK, Sohn YH. Detection of glaucoma progression by assessment of segmented macular thickness data obtained using spectral domain optical coherence tomography. Invest Ophthalmol Vis Sci. 2012 Jun 20;53(7):3817-26

Conclusions

- The high reproducibility of macular thickness holds promise for objective measurement of glaucoma progression
- Detection of glaucoma and measuring progression is made easier by combining the diagnostic potential of RNFL thickness and the modified macular thickness map
- Artifacts need to be ruled out before accepting results from any technology
- As a predictable and significant structural relationship exists between macular thickness and VF defects, such measurements should be studied further