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1 **Choroidal Vascular Changes after Encircling Scleral Buckling for Rhegmatogenous Retinal**
2 **Detachment**

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12

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25

26 **Abstract**

27 **Background/Objectives:** There is an ongoing debate on whether encircling scleral buckling (SB)
28 procedure for the treatment of rhegmatogenous retinal detachment (RRD) may cause an impairment
29 in choroidal blood flow. The aim of this study was to compare choroidal vascularity index (CVI) and
30 subfoveal choroidal thickness (CT) between eyes that had undergone encircling SB with unoperated
31 fellow eyes (FEs).

32 **Subjects/Methods:** Thirty patients treated with encircling SB for unilateral RRD were included.
33 Demographic and clinical characteristics as well as Enhanced Depth Imaging – Optical Coherence
34 Tomography scans were retrospectively collected. Images were binarised using ImageJ software,
35 total choroidal area along with luminal and stromal area (respectively, TCA, LA and SA) were
36 segmented and the CVI was computed as the ratio of LA/TCA. In addition, CT was evaluated.

37 **Results:** The mean follow-up interval between surgery and examination was 25.5 ± 16.8 months.
38 Choroidal thickness, TCA, LA, and SA were significantly increased in the operated eyes compared
39 to FEs (respectively, $271.7 \pm 78.0 \mu\text{m}$ vs 238.5 ± 83.4 , $P=0.001$; $1.804 \pm 0.491 \text{mm}^2$ vs 1.616 ± 0.496 ,
40 $P=0.001$; $1.199 \pm 0.333 \text{mm}^2$ vs 1.067 ± 0.337 , $P<0.001$ and $0.605 \pm 0.171 \text{mm}^2$ vs 0.550 ± 0.171 ,
41 $P=0.001$). Conversely, CVI did not significantly differ between the two groups (66.4 ± 3.6 vs.
42 65.9 ± 3.2 , $P=0.490$).

43 **Conclusions:** In conclusion, eyes treated with encircling SB for RRD presented increased LA, SA
44 and CT compared with FEs, but showed no difference in CVI.

45

46 **Key words:** Encircling scleral buckling; Choroidal vascularity index; Choroidal Thickness; Choroid;
47 Rhegmatogenous Retinal Detachment.

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52 **Introduction**

53 Rhegmatogenous retinal detachment (RRD) is a sight-threatening condition caused by the
54 passage of fluid from the vitreous cavity into the subretinal space through one or more retinal breaks,
55 leading to the separation of the neurosensory retina from the underlying retinal pigment epithelium ¹.
56 Encircling scleral buckling (SB) represents an effective and well-established surgical technique for
57 the treatment of selected cases of primary or recurrent RRD. The positioning of an encircling element
58 around the circumference of the eye provides the reduction of vitreoretinal traction and the closure of
59 the retinal defect(s), allowing retinal re-attachment ¹. Although uncommon, complications such as
60 anterior and posterior segment ischemia and serous choroidal detachment could occur postoperatively
61 ². The mechanical force exerted by the encircling band induces changes in anatomical and functional
62 parameters of the eyeball, such as axial length, anterior chamber depth and corneal biomechanics ³⁻
63 ⁵. Moreover, previous studies disclosed an impaired ocular circulation, reporting postoperative
64 changes in both choroidal and retinal blood flow ⁶⁻¹⁴. These findings suggest that a subclinical
65 ischaemia may exist in more cases than reported.

66 The advancements in spectral coherence optical coherence tomography (SD-OCT) technology
67 made it possible to visualize the choroidal structure in great detail, and allowed the accurate
68 calculation of different quantitative parameters ¹⁵. In particular, choroidal thickness (CT) has been
69 used to investigate vascular changes after encircling SB. Although there seems to be some agreement
70 that the encircling element affects CT, the results are somewhat contradictory ^{13,16-19}.
71 The recent introduction of binarisation algorithms on enhanced depth imaging SD-OCT (EDI SD-
72 OCT) images allows to separately investigate the vascular and stromal choroidal components ²⁰.
73 In particular, choroidal vascularity index (CVI), which is the proportion of the luminal area (LA) to
74 the cross-sectional choroidal area, represents a novel choroidal biomarker that has been used to
75 monitor choroidal status in several chorioretinal disorders ²¹⁻²⁵. Compared to CT, CVI seems to be
76 less influenced by biological variables such as axial length, intraocular pressure, and diurnal variation
77 ²⁶.

78 The aim of this study was to compare CVI between eyes that had undergone encircling SB for
79 RRD and fellow eyes (FEs), and to further investigate possible correlations with clinical parameters.

80

81 **Subjects and Methods:**

82 *Study Design and Patients*

83 This retrospective cross sectional study included patients treated for RRD at a single tertiary-referral
84 center (S.Orsola-Malpighi University Hospital, Bologna, Italy) between January 2016 and December
85 2019. The study was performed in accordance with the principles of the Declaration of Helsinki and
86 was approved by the local Institutional Review Board. Written informed consent was obtained from
87 all subjects included in the study. Consecutive patients underwent uneventful SB for RRD in one eye
88 were screened for enrolment. SB was performed by the same surgeon (P.G.T.) in phakic patients with
89 RRD due to single retinal break or small confluent multiple breaks without significant lens
90 opacification. Eyes with SB were included as the study eyes and the FEs served as controls. Exclusion
91 criteria were any previous ocular surgery except for SB in one eye, history of retinal diseases (e.g.
92 choroidal neovascularization, diabetic retinopathy, retinal dystrophy and central serous
93 chorioretinopathy), glaucoma, spherical equivalent ≥ 6 diopters (D), anisometropia ≥ 1.5 D, poor
94 image quality and missing data from medical records.

95 The following data were extrapolated from medical records: age, sex, preoperative status of the
96 macula, postoperative BCVA in logMAR, postoperative fundus examination and spectral domain
97 EDI-OCT scan.

98

99 *Encircling Scleral Buckling Procedure*

100 A 360-degree limbal conjunctival peritomy incision was made and traction sutures were placed
101 beneath the insertions of the exposed rectus muscles to facilitate positioning the globe. A 2.5 mm
102 wide silicone band (No. 240) was passed around the circumference of the globe and beneath the rectus
103 muscles at a distance of 14 mm from the limbus. The band was anchored with single interrupted

104 suture with bites parallel to the limbus placed in the center of each quadrant, the ends of the band
105 were then joined in the opposite quadrant of the retinal break(s) with a silicone sleeve. In all cases,
106 drainage procedure was performed by a sclerotomy just below the retinal break(s) then sutured by a
107 single scleral stitch. Ab externo cryotherapy was done in the retinal break(s) location. In order to
108 increase the buckling effect an adjunctive biconvex silicone 9 mm wide element (No. 279) was placed
109 beneath the band above the retinal break(s). In all patients included, their extension ranged from 3 to
110 5 clock hours. The ends of the encircling silicone band were then pulled until the desired buckle effect
111 was reached. A paracentesis was done and SF6 injection was performed 4 mm posterior to the limbus.
112 There were no intraoperative complications. At the end of the procedure, indirect ophthalmoscopy
113 revealed retinal reattachment in all patients.

114

115 *Image Analysis*

116 The SD-OCT scans were obtained in all patients using the Spectralis HRA-OCT (Heidelberg
117 Engineering, Heidelberg, Germany). Each session was performed at approximately the same time of
118 the morning, to avoid diurnal variations. Macular OCT images were acquired with EDI mode using
119 a volume scan of 30 X 10 degrees centred on the fovea, with 100 frames averaged in each scan. The
120 OCT scan passing through the central foveal region was chosen for the analysis. The choroid was
121 defined as the space between the outer border of the retinal pigment epithelium and the choroidal–
122 scleral junction. The subfoveal CT was measured manually by two independent examiners (F.B. and
123 P.R.R.) using the caliper function tool of the image analysis software. The mean of the two
124 measurements was used for the analysis. The OCT images were binarised and segmented by the same
125 examiners using the public domain software ImageJ 1.51s (National Institutes of Health, Bethesda,
126 MD), with a semiautomated method previously described^{20,22}. Briefly, the OCT image was opened
127 in ImageJ and the polygon tool was used to select the region of interest across the entire length of the
128 OCT scan. The upper boundary of the region of interest was traced along the choroidal–retinal
129 pigment epithelium junction and the lower boundary along the choroidal–scleral junction to identify

130 the total choroidal area (TCA) (Figure 1, part A). After conversion to an 8-bit image, Niblack's
131 autolocal threshold was applied to binarise the image and demarcate the LA and stromal area (SA)
132 (Figure 1, part B). The image was converted back to a red, green, blue image, and the colour threshold
133 tool was used to select the dark pixels, representing the LA (Figure 1, part C). The TCA and LA were
134 measured. The SA was calculated by subtracting LA from TCA. The CVI, defined as the LA divided
135 by the TCA, was then computed. The choroidal parameters calculation was performed separately by
136 2 investigators, both blinded for patients' characteristics (F.B. & M.P.), and the mean value for each
137 parameter calculated was used for the statistical analysis.

138

139 *Statistical Analysis*

140 The R studio software, version 1.2.5042, (<http://www.r-project.org>) was used for data analysis.
141 Values are expressed as mean \pm standard deviation. The Shapiro-Wilk test was used to determine
142 normality of data. The Student's t-test was used to compare normally distributed continuous variables
143 between operated eyes (OEs) and FEs, whereas the Wilcoxon signed-rank test was used for not
144 normally distributed variables. The correlations of choroidal parameters with demographic and
145 clinical parameters were examined using the Pearson correlation analysis with a Bonferroni
146 correction for multiple comparisons. A *P* value < 0.05 was considered statistically significant.

147

148 **Results**

149 Thirty-nine patients treated with SB for RRD were initially identified. Of these, 9 patients did not
150 satisfy the inclusion/exclusion criteria and were excluded from the final analysis. In particular, 2
151 presented high myopia, 3 had previous eye surgery in both eyes, 1 had glaucoma, 1 was lost to follow
152 up and 2 presented poor OCT scans quality. Finally, 30 patients were enrolled in the study. Mean age
153 was 61.7 ± 6.1 years (range 51–75 years), and 19 of the patients (63.3%) were male. Eighteen patients
154 (60%) presented macula off RRD at the time of the procedure. The mean time interval between the
155 surgery procedure and the follow-up visit was 25.5 ± 16.8 months (range 4–59 months). Mean BCVA

156 was 0.05 ± 0.07 logMAR in the OEs. Macular pucker was present in 9 of the OEs (30%) at follow-
157 up visit. Choroidal parameters in eyes treated with encircling SB for RRD and FEs are reported in
158 Table 1. Choroidal thickness, TCA, LA, and SA were significantly increased in the OEs compared
159 with FEs (respectively, 271.7 ± 78.0 μm vs. 238.5 ± 83.4 , $P = 0.001$; 1.804 ± 0.491 mm^2 vs. $1.616 \pm$
160 0.496 , $P = 0.001$; 1.199 ± 0.333 mm^2 vs. 1.067 ± 0.337 , $P < 0.001$ and 0.605 ± 0.171 mm^2 vs. 0.550
161 ± 0.171 , $P = 0.001$). On the contrary, CVI did not significantly differ between the two groups (66.4
162 ± 3.6 % vs. 65.9 ± 3.2 , $P = 0.490$). No significant correlations between choroidal parameters and
163 demographical and clinical parameters, including follow-up period, were found (always $P > 0.05$).

164

165 **Discussion**

166 In the present study we investigated the choroidal structure in eyes treated with encircling SB
167 after a relatively long term follow up. The evaluation was made using a previously validated
168 technique, which allows to evaluate separately the stromal and the luminal choroidal components ²⁰.
169 We found that both LA and SA were increased in the OEs compared with FEs. Interestingly, the CVI,
170 that represents the ratio of LA to TCA, was not different between the two groups, suggesting that
171 both LA and SA increased without changing their proportions.

172 It has been speculated that the mechanical force exerted by encircling and buckling elements
173 could determine a venous drainage obstruction, inducing an increased vascular resistance and thus, a
174 decreased ocular blood flow ⁶. Previous studies investigated ocular blood flow after SB procedure
175 using different techniques, including ocular pulse measurements, bidirectional laser Doppler, laser
176 speckle flowmetry and color Doppler imaging, disclosing an impaired chorioretinal circulation ⁶⁻¹⁴.
177 However, mixed results on its changes over time have been reported. Some studies showed that the
178 reduction of chorioretinal blood flow still persisted after a long term follow-up and improved only
179 after the removal of the encircling band ^{6,9-11}. Our results could support this hypothesis, since the
180 increase in LA had previously been interpreted as an indirect marker of blood flow stasis secondary
181 to an impaired circulation ²⁴. Conversely, others reports showed a post-operative reduction in

182 choroidal blood flow that returned to baseline values 3 to 6 months after surgery ^{12,14}. It is difficult to
183 compare the results of these studies because they differ in terms of surgical technique, follow-up
184 period and measurement methods.

185 Recently, CT has been evaluated in patients after SB as a surrogate marker of choroidal blood
186 flow ^{13,16-19}. Previous studies indicated that segmental SB procedure, characterised by the placement
187 of a local buckling element, induces a temporary increase of subfoveal CT that returns to baseline
188 values 1 to 3 months after surgery ^{13,18,19}. Conversely, the use of encircling band in addition to the
189 local buckling element seems to lead to a long term increase in CT ^{17,27}.

190 Several factors might be related with the development of choroidal changes, including the
191 material of the buckling element and its extent (length, width and thickness), along with the use of
192 cryotherapy, which can induce a post-operative inflammatory response ^{13,19}. We found that OEs
193 showed an increased CT along with a greater TCA compared with FEs. These results are consistent
194 with Odrobina and collaborators who disclosed an increased CT in patients treated with a 3.5 mm
195 encircling SB after a mean follow-up of 22 months ¹⁷. These findings suggest that different
196 mechanisms might occur depending on whether an encircling band has been used or not. In fact, it is
197 reasonable to hypothesize that the presence of an encircling element may induce an impairment of
198 choroidal circulation over a longer period of time and may reduce the possibility of choroidal tissue
199 to return to baseline status.

200 The absence of change in CVI between OEs and FEs could be explained in two different ways:
201 on the one hand, also the stromal component of the choroid might be affected by the placement of the
202 encircling band; on the other hand, an adaptation process of the stromal tissue might occur following
203 vascular changes. However, these hypotheses remain speculative and a prospective study is required
204 to evaluate when stromal change occur.

205 Interestingly, none of the patients included presented any complication related with vascular
206 impairment following the surgery. Moreover, all of them experienced an overall good prognosis in
207 terms of visual acuity. According to a previous report, although an alteration of the choroidal blood

208 flow seems to be common after encircling SB procedure, patients generally do not experience long-
209 term visual complications. These complications could be related with an individual susceptibility or
210 with the degree of tightness of the encircling band ⁶.

211 This study has some limitations that should be taken into account. The main limit is related to its
212 retrospective design, which hampered the evaluation of choroidal parameters before and after
213 encircling SB, as well as the monitoring of their trend over time. In addition, the algorithm used for
214 the calculation of choroidal parameters does not allow the evaluation of the different choroidal layers,
215 namely the choriocapillaris, the medium choroidal vessel layer and the large choroidal vessel layer,
216 thus it was not possible to determine their respective degree of involvement.

217 In conclusion, eyes treated with encircling SB for RRD show increased luminal and stromal areas
218 along with a greater choroidal area, compared to FEs. Furthermore, OEs show no difference in CVI
219 compared to FEs, suggesting that the increase in stromal and vascular components maintained their
220 proportion unchanged. These results support the theory that encircling SB induces subclinical
221 changes in choroidal circulation and provide a deeper characterisation of this phenomenon.

222

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311

312 **Figure Legends**

313 **Figure 1.** Choroidal vascularity index calculation with binarisation of OCT images in a representative
314 eye treated with encircling scleral buckling for rhegmatogenous retinal detachment. A. Choroidal
315 boundaries are traced to identify the total choroidal area (orange lines). B. The image is binarised
316 with Niblack’s auto-local threshold. C. The colour threshold tool is used to select the dark pixels,
317 representing the luminal area (yellow lines). The choroidal vascularity index is obtained dividing
318 luminal area by total choroidal area.

319

Table 1. Choroidal parameters in eyes treated with encircling scleral buckling for rhegmatogenous retinal detachment and fellow eyes

Parameter	Operated Eye	Fellow Eye	<i>P</i>
Subfoveal CT (μm)	271.7 \pm 78.0	238.5 \pm 83.4	0.001
TCA (mm^2)	1.804 \pm 0.491	1.616 \pm 0.496	0.001
LA (mm^2)	1.199 \pm 0.333	1.067 \pm 0.337	<0.001
SA (mm^2)	0.605 \pm 0.171	0.550 \pm 0.171	0.001
CVI (%)	66.4 \pm 3.6	65.9 \pm 3.2	0.490

320 CT: choroidal thickness; TCA: total choroidal area; LA: luminal area; SA: stromal area; CVI:
321 choroidal vascularity index. Significant P values (<0.05) are in bold.

322

