

1 Identification of Amblyogenic Risk Factors
2 with the Brückner Reflex Test using the low-
3 cost 'Arclight' Direct Ophthalmoscope

4
5 **Dr Sahib Y. Tuteja**

6 Foundation Year 1 Doctor

7 Royal Victoria Infirmary, Newcastle-Upon-Tyne, England

8
9
10 **Dr Andrew Blaikie**

11 (corresponding author)

12 Senior Lecturer

13 University of St Andrews School of Medicine, St Andrews, Scotland

14 Email: ab312@st-andrews.ac.uk

15
16 Consultant Ophthalmologist

17 Department of Ophthalmology

18 Queen Margaret Hospital

19 Dunfermline, Scotland

20
21
22 **Dr Ramesh Kekunnaya**

23 Consultant Ophthalmologist,

24 L V Prasad Eye Institute (LVPEI), Hyderabad, India

25
26
27
28 Conflict of interest statement: Dr Blaikie is seconded to the University of St Andrews from NHS
29 Fife. The University owns a social enterprise subsidiary company, for which he acts as an unpaid
30 adviser. The social enterprise business sells the Arclight to users in high resource countries with
31 all profits being used to fund distribution and education exercises of the device in low income
32 countries via the Global Health Implementation team at the University of St Andrews. Both Dr
33 Tuteja and Dr Blaikie have previously published on the topic of the Arclight. Dr Kekunnaya does
34 not declare any potential conflict of interest.

35 Abstract

36

37 **Background/Objectives:** The Arclight is a novel, low-cost, solar powered direct
38 ophthalmoscope developed for low resource settings as an alternative to more expensive,
39 conventional devices. The Brückner reflex test (BRT) is a quick and effective means to
40 screen for eye disease and amblyogenic risk factors. This test is however rarely performed
41 in low resource settings due to lack of access to ophthalmoscopes and trained health care
42 workers. Our aim was to establish the sensitivity and specificity of the BRT when
43 performed by a non-expert using an Arclight and compare to an expert as well as the
44 results of a full clinic workup.

45

46 **Subjects/Methods:** In this prospective, blinded study, 64 patients referred to a paediatric
47 ophthalmology clinic had the BRT performed by a 'non-expert' observer (medical
48 student) then an 'expert' observer (consultant ophthalmologist). These results were then
49 compared against the 'gold standard' outcomes of a full clinical workup.

50

51 **Results:** BRT screening by the expert observer led to a sensitivity of 75.0% [95%CI:57.9%
52 to 86.8%] and a specificity of 90.6% [95%CI:75.8% to 96.8%] in picking up media opacity,
53 strabismus, refractive error, or a combination of the above. For the non-expert, the
54 sensitivity and specificity were 71.9% [95%CI:54.6% to 84.4%] and 84.4% [95%CI:68.3%
55 to 93.1%] respectively.

56

57 **Conclusions:** The Arclight can be effectively used to perform the BRT and identify eye
58 disease and common amblyogenic risk factors. Even when performed by a non-expert
59 the results are highly specific and moderately sensitive. This study consequently offers

60 support for the use of this low-cost ophthalmoscope in the expansion of eye screening

61 by health care workers in low resource settings.

62

63 Introduction

64

65 Sight loss is greatest in low and middle income countries (LMIC's) where eye health
66 worker numbers and their access to diagnostic tools is least (1). While childhood visual
67 impairment is less prevalent than in adults, the overall loss of life years is second only to
68 that of adult cataract. Importantly, if identified early nearly half of such disability is
69 treatable and preventable by known cost-effective means (2).

70

71 The Brückner reflex test (3) (BRT) (Figure 1) is a simple yet effective means to identify the
72 early signs of childhood eye disease such as corneal scarring, cataract and retinoblastoma
73 as well as risk factors for amblyopia including strabismus, high refractive error and
74 anisometropia.

75

76 The BRT is performed using a direct ophthalmoscope, ideally in a dim room at arm's
77 length, illuminating both eyes of the patient at the same time. The child should be seated
78 comfortably ideally on a parent's lap. The reflected light (reflex) from both eyes is
79 observed simultaneously. The relative colour, brightness and position of the crescents
80 within the pupil space are compared. This is called the 'red reflex' test. It is important to
81 note that the colour of the central 'red' reflex can be very variable and although orange-
82 red in Caucasians can be almost blue-white in darker pigmented eyes (3). In addition the
83 centration of the small 'corneal' reflex is noted. This is known as the Hirschberg Test (4).
84 The combination of these two tests is the BRT.

85

86 This non-touch arm's length combination test lets users make swift on-the-spot decisions,
87 to identify disease early for better outcomes. Despite the benefits of routinely performing

88 the BRT, in LMIC's it is rarely performed by primary or mid-level health care workers; with
89 disease presenting often sadly very late (5,6). Absence of appropriate frugal kit and the
90 circular lack of teaching of practical and interpretation skills are perpetual well observed
91 challenges.

92

93 The Arclight(7–9) (Figure 2) is a DO developed specifically with the needs of users in low
94 resource settings in mind. Low cost (~£10), portable, LED illuminated and solar powered:
95 it does not rely on expensive and hard to find consumables such as batteries and bulbs.
96 Studies amongst mid-level eye care workers in LMIC's have demonstrated it to be easier
97 to use than more expensive traditional devices yet remaining as effective for funduscopy
98 and 'red' reflex examination (9,10).

99

100 Our study aims to describe the effectiveness in children, of the BRT in identifying eye
101 disease that can lead to amblyopia, using this new low cost Arclight ophthalmoscope. The
102 results of an 'expert' ophthalmology consultant and a 'non-expert' medical student were
103 compared with each other, and then against the results of a 'gold standard' full clinic
104 workup.

105

106 **Materials and Methods**

107

108 This blinded, prospective study was approved by the institutional review board of the
109 hospital and the ethics review committee of the University of St Andrews. Signed
110 informed consent was obtained from the parents of all study participants. Children

111 between the ages of 3 months and 14 years presenting consecutively to the paediatric
112 ophthalmology clinic at LVPEI were enrolled in the study. Patients previously known to
113 the expert observer were excluded.

114

115 Prior to the study, the non-expert examiner participated in an Arclight training workshop
116 on how to use the device as well as perform and interpret the BRT. This included 1 hour
117 with a pediatric ophthalmologist familiar with the device and then examination of
118 simulation red reflex eyes displaying pathology as well as normal adult eyes.

119

120 Study participants were seated comfortably, typically on a parent's lap in a dimly lit room.

121 Using the brightest light on the Arclight with the lens set to zero both eyes were observed
122 un-dilated at arm's length. The expert and non-expert examiners recorded their
123 observations as either normal or abnormal. If abnormal, the examiners classified their
124 observations into further subcategories of media opacity, strabismus, refractive error or
125 a combination of the above.

126

127 After the BRT each patient underwent routine full clinic workup involving history taking,
128 orthoptic assessment, slit lamp examination, dilated fundoscopy and refraction. The
129 findings of the a 'gold standard' full clinic workup were then used to classify the cases
130 into the same subcategories described above by a different and independent
131 experienced paediatric ophthalmologist.

132

133

134 Results

135

136

137 64 patients (36 male and 28 female) were enrolled into the study. The participants ranged

138 from 8 months to 14 years with a mean age of 6 years. 3 patients were excluded as they

139 were previously known to the expert observer. Full clinic workup identified 32 patients

140 having either media opacity, strabismus, anisometropia (≥ 1.00 D SPH) or high refractive

141 error ($>+5.00$ D SPH or <-5.00 D SPH). The remaining 32 participants based on the full

142 clinic workup were deemed to have findings that would be consistent with a normal BRT.

143

144 The results of both examiners BRT and the 'gold standard' full clinic workup are

145 summarised in Table 1. Table 2 displays the results of the non-expert and expert's BRT

146 findings.

147

148 The non-expert and expert BRT findings produced similar sensitivities and specificities to

149 each other [Table 3]. Both observers despite their difference in level of experience

150 achieved sensitivities of over 70% and specificities of over 80% compared to the 'full clinic

151 workup' with the expert being statistically higher at 90.6% [95% CI: 75.8% to 96.8%]. As

152 a consequence good agreement between both observers was found with a Cohen's

153 kappa of 0.71 [95% CI: 0.47 to 0.96]. Cohen's kappa showed moderate agreement with

154 the gold standard results of the full clinic workup: 0.56 [95% CI: 0.32 to 0.81] for the non-

155 expert observer and slightly higher agreement of 0.66 [95% CI: 0.41 to 0.89] for the expert.

156

157 Of the 24 cases that the expert observer felt had abnormal BRTs 23 were correctly
158 subclassified based on the results of the full clinic workup. The non-expert observer
159 identified 23 cases with abnormal BRT and subclassified 17 of these correctly.

160

161 Of the 8 patients incorrectly identified by the expert as having a normal reflex (false
162 negatives) when based on the findings of the full clinic work up they were classified as an
163 'abnormal' BRT, 1 had anisometropia, 2 had symmetrical significant refractive error, 3
164 patients had esotropia of 10PD, 12PD and 35PD, and 2 had a combination of
165 anisometropia (dominant pathology) and strabismus. The non-expert observer
166 incorrectly identified 9 patients as having a normal reflex (false negatives). 7 of these
167 cases were the same as the expert with the other 2 being anisometropia with strabismus
168 and anisometropia only.

169

170

171 Discussion

172

173 Our results show that the BRT when performed with the Arclight ophthalmoscope can be
174 used as a quick means to identify risk factors for amblyopia in a high volume paediatric
175 ophthalmology clinic. When performed by an expert, it has a sensitivity of 75% and a
176 specificity of 91%. An important finding of this study is that the non-ophthalmic medical
177 student observer's performance was statistically comparable to the expert observer. This
178 is consistent with a previous study where Gole et al (11) reported 85.6% sensitivity and
179 65% specificity when the BRT was performed by a non-ophthalmologist with an
180 experienced ophthalmologist reporting 73% sensitivity and 87% specificity. Closer
181 analysis of the cases identified and missed suggests that the BRT is best suited to the
182 identification of media opacities and larger angled strabismus (>35PD). The BRT as

183 expected, was less effective at identifying cases of smaller strabismus (<35PD) and
184 refractive error with clear media. Symmetrical refractive errors were typically hard to
185 identify. For example two patients with symmetrical myopia of -4.00 dioptres as well as
186 a patient with a refraction of -5.00 dioptres in the right eye and -6.00 in the left eye were
187 falsely classified as normal by both observers. These patients were noted to demonstrate
188 an increasingly dim reflex but the brighter lower crescent associated with myopia was
189 not appreciable(12–14). Another group of patients with a combination of both
190 strabismus and refractive error were also found in the false negative results. This could
191 be due to the brighter reflex from the manifestly squinting eye being neutralised by the
192 dimming effect of a high refractive reflex.

193

194 A similar study from Pakistan assessed the effectiveness of the BRT in identifying
195 refractive errors in children. They reported sensitivity of 97% and specificity of 79% (12),
196 higher than in our study. Another study reported similarly accurate detection rates of
197 refractive errors with a sensitivity of 91% and specificity of 72.9% (13). One study (14)
198 evaluated the BRT of paediatric patients using a camera (in place of a direct
199 ophthalmoscope) and reported 86% sensitivity and 85% specificity. There are a number
200 of possible reasons for these different findings including different age groups of
201 participating children, varying degrees of appreciable pathology and the use of different
202 brands of ophthalmoscope. Even though there are differences in sensitivity and
203 specificity they are generally high and clinically useful confirming the potential benefits
204 of using this simple and non-invasive the test more widely. This is especially the case now
205 that a low cost and consumable independent device such as the Arclight is available.

206

207 Performing a formal comprehensive eye examination in babies and young children is
208 challenging. The attraction of the BRT reflex lies in its simplicity; it takes just a few
209 seconds of the child looking straight at the light to make an assessment. Non-ophthalmic
210 staff who provide care to children, such as pediatricians, staff delivering immunisation
211 programmes and neonatal/obstetric nurses could be trained to perform the BRT both
212 opportunistically and systematically in their daily work. The feasibility of this approach
213 has recently been evaluated in Tanzania demonstrating the Arclight to have sensitivity
214 and specificity of over 90%(15). This could lead to earlier identification of eye conditions
215 benefiting from intervention potentially improving outcomes of treatment and reducing
216 the burden of visual impairment in children.

217

218 Importantly the Arclight can also be attached to the camera of a mobile phone to acquire
219 an image or video (8,16). Telemedicine could complement expansion of the use of the
220 BRT with electronic transfer of suspect findings to remote experts for an opinion or
221 interpretation of the images in real time by an algorithm within the mobile phone. This
222 approach could further assist in reducing the burden of eye disease and associated visual
223 impairment amongst children particularly in low resource settings where local access to
224 paediatric ophthalmology services can be limited.

225

226 The main limitations of this study include the small number of very young participants
227 (who would benefit most from early diagnosis) and of performing the 'screening' in a
228 contrived 'pathology-rich' paediatric ophthalmology clinic. Future work should aim to
229 assess the real-world feasibility of implementing high volume screening of infants and
230 babies in immunisation clinics (17), birthing facilities and child health clinics by primary

231 health care workers. These are settings where it would be more beneficial to screen but
232 also challenging to successfully implement. One such initiative which piggybacks onto
233 routine national child health surveillance programmes has been rolled out in Kenya and
234 Uganda(18), with positive results(19) and is now being expanded to Tanzania.

235

236 Overall these findings raise the prospect of being able to equip at low cost and effectively
237 train non-expert primary health care workers (PHCWs) to perform the BRT in LMICs
238 complementing other on-going blindness reduction strategies.

239

240

241 Acknowledgements

242 We would like to thank William J Williams for his assistance in preparing illustrations
243 and all of our colleagues at LVPEI for their support in carrying out this study.

244 Conflict of Interest

245 Dr Blaikie is seconded to the University of St Andrews from NHS Fife. The University owns a
246 social enterprise subsidiary company, for which he acts as an unpaid adviser. The social
247 enterprise business sells the Arclight to users in high resource countries with all profits being
248 used to fund distribution and education exercises of the device in low income countries via the
249 Global Health Implementation team at the University of St Andrews. Both Dr Tuteja and Dr
250 Blaikie have previously published on the topic of the Arclight. Dr Kekunnaya does not declare
251 any potential conflict of interest.

252 Funding

253 This study was performed as part of an undergraduate medical elective. It was not
254 funded by any specific grant-awarding body.

255

256

257

258 References

259

- 260 1. Bastawrous A, Hennig BD. The global inverse care law: a distorted map of
261 blindness. *Br J Ophthalmol* [Internet]. 2012 Oct 1;96(10):1357 LP – 1358.
262 Available from: <http://bjo.bmj.com/content/96/10/1357.2.abstract>
- 263 2. Gilbert C, Foster A. Childhood blindness in the context of VISION 2020--the right
264 to sight. *Bull World Health Organ* [Internet]. 2003/07/07. 2001;79(3):227–32.
265 Available from: <https://pubmed.ncbi.nlm.nih.gov/11285667>
- 266 3. Brückner R. Exakte Strabismusdiagnostik bei 1/2–3jährigen Kindern mit einem
267 einfachen Verfahren, dem «Durchleuchtungstest». *Ophthalmologica* [Internet].
268 1962;144(3):184–98. Available from:
269 <https://www.karger.com/DOI/10.1159/000304320>
- 270 4. Kanski JJ, Bowling B. *Clinical Ophthalmology: A Systematic Approach*. Edinburgh,
271 Elsevier/Saunders; 2015. 316 p.
- 272 5. Sheeladevi S, Lawrenson JG, Fielder A, Kekunnaya R, Ali R, Borah RR, et al. Delay
273 in presentation to hospital for childhood cataract surgery in India. *Eye* [Internet].
274 2018;1811–8. Available from: <http://dx.doi.org/10.1038/s41433-018-0176-2>
- 275 6. Bronsard A, Geneau R, Shirima S, Courtright P, Mwendu J. Why are Children
276 Brought Late for Cataract Surgery? Qualitative Findings from Tanzania.
277 *Ophthalmic Epidemiol* [Internet]. 2008 Jan 1;15(6):383–8. Available from:
278 <https://doi.org/10.1080/09286580802488624>
- 279 7. Blaikie A, Sandford-Smith J, Tuteja SY, Williams CD, O’Callaghan C. Arclight: a
280 pocket ophthalmoscope for the 21st century. *BMJ* [Internet]. 2016;355. Available
281 from: <http://www.bmj.com/content/355/bmj.i6637>
- 282 8. Kousha O, Blaikie A. The Arclight and how to use it. *Community eye Heal*
283 [Internet]. 2019/12/17. 2019;32(107):50–1. Available from:
284 <https://pubmed.ncbi.nlm.nih.gov/32123473>
- 285 9. Dooley E, Kousha O, Msosa J, Ndaule E, Abraham C, Parr J, et al. Comparative
286 evaluation of a low cost direct ophthalmoscope (Arclight) for red reflex
287 assessment among healthcare workers in Malawi. *BMJ Innov* [Internet]. 2020 Apr
288 9;bmjinnov-2019-000361. Available from:
289 [http://innovations.bmj.com/content/early/2020/04/09/bmjinnov-2019-](http://innovations.bmj.com/content/early/2020/04/09/bmjinnov-2019-000361.abstract)
290 [000361.abstract](http://innovations.bmj.com/content/early/2020/04/09/bmjinnov-2019-000361.abstract)
- 291 10. Blundell R, Roberts D, Fioratou E, Abraham C, Msosa J, Chirambo T, et al.
292 Comparative evaluation of a novel solar powered low-cost ophthalmoscope
293 (Arclight) by eye healthcare workers in Malawi. *BMJ Innov*. 2018;4(2):98–102.
- 294 11. Gole GA, Douglas LM. Validity of the Bruckner reflex in the detection of
295 amblyopia. *Aust N Z J Ophthalmol*. 1995;23(4):281–5.
- 296 12. Jalis M, Ashfaq MW, Imdad A. Use of Bruckner Test for the Detection of
297 Significant Refractive Errors in Children. *J Rawalpindi Med Coll* [Internet].
298 2015;19(3):200–3. Available from:
299 [https://pdfs.semanticscholar.org/7ab0/a5ca99ecf21c28bce70cd09c79f5f5cd8e1](https://pdfs.semanticscholar.org/7ab0/a5ca99ecf21c28bce70cd09c79f5f5cd8e17.pdf)
300 [7.pdf](https://pdfs.semanticscholar.org/7ab0/a5ca99ecf21c28bce70cd09c79f5f5cd8e17.pdf)
- 301 13. Kothari M. Can the Bruckner test be used as a rapid screening test to detect
302 significant refractive errors in children? *Indian J Ophthalmol* [Internet]. 2007 May
303 1;55(3):213–5. Available from: <http://www.ijo.in/article.asp?issn=0301-4738>
- 304 14. Bani SAO, Amitava AK, Sharma R, Danish A. Beyond photography: Evaluation of

- 305 the consumer digital camera to identify strabismus and anisometropia by
306 analyzing the Bruckner's reflex. *Indian J Ophthalmol* [Internet]. 2013 Oct
307 1;61(10):608–11. Available from: <http://www.ijo.in/article.asp?issn=0301-4738>
- 308 15. Mndeme FG, Mmbaga BT, Kim MJ, Sinke L, Allen L, Mgaya E, et al. Red reflex
309 examination in reproductive and child health clinics for early detection of
310 paediatric cataract and ocular media disorders: cross-sectional diagnostic
311 accuracy and feasibility studies from Kilimanjaro, Tanzania. *Eye* [Internet]. 2020;
312 Available from: <https://doi.org/10.1038/s41433-020-1019-5>
- 313 16. Wu GT, Kang JM, Mirza RG, Bidwell AE, Gray JP. The Use and Evaluation of an
314 Inexpensive Eye Model in Direct Ophthalmoscopy Training. *J Acad Ophthalmol*.
315 2014;1(212).
- 316 17. Jac-okereke CC, Jac-okereke CA, Ezegwui IR, Okoye O. Vision Screening in Infants
317 Attending Immunization Clinics in a Developing Country. *J Prim Care Community*
318 *Health* [Internet]. 2020;11:2150132720907430–2150132720907430. Available
319 from: <https://pubmed.ncbi.nlm.nih.gov/32100627>
- 320 18. Sense International. Sense International launches pioneering screening
321 programme for infant deafblindness in Kenya and Uganda [Internet]. 2017 [cited
322 2020 Nov 10]. Available from: [https://senseinternational.org.uk/news/sense-](https://senseinternational.org.uk/news/sense-international-launches-pioneering-screening-programme-infant-deafblindness-kenya-and)
323 [international-launches-pioneering-screening-programme-infant-deafblindness-](https://senseinternational.org.uk/news/sense-international-launches-pioneering-screening-programme-infant-deafblindness-kenya-and)
324 [kenya-and](https://senseinternational.org.uk/news/sense-international-launches-pioneering-screening-programme-infant-deafblindness-kenya-and)
- 325 19. Sense International. Celebrating the results of the screening and early
326 intervention programme funded by the 'Finding Grace' appeal [Internet]. 2020
327 [cited 2020 Nov 10]. Available from:
328 [https://www.senseinternational.org.uk/news/celebrating-results-screening-and-](https://www.senseinternational.org.uk/news/celebrating-results-screening-and-early-intervention-programme-funded-finding-grace-appeal)
329 [early-intervention-programme-funded-finding-grace-appeal](https://www.senseinternational.org.uk/news/celebrating-results-screening-and-early-intervention-programme-funded-finding-grace-appeal)
- 330
331
332

333 Titles and legends to figures

334 Figure 1: Left panel; The room should be dimly lit and quiet. The child should be sat
335 comfortably on parent's lap with undilated pupils. The ophthalmoscope should be set at
336 the brightest setting and lens at zero. It should be held at arm's length away and reflex
337 should be viewed simultaneously in both eyes. Right panel; A; Normal: central corneal
338 reflections, symmetrical brightness & colour. B; Media opacity left eye: dark reflex. C;
339 Esotropia left eye: corneal reflection displaced temporally & reflex lighter. D; Exotropia
340 right eye: corneal reflection displaced nasally & reflex lighter. E; Hypermetropia right:
341 prominent bright crescent superiorly and myopia left: prominent bright crescent
342 inferiorly

343 Figure 2: The Arclight Direct Ophthalmoscope

344 Table 1: BRT results of the expert and non-expert observer compared against the gold
345 standard.

346 Table 2: Non-expert BRT compared against the expert BRT

347 Table 3: Statistical analysis of the BRT examination results of both observers

348

349