

Effect of time to primary repair on final visual outcome after open globe injury

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1 Title: The effect of time to primary repair on final visual outcome after open globe injury

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15 Synopsis

16 When primary repair is delayed beyond 24 hours after open globe injury, presenting visual acuity
17 and time from injury to repair are the strongest predictors of outcome, independent of the
18 development of endophthalmitis.

19

20 Abstract

21 Background/Aims: Historic data suggests that open globe injuries should be repaired within 12-24
22 hours to reduce the risk of endophthalmitis. However, endophthalmitis is uncommon when
23 systemic antibiotic prophylaxis is given. It is not clear whether delayed primary repair impacts visual
24 outcomes in other ways or what is the optimum time to repair. We aimed to examine the effect of
25 time to primary repair on visual outcomes.

26 Methods: Retrospective comparative case series, including all open globe injuries presenting to the
27 Birmingham Midland Eye Centre between 1st Jan 2014 and 15th Mar 2016. Presenting features,
28 mechanism of injury, 6-12 month visual acuity and demographic data were examined.

29 Results: 56 open globe injuries were repaired, of which sufficient data for analysis was available on
30 52 cases. The mean time to primary repair was 1 day after injury (range 5 hours to 7 days). Final
31 visual acuity at 6-12 months was related to the presenting visual acuity and ocular trauma score and
32 to the time between injury and primary repair, with a reduction in predicted visual acuity of logMAR
33 0.37 for every 24 hours delay (95% CI 0.14-0.6).

34 Discussion: Open globe injuries should be repaired promptly. Presenting visual acuity remains the
35 strongest predictor of outcome, however, delay to primary repair also reduced final visual acuity and
36 any significant delay from injury to repair is likely to negatively impact final visual outcome.

37

38 The estimated annual incidence of open globe injuries in the industrialised world is 3.5/100 000[1]
39 Open globe injury causes significant visual loss in the civilian population, but is more common in the
40 military, where 5-10% of all cases of major trauma involve the eye.[2] Injury severity may be
41 assessed using the Ocular Trauma Score (OTS) or the Classification and Regression Tree (CART)
42 classification systems, both of which predict some of the variability in visual outcomes.[3, 4]
43 Complications of open globe injury include endophthalmitis, retinal detachment, cataract, corneal
44 scarring, proliferative vitreoretinopathy, phthisis and irreparable injury requiring evisceration or
45 enucleation. In historic studies, the risk of endophthalmitis is increased when primary repair is
46 performed more than 24 hours after injury,[5] or more than 12 hours in a recent series.[6] However,
47 military case series in which intraocular foreign body (IOFB) removal and, in some cases primary
48 repair, was delayed far beyond 24 hours suggest that even with retained organic IOFB,
49 endophthalmitis is uncommon if broad spectrum systemic antibiotic prophylaxis is given.[7, 8]
50 In one large Brazilian case series, delays to primary repair greater than 24 hours increased the odds
51 of a poor outcome in patients without endophthalmitis by 1.16,[9] though other studies did not
52 associate delayed repair with a clinically meaningful change in outcome.[10] In a series of military
53 injuries, delays to primary repair of more than 24 hours increased the odds of a poor outcome by
54 1.69, though this was borderline significant ($p=0.08$).
55 There is therefore some evidence that primary repair should not be delayed beyond 24 hours, but
56 the magnitude of that effect is not defined. The practice in our centre is to offer emergency
57 ophthalmic surgery between 0900 and 1900 hours only. We therefore have a range of times to
58 primary repair from a few hours after injury to several days where other factors delay repair.
59 We aimed to study the relationship between the delay from open globe injury to primary repair and
60 the visual outcomes in patients repaired in our centre.

61 **METHODS**

62 The study was approved by the Clinical Governance Department of the Sandwell and West
63 Birmingham Hospitals NHS Trust.

64 We studied a retrospective comparative consecutive case series. We included all open globe injuries
65 presenting to the Birmingham Midland Eye Centre, a major UK tertiary referral eye unit, between 1st
66 Jan 2014 and 15th Mar 2016. Cases were identified from the emergency operating theatre logs.

67 We recorded the presenting features including presenting best-corrected visual acuity (VA),
68 presence of an afferent pupillary defect and endophthalmitis, the injury classification according to
69 the Birmingham Eye Trauma Terminology System,[11] mechanism of injury, demographic data
70 including age, multiple index of deprivation (IMD) score derived from postcode data, working
71 pattern at the time of repair, surgeries performed and visual outcomes in terms of VA.[12] Working
72 pattern at the time of repair was taken as the time at which surgery started, classified as: normal
73 working day (NWD; 9am-5pm Monday to Friday), evening (after 5pm Monday to Friday) and
74 weekend (Saturday and Sunday). Surgery was considered out-of-hours when started in the evening
75 or the weekend. Secondary procedures were considered as any surgical procedure, directly related
76 to the trauma, performed after the time of primary repair. Because of the problems associated with
77 recording final VA with variable time to follow up we recorded the best-corrected VA between 6 and
78 12 months after injury, using the closest measurement to 12 months where more than one result
79 was available and this is referred to as final VA. VA measurements were converted to logMAR
80 equivalents for analysis, including those less than 20/1200, as previously described.[8] Time of
81 repair was recorded as the time at which primary repair was completed.

82 Statistical analyses were conducted in R,[13] (www.r-project.org) using the rms and mice
83 packages.[14, 15] Average values are displayed as mean \pm estimated population standard deviation.

84 To examine the relationship between injury severity, time between injury and primary repair and
85 visual outcomes, we performed linear regression analysis with sequential addition of the predictors:
86 presenting VA; time to repair; OTS. Student's t-test and 1-way ANOVA were used for comparisons

87 between two and three groups respectively. Sensitivity analysis used multiple imputation with a
88 chained equations method (with 10 imputed datasets) to assess the impact of missing values.

89 RESULTS

90 Fifty six consecutive open globe injuries were included, of which 52 cases had sufficient follow-up
91 data for analysis. All were unilateral. The mean time to primary repair was 24.2 ± 26.9 hours after
92 injury (range 5 hours to 7 days). Twenty six were penetrating injuries (46.4%), seven had IOFB
93 (12.5%) and 23 (41.1%) were ruptures. Patient demographics and injury mechanisms are
94 summarised in Table 1.

Mechanism of Injury	Number of patients (%)	Mean patient age (Std dev)	Number male (%)	Mean IMD score (Std dev)
Domestic injury	35 (63)	53.7 (24.3)	25 (71)	27.3 (17.0)
Blunt object	8 (14)	57.2 (21.2)	5 (63)	20.3 (11.3)
Sharp object	15 (27)	38.5 (17.7)	15 (100)	27.5 (17.7)
Fall	12 (21)	70. (22.5)	5 (42)	31.6 (18.8)
Assault	8 (14)	44.2 (22.9)	6 (75)	46.6 (22.1)
Blunt object	6 (11)	48.4 (25.4)	5 (83)	39.1 (19.6)
Sharp object	2 (3.6)	31.5	1 (50)	68.80
Work-related	7 (13)	47.9 (16.9)	5 (71)	15.6 (9.73)
Blunt object	4 (7.1)	44.1 (20.4)	3 (75)	16.8 (11.6)
Sharp object	3 (5.3)	53.0 (12.6)	2 (67)	14.1 (8.72)
Other	1			
Unknown mechanism	5 (8.9)	23.4 (19.1)	4 (80)	32.1 (16.2)

95 Table 1. Patient demographics and injury mechanisms. Std dev, standard deviation; IMD, index of
96 multiple deprivation.

97 Time to repair

98 Forty two cases were repaired less than 24 hours after injury and 10 more than 24 hours. Fitting a
99 linear regression model to the data explained a high proportion of variance in final VA (Fig. 1;
100 $R^2=0.74$). We modelled OTS as a five point categorical variable; however, for illustrative purposes,
101 the difference in outcomes between an initial OTS of 1-3 compared to 4-5 is an increase in final VA
102 of logMAR 2.20 (Fig. 1A; 95% CI: 1.10-3.29; $p=0.0002$). For time to repair, every 24 hours of delay

103 was associated with an increase in logMAR final VA of 0.37 (Fig. 1B; 95% CI 0.14-0.6; $p=0.0028$).

104 There was also a strong association between presenting VA and final VA, with an increase of logMAR

105 1 in presenting VA associated with an increase of logMAR 1.77 in final VA (Fig. 1C; 95% CI 1.16-2.38;

106 $p<0.0001$). The significance of including each term in the model, when tested sequentially using

107 ANOVA was: presenting VA, $p<0.0001$; time to repair, $p=0.077$; OTS, $p=0.0006$. Age, gender, IMD

108 score and working pattern at the time of repair did not add significant explanatory value to the

109 model.

110 When two cases who developed endophthalmitis were excluded from the analysis, presenting VA

111 ($p<0.001$) and time to repair ($p=0.04$) remained significant predictors of final VA, but OTS no longer

112 demonstrated a statistically significant association ($p=0.49$).

113 When the analysis was limited to cases repaired less than 24 hours after presentation, only

114 presenting VA remained a significant predictor of final VA ($p<0.001$), whilst time to repair ($p=0.75$)

115 and OTS ($p=0.48$) did not demonstrate any relationship with final VA in this subgroup.

116 Sensitivity analysis using multiple imputation of missing values with pooled analysis of the 10

117 imputed datasets yielded results consistent with the primary analysis. For time to repair, every 24

118 hours of delay was associated with an estimated increase in logMAR final VA of 0.292 (95% CI 0.054-

119 0.529; $p=0.017$). An increase of logMAR 1 in presenting VA was associated with an estimated

120 increase of logMAR 1.548 in final VA (95% CI 0.867-2.228; $p<0.0001$). Considering OTS as a binary

121 variable (as above), the estimated difference in final VA between an OTS of 1-3 and 4-5 is an increase

122 of logMAR 1.629 (95% CI: 0.525-2.734; $p=0.005$).

123 Compared to cases repaired more than 24 hours after injury, cases repaired less than 24 hours after

124 injury presented sooner after injury (5.34 ± 4.84 vs 35.6 ± 50.2 hours; $p=0.06$), were older (50.7 ± 24.5

125 vs 41.4 ± 23.5 years; $p=0.43$) and had similar IMD scores (30.3 ± 19.1 vs 28.9 ± 18.6) and presenting VA

126 (logMAR 2.22 ± 1.27 vs 2.11 ± 1.38 ; $p=0.68$) and OTS (2.73 ± 1.42 vs 2.89 ± 1.31 ; $p=0.42$). Cases presenting

127 less than and more than 24 hours after injury had similar times between presentation and surgery
128 (12.0 ± 9.05 vs 14.5 ± 8.12 hours; $p=0.60$).

129 **Endophthalmitis**

130 Two patients developed endophthalmitis before presentation, which was at 32 and 26 hours after
131 injury, leading to final VA of logMAR 2 and 1.18 respectively. No patients developed new signs of
132 endophthalmitis after presentation. It is standard practice in our centre to give oral ciprofloxacin to
133 open globe injuries, but this was not well documented, so it is not possible to state reliably what
134 proportion of patients received antibiotic prophylaxis.

135 **Secondary procedures**

136 Eight patients required delayed vitreoretinal surgery. Two patients developed funnel retinal
137 detachment after primary repair and vitreoretinal surgery was deemed to be futile. Of six patients
138 with IOFB, three had IOFB removal at the time of primary repair, one of whom required repeat
139 vitreoretinal surgery, initially having *Bacillus cumulus* endophthalmitis and subsequently developing
140 a PVR detachment under silicone oil that was treated with retinectomy and heavy oil (final VA
141 logMAR 2). Five patients underwent delayed lens extraction, 3 patients had secondary IOL insertion.
142 Four patients required secondary evisceration. No eyes were primarily eviscerated or enucleated.
143 The mean presenting OTS and final VA were similar between patients who underwent secondary
144 vitreoretinal surgery (OTS 2.56; final VA logMAR 1.98) and patients who did not (OTS 2.82 $p=0.60$;
145 logMAR 1.25; $p=0.17$).

146 **Out-of-hours surgery**

147 In 22 cases, repair was started in the NWD, 19 cases were repaired on weekday evenings and 14 at
148 weekends (Fig. 2A). The visual outcome did not vary by working pattern at the time of repair with

149 mean final VA of logMAR 1.31 ± 1.51 for cases repaired in the NWD, 1.21 ± 1.53 in the evening and
150 1.59 ± 1.25 at the weekend ($p=0.471$; OTS 2.64 ± 1.47 , 3.11 ± 1.29 , 2.64 ± 1.15 respectively).

151 Forty eight percent of all open globe injuries repaired between Monday and Friday were done in the
152 evening, whereas 0% of weekend repairs were in the evening (Fig. 2A; $p=0.002$, Fisher's exact test).

153 Cases repaired in the evening had a mean time between presentation and surgery of 7.19 ± 5.79
154 hours compared to 14.91 ± 10.8 for those repaired in the NWD and 15.18 ± 6.67 at weekends (Fig 2B;
155 $p=0.02$, 1-way ANOVA). However, the total time between injury and repair did not differ
156 significantly between NWD, evenings and weekends being 26.5 ± 33.1 , 21.4 ± 27.7 and 25.4 ± 12.3
157 respectively (Fig. 2B; $p=0.835$. 1-way ANOVA).

158 **DISCUSSION**

159 Our data provides evidence for an association between time to primary repair and VA at 6-12
160 months after injury and demonstrates that delays of 24 hours are associated with measurable
161 reductions in VA. The magnitude of the effect appears to be a worsening of logMAR 0.37 for every
162 24 hours of delay, equivalent to the loss of two to three lines on a Snellen chart.

163 This is retrospective data, so unmeasured confounders cannot be excluded. Unsurprisingly, delayed
164 presentation was associated with an overall delay to repair. Late presentation is expected to be
165 associated with endophthalmitis,[5] which was the case in our series, but the relationship between
166 time to repair and outcome remained significant even when the endophthalmitis cases were
167 excluded, suggesting that other consequences of the delay to surgery rather than infection explains
168 this relationship. The similarity in time between presentation and repair for early and late
169 presenters, suggests that treatment is not prioritised differently in cases that present late. One
170 might also expect delayed presentation to be associated with reduced educational level, but there
171 was no evidence of a relationship between IMD and time to presentation in our data. Surgical delay
172 may also be a clinical decision to afford better conditions for repair of complex injuries or give lower

173 priority to less severe injuries. Neither better conditions for repair nor less severe injuries are likely
174 to prejudice outcomes and there was no difference in OTS between injuries repaired sooner or later
175 Patients repaired later were younger than those repaired sooner, and it seems unlikely that
176 increasing age could confound our findings by having a positive influence on outcome, which would
177 be the opposite effect to that seen in traumatic brain injury and we found no effect of including age
178 in the regression model.[16]

179 Previous retrospective studies report that endophthalmitis start to increase after 12-24 hours and
180 the probability of a good visual outcome declines when repair is delayed more than 24 hours after
181 injury.[5, 6, 9, 10]. However, systemic antibiotic prophylaxis reduces the risk of endophthalmitis and
182 the magnitude of other effects of delay on final VA has not been reported.[7] Eyes may be
183 potentially viable even when primary repair is delayed for as long as 21 days,[17] though in this case
184 series the injury severities and the detailed effects of such delays were not reported. Our data is in
185 line with previous studies, but goes further to show that the magnitude of the effect of delaying
186 surgery by 24 hours is between logMAR 0.14 and 0.6, equivalent to between one and four Snellen
187 lines, compared to immediate repair, whilst a delay of 48 hours is associated with a greater average
188 reduction of logMAR 0.74. It should be noted though, that increased delay is associated with a linear
189 increase in the uncertainty of the regression model, so the 95% confidence interval at 48 hours for
190 the increase in logMAR final VA is 0.27-1.22.

191 The time of day at which repair was conducted did not affect visual outcome in our series,
192 suggesting that our on call arrangements, in which senior trainees (with 5 or more years of
193 ophthalmic surgical experience) cover out-of-hours work, do not adversely affect patient outcomes.
194 Cases operated in the evening are expected to have a shorter time to surgery compared to patients
195 operated in the NWD because the latter may have presented overnight or the previous evening.
196 However, the disparity in evening operating between weekdays and the weekends, suggests either a

197 hidden barrier to emergent operating in the weekend evenings or preferential scheduling into the
198 weekday evenings.

199 An understanding of the impact of delayed primary repair on patient outcomes is important to
200 planning hospital eye services in the civilian environment where “on call” surgical capacity is often
201 significantly limited compared to the NWD and work in the NWD competes with elective surgery. It
202 is also relevant to planning the provision of ophthalmic care to the military environment where
203 deployed assets are limited compared to those available at hospitals in the home country and
204 evacuation timelines may be several days. The number of cases is relatively small and the
205 association between delayed repair and visual outcome is weak. These results would therefore
206 benefit from confirmation in a larger cohort. However, the cumulative strength of this and other
207 published data and the lack of conceivable disadvantages of early repair would make it unethical to
208 definitively answer the question by conducting a randomised trial intentionally delaying repair.
209 Whilst this paper provides evidence on the magnitude of the effect of delaying repair, limited
210 information is provided on the effects of surgical environment, surgeon’s experience or surgical
211 team, which may also be trade-offs engendered by a decision to repair a globe urgently, such as
212 overnight in an emergency theatre by “on call” staff compared to repair on an elective theatre list
213 the next day, though our data suggests that these effects are not significant in our current surgical
214 set-up. When planning ophthalmic emergency services it is important that provisions are made for
215 prompt primary repair, but until evidence exists on the effects of other factors it is also important
216 that the surgical environment and equipment are not compromised.

217 **COMPETING INTERESTS**

218 The authors have no competing interests.

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221 for-profit sectors.

222 **CONTRIBUTORSHIP**

223 RB and PM conceived and designed the study. RB acquired the data. RB and JB analysed and
224 interpreted the data. RJB drafted the final manuscript and all authors revised it critically for
225 important intellectual content and gave final approval of the version to be published. All authors
226 agree to be accountable for all aspects of the work in ensuring that any questions related to the
227 accuracy or integrity of any part of the work are appropriately investigated and resolved.

228 **Figure legends**

229 **Figure 1:** Visualisation of the model-based effects of each predictor by plotting fitted values. **A.** The
230 effect of OTS. Patients with an OTS in categories 1, 2 and 3 exhibit similar levels of final VA, whereas
231 those with an OTS in categories 4 and 5 exhibit levels of final VA 2.20 higher (95% CI: 1.10-3.29;
232 $p=0.0002$). **B.** Time to repair. An increase of 1 unit in time to repair is associated with an increase of
233 0.37 (95%CI: 0.14 - 0.60) units in final VA. **C.** Presenting VA has a strong association with final VA
234 with an increase of 1 unit in presenting VA associated with an increase of 1.77 (95%CI: 1.16 - 2.38)
235 units in final VA.

236 **Figure 2.** Cases analysed by working pattern at the time of repair. **A.** Approximately half of all
237 weekday cases were repaired in the NWD and half in the evening. The proportion repaired at
238 weekends (25.5%) is similar to that expected (28.5% of the week), however, no cases were repaired
239 in the evening at weekends, which is significantly less than expected ($p=0.002$). **B.** Cases repaired in
240 the evening were repaired significantly sooner after admission than either cases repaired in the
241 NWD or at weekends ($p=0.02$), however, the total time between injury and repair was similar for
242 cases repaired at different times of day.

243

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