1   **The influence of hours worked prior to delivery on maternal and neonatal**

2   **outcomes: a retrospective cohort study**

3

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35 **Condensation:** The number of hours already worked by obstetricians prior to

36 undertaking unscheduled deliveries significantly influences the risk of adverse

37 outcomes.

38

39 **Short Version of Article Title:** Influence of delivery timing on outcomes

40 **Abstract**

41 **Background:** Long continuous periods of working contribute to fatigue, which is an

42 established risk factor for adverse patient outcomes in many clinical specialties. The

43 total number of hours worked by delivering clinicians prior to delivery may therefore

44 be an important predictor of adverse maternal and neonatal outcomes.

45 **Objective:** We aimed to examine how rates of adverse delivery outcomes vary with

46 number of hours worked by the delivering clinician prior to delivery during both day

47 and night shifts.

48 **Study design:** We conducted a retrospective cohort study of 24,506 unscheduled

49 deliveries at an obstetrics center in the United Kingdom between 2008 and 2013. We

50 compared adverse outcomes between day shifts and night shifts using random-effects

51 logistic regression to account for inter-operator variability. Adverse outcomes were

52 estimated blood loss ≥ 1.5 liters, arterial cord pH ≤ 7.1, failed instrumental delivery,

53 delayed neonatal respiration, severe perineal trauma, and any critical incident.

54 Additive dynamic regression was used to examine the association between hours

55 worked prior to delivery (up to 12 hours) and risk of adverse outcomes. Models

56 controlled for maternal age, maternal body mass index, parity, birth weight, gestation,

57 obstetrician experience, and delivery type.

58 **Results:** We found no difference in the risk of any adverse outcome studied between

59 day *versus* night shifts. Yet risk of estimated blood loss ≥ 1.5 liters and arterial cord

60 pH ≤ 7.1 both varied by 30-40% within 12-hour shifts ($p<0.05$). The highest risk of

61 adverse outcomes occurred after 9-10 hours from the beginning of the shift for both

62 day and night shifts. The risk of other adverse outcomes did not vary significantly by

63 hours worked, or by day *versus* night shift.

64 **Conclusions:** Number of hours already worked prior to undertaking unscheduled

65 deliveries significantly influences the risk of certain adverse outcomes. Our findings

66 suggest that fatigue may play a role in increasing the risk of adverse delivery

67 outcomes later in shifts, and that obstetric working patterns could be better designed

68 to minimize the risk of adverse delivery outcomes.

69

70 **Key words:** maternal outcomes, neonatal outcomes, delivery, working patterns, night

71 work, intra-partum care

72

73 **Introduction**

74 Minimizing the risk of adverse outcomes at delivery is simultaneously a central goal

75 and a major challenge for obstetric services. Previous studies have suggested that the

76 timing of delivery influences the risk of adverse perinatal outcomes. In particular, the

77 risk of neonatal death is higher for babies delivered outside of the normal 09.00-17.00

78 Monday-to-Friday working week [1]. Other studies have produced conflicting evidence

79 regarding whether neonatal mortality is higher overnight [2-4] or at weekends [5, 6].

80 However, neonatal mortality is a rare outcome (4 per 1,000 in the United States and

81 2.8 per 1,000 in the United Kingdom [7]), which is determined not only by intra-partum

82 care, but heavily influenced by the antenatal course and immediate neonatal

83 management. There is less evidence regarding variation in the risk of other, more

84 common, adverse maternal and neonatal outcomes depending on the timing of

85 delivery [2, 8]. In this study we focus on commonly occurring adverse outcomes that are

86 closely related to intra-partum management and therefore most likely to be influenced

87 by the timing of delivery.

88

89 Previous studies have considered adverse outcomes in relation to the day of the week

90 and time of day at which delivery occurred [1-3]. However, we hypothesize that total

91 number of hours worked by delivering clinicians prior to delivery may be a more

92 important predictor of adverse outcomes than day of the week or time of day. Long

93 continuous periods of working contribute to fatigue, which is an established risk

94 factor for adverse patient outcomes in many clinical specialties, however adverse

95 outcomes have not previously been explored in relation to number of hours worked.

96 Fatigue is associated with numerous factors that contribute to poor outcomes,

97 including decline in technical skills [9, 10], slower reaction times [11] and riskier decision-

98 making [12, 13], Delivery can be a high-risk situation requiring identification of potential

99 complications and decisive action. Identifying times of increased risk with respect to

100 working patterns is important to optimizing quality and safety in obstetric services

101 worldwide [14]. The major advantage of this approach is that in contrast to day and time

102 of non-elective delivery, working patterns are modifiable, predictable, and under the

103 control of individuals and institutions. As previous work has suggested that increased

104 rates of adverse outcomes may occur during night compared to day shifts [caughey],

105 it is possible that the effect of continuous hours worked prior to delivery is

106 systematically different between day and night shifts. Particularly if provider fatigue

107 is a major contributing factor to the risk of adverse outcome, then the effect of

108 continuous hours worked may be magnified in night compared to day shifts.

109

110 We aim to determine: (i) whether common adverse maternal and neonatal outcomes

111 occur more frequently during night shifts; and (ii) how risk of adverse outcomes

112 varies with number of hours worked prior to delivery, either during the day or

113 overnight.

114

115 **Materials and Methods**

116 29,112 women underwent delivery of a singleton, live-born infant of >24 completed

117 weeks of gestation in a UK tertiary obstetrics center between January 2008-October

118 2013. We excluded 4,611 women who gave birth by elective cesarean section. All

119 other deliveries (24,506) were included in the sample, regardless of final mode of

120 delivery. The working pattern for obstetricians within the study center follows 12-

121 hour shifts from 08.00-20.00 (day shift) and 20.00-08.00 (night shift). This pattern

122 remained constant throughout the study period. Midwives work the same 12-hour

123   shifts as do the obstetricians in the study center. Handover periods occurred during

124   the first 30 minutes of each shift.

125

126   The midwife assigned to the parturient recorded data regarding the pregnancy,

127   delivery and neonate in an electronic maternity database as soon as possible after

128   birth. This database is routinely maintained as part of hospital records and was not

129   created specifically for study purposes. The database is regularly validated by a

130   rolling program of audits where the original case notes are checked against the

131   information recorded in the database. No patient-identifiable data were accessed

132   during this research, which was performed as a provision-of-service study approved

133   by the obstetrics center. Individual medical records were not accessed at any stage,

134   and our institutions determined that Institutional Review Board approval was not

135   required.

136

137   Available maternal, neonatal, and delivery characteristics included maternal age,

138   maternal BMI (measured at first-trimester booking), parity, maternal ethnicity, and

139   birth-weight (measured to the nearest gram). Gestational age (measured by crown-

140   rump length at first-trimester ultrasound) was recorded to the nearest week. Mode of

141   delivery was classified as cesarean section, forceps, ventouse, or spontaneous vaginal

142   delivery (including vaginal deliveries that occurred both cephalic and breech).

143   Inductions of labor were included in the analytic sample, as the timing of delivery

144   (during the day *versus* night shift) was not chosen by the woman or her caregivers.

145   The mode of onset of labor was recorded as induction of labor 'yes', 'no' or 'not

146   applicable' (for women not in established labor when emergent delivery occurred).

147 The year of delivery and day of the week on which delivery occurred were also

148 available.

149

150 The type of healthcare professional delivering the baby was classified as follows:

151 midwives, obstetricians with ≤ 5 years obstetric training, or obstetricians with >5

152 years obstetric training. In the study center most spontaneous vaginal deliveries are

153 performed by midwives, in line with usual practice across the UK. Instrumental

154 deliveries and cesarean sections are performed only by obstetricians. A small number

155 of spontaneous vaginal deliveries was also performed by obstetricians, but these were

156 mainly high-risk cases, for example pre-term or breech presentation. In the study

157 center, an obstetric team consisting of 3 doctors is available for every 12-hour shift.

158 The team comprises: a junior doctor with ≤ 2 years of obstetric experience, an

159 obstetrician-in-training with ≥3 – ≤5 years of obstetric experience, and a senior

160 obstetrician with >5 years of obstetric experience. Our cohort has the advantage that

161 none of the clinicians provided obstetric care to any patients outside of the time

162 recorded in the study. These clinicians were present solely for the purpose of

163 attending women in labour and undertaking deliveries as required. Elective caesarean

164 sections and any other scheduled obstetric procedures were undertaken by a separate,

165 dedicated team. Inductions of labour are commenced on a scheduled day (including

166 weekends) but at various times throughout the day and night as the workload allows.

167

168 Delay in neonatal respiration was recorded where spontaneous respiration was not

169 achieved within 1 minute of delivery. Umbilical arterial pH was measured from cord

170 blood taken immediately after delivery, where the delivering professional determined

171 that this was required (9,143 cases, 37.3%). This included all cases of operative

172   delivery and any case where there was concern regarding fetal wellbeing. Correlation

173   between arterial and venous pH was checked to confirm accuracy of the

174   measurements. Arterial pH was categorized as ≤ 7.1 or >7.1[15]. Failed instrumental

175   delivery was recorded where an operator applied an instrument, but eventually

176   delivered the baby by any other method (249/4,042 cases, 6%). A critical-incident

177   form was generated at delivery in the case of any obstetric or neonatal emergency,

178   including neonatal resuscitation, shoulder dystocia, maternal visceral injury, or any

179   other event generating an obstetric emergency call. The generation of a critical

180   incident form was used to compile a composite outcome of rare and serious

181   morbidity, which captures rare instances of neonatal death. No peripartum maternal

182   deaths occurred in the center during the study period. Maternal blood loss was

183   estimated immediately after delivery, using suction blood collection and weighing of

184   swabs and other pads. Blood loss was categorized as <1.5 liters or ≥ 1.5 liters. Severe

185   maternal perineal trauma was defined as any disruption to the anal sphincter complex.

186

187   We compared the characteristics of deliveries occurring during the day *versus* night

188   using binary logistic regression. We defined two cohorts: 1) all the deliveries that met

189   our inclusion criteria during the study period (n=24,506); and 2) subset of these where

190   delivery was performed by an obstetrician (n=7,680). We hypothesized that, if the

191   chance of an adverse outcome were significantly influenced by operator fatigue, then

192   this would be more apparent in the obstetrician-only cohort, because complex

193   operative procedures are more likely to have been performed. However, decision-

194   making and management during labor is an important mediator of adverse outcomes

195   regardless of whether surgery is required, and thus we also present outcomes for the

196   full dataset including spontaneous vaginal deliveries. The results from this

197   comparison of delivery characteristics were used to determine covariates included in

198   the models examining the risk of adverse delivery outcomes.

199

200   We compared adverse maternal and fetal outcomes during day and night shifts, both

201   for all deliveries and for deliveries conducted by obstetricians only, using binary

202   logistic regression. To control for variation in baseline complication rates between

203   individual obstetricians, and to account for multiple deliveries by the same operator,

204   we also compared adverse outcomes during day and night shifts using mixed-effects

205   logistic regression models including a random effect for each individual obstetrician.

206   Data from all obstetricians who delivered >100 babies during the study time period

207   were included in this model (n=3,203 deliveries by 28 operators).

208

209   Finally, we examined the risk of each adverse outcome dependent on the number of

210   hours worked prior to delivery—*i.e.* the time in full hours between the start of each

211   shift and the time of delivery—using a generalized additive model in which all events

212   were considered equivalent. This model incorporated a nonlinear term for hours

213   worked prior to delivery on the risk of an adverse outcome, estimated using cubic

214   splines. This model allows us to avoid making any prior assumptions about the nature

215   of the relationship between hours worked and the risk of adverse outcomes, thus

216   allowing the model to best fit the data. Statistical significance of the nonlinear effect

217   of hours worked was assessed using a likelihood-ratio test. We fit a model for all

218   deliveries as well as two separate models for deliveries taking place during night

219   shifts and during day shifts.

220

221   Findings were considered statistically significant at an alpha level of 0.05. Power

222   calculations were performed by Monte Carlo simulation. All analyses were

223   conducted using the R statistical software package version 2.14.1[16].

224

225   **Results**

226   Women who delivered overnight were more likely to be delivered by an obstetrician

227   (with ≤ 5 years experience $p < 0.01$; with > 5 years experience $p < 0.05$) and less likely

228   to have labored prior to delivery ($p < 0.05$) (Table 1). Deliveries overnight were also

229   less likely for women of higher parity (parity 1 $p < 0.05$; parity ≥ 2 $p < 0.01$), to involve

230   induction of labor ($p < 0.05$), or to involve the use of obstetric instruments (ventouse

231      $p < 0.01$; forceps $p < 0.05$). Deliveries overnight were also associated with slightly

232   lower gestational age ($p < 0.05$). While statistically significant, this difference

233   represents a very small difference in actual gestational age, which is unlikely to be

234   clinically meaningful. For women who required delivery by an obstetrician, deliveries

235   overnight were more likely to be performed not in active labor ($p < 0.01$) (Table 1).

236   Women delivered by obstetricians at night were less likely to be of higher parity

237   ($p < 0.05$) or to be delivered by obstetricians with > 5 years experience ($p < 0.05$).

238

239   After adjusting for delivery characteristics, we found no significant differences in the

240   rates of adverse outcomes occurring among all deliveries during day *versus* night

241   shifts, (Table 2). We also found no significant differences between rates of adverse

242   outcomes between day *versus* night shifts for deliveries performed by obstetricians

243   only (Table 2).

244

245   Accounting for inter-operator variability, we found no significant differences in the

246   rates of adverse outcomes at deliveries performed by the same obstetricians during

247   their day shifts *versus* their night shifts (Table 3). We observed a tendency towards

248   more babies being born with an arterial pH $\leq$7.1 during night shifts, but this finding

249   was not statistically significant (p=0.09) (Table 3).

250

251   While we found no associations between risk of adverse outcomes *between* day and

252   night shifts, we did observe significant associations *within* day and night shifts. The

253   risk of estimated maternal blood loss $\geq$1.5 liters varied significantly over the course of

254   all 12-hour shifts (p<0.05) (Figure 1A). The estimated difference in the magnitude of

255   risk between the time of lowest risk (after 3-4 hours worked since the beginning of the

256   shift) and the time of highest risk (after 9-10 hours worked since the beginning of the

257   shift) was approximately 30%. Similarly, the risk of umbilical arterial pH $\leq$7.1 varied

258   by approximately 45% during the course of 12-hour shifts (p<0.05) (Figure 1B). For

259   arterial pH $\leq$7.1, the time of lowest risk was at the start of the shift (after 0-1 hours

260   worked) and the time of highest risk was again after 9-10 hours worked since the

261   beginning of the shift. None of the other outcomes studied showed any significant

262   difference in risk magnitude during the course of 12-hour shifts (data not shown).

263

264   Comparing the patterns of risk during the course of day shifts and night shifts

265   separately, we observed that for estimated blood loss $\geq$1.5 liters, there was a tendency

266   towards a significant difference in risk across the course of 12-hour day shifts

267   (p=0.07) (Figure 2A). During night shifts, there was no significant difference in the

268   risk of estimated blood loss $\geq$1.5 liters dependent on hours worked (Figure 2B). For

269   arterial pH $\leq$7.1, we found no significant difference in risk dependent on hours

270 worked during day shifts (Figure 2C), but there was a significantly increased risk with

271 increasing hours worked during night shifts (p<0.01) (Figure 2D). For all models,

272 regardless of the significance of the trend, the highest risk of adverse outcomes was

273 between 8-10 hours worked since the beginning of the shift. None of the other adverse

274 outcomes studied showed any difference in risk of adverse outcomes dependent on

275 number of hours worked for either day or night shifts.

276

277 **Comment**

278 We observed no significant differences in the risk of adverse maternal and neonatal

279 outcomes for deliveries taking place during day shifts *versus* night shifts. However,

280 the number of hours worked since the beginning of the shift by obstetricians and

281 midwives prior to delivery does influence the risk of adverse outcomes. In particular,

282 the risks of heavy maternal blood loss and fetal acidosis are increased. The highest

283 risk for these outcomes occurs after 8-10 hours into a 12-hour shift. This is a novel

284 finding, as the risk of adverse outcomes has not previously been studied with respect

285 to shift-patterns within an obstetric cohort.

286

287 An interesting feature of the relationship between hours worked and risk of adverse

288 outcomes is the risk profile within the initial and final hours of shifts. While the

289 overall pattern demonstrates increased risk of both heavy maternal blood loss and

290 fetal acidosis across shifts, in both cases there is a fall in risk within the final 2 hours

291 of the shift. While we are unable to provide a definitive causal explanation of this

292 trend from the data available, we hypothesize that this decline may be related to a

293 process of deferment, whereby an increasingly fatigued team may chose not to

294 undertake further very high risk cases unless time is of the essence. Conversely, for

295   the outcome of maternal blood loss ≥1.5 liters, the risk is elevated in the first 2 hours

296   of the shift (relative to the time of minimum risk, although not to the average risk

297   across the whole 12 hours). This increased risk may result from deferred high-risk

298   cases, or may be related to the process of hand-over. Previous studies of adverse

299   outcomes in a variety of hospital settings have identified hand-overs as times of

300   increased risk [17] when errors are liable to be introduced into care. While the variations

301   in the rates of other outcomes studied with respect to hours worked did not reach the

302   defined thresholds for statistical significance, the data showed similar trends. It is

303   possible that the outcomes that did vary significantly with hours worked (heavier

304   blood loss and lower fetal pH) were the most likely to be influenced by operator

305   fatigue.

306

307   A key strength of our study is the use of non-parametric dynamic additive models.

308   These models provide a powerful and flexible way to determine the risks of adverse

309   outcomes relative to baseline risk at any point in the shift and avoid making strong

310   assumptions about the form of the risk/time relationship. A further strength is that the

311   outcomes studied here are patient-centered, immediate, issues that frequently

312   influence the cost of the immediate hospital episode, patient satisfaction, and long-

313   term health outcomes of the mother and her infant after delivery. Furthermore, the

314   outcomes are selected to relate as closely as possible to intra-partum management and

315   are carefully controlled for pre-existing factors. Deliveries occurred throughout the

316   day and night as-if-at-random within our analytic cohort [8], and there was no increase

317   in the number of deliveries occuring later in shifts.

318

319   A limitation of our study is that the data are derived from a single large obstetrics

320   center in the UK. Therefore, our result may not be generalizable to other settings. The

321   advantage of data from a single center, however, is that working patterns are clearly

322   defined and remain constant throughout the study period, making detailed analyses

323   with respect to working time possible. Data from national cohorts are prone to

324   heterogeneity in the shift patterns actually worked by obstetric teams in different

325   hospitals and other clinical duties fulfilled outside of the delivery unit hours, making

326   such analyses unfeasible. A further limitation of our study is that our cohort is not

327   sufficiently powered to isolate the outcomes of neonatal and maternal mortality, other

328   than as part of the composite outcome of critical incidents occurring at delivery. The

329   UK maternal mortality rate is currently 1:10,000 [18], meaning that over 4.5 million

330   births would be required to detect even a very large effect size – this exceeds the total

331   number of UK births during the study period. Neonatal mortality is a more tractable

332   study question, with a current perinatal mortality rate of 6:1,000 births (although this

333   figure includes antepartum stillbirths, which would not be expected to vary with

334   working patterns in intrapartum care). Neonatal mortality rates have been examined

335   by other studies using national data [1] and were found to be higher outside the 09.00-

336   17.00 working week.

337

338   Deliveries occur with equal frequency throughout day and night shifts, 7 days a week

339   within our analytic cohort. Emergencies may happen at any time and it is reassuring

340   that working patterns that employ 'night float'-type system, do not put women who

341   deliver overnight at higher risk of adverse outcomes than those delivering during the

342   day. Despite some systematic differences between women who deliver overnight and

343   during the day (for example higher risk women are more likely to be induced and to

344 deliver during the day), the consistent availability of an experienced obstetric team

345 means that the risk remains similar in both periods.

346

347 Our finding of increasing risk with hours worked is concerning and suggests that

348 improvements may be possible to minimize risk to mothers and babies. Our results

349 suggest that fatigue may play a role in increasing the risk of adverse delivery

350 outcomes later in shifts. Literature from other disciplines suggests that fatigue is a

351 plausible factor influencing patient outcomes, both in terms of deterioration in

352 technical skills [10] and in impairing decision-making [12]. Our results support the idea

353 that limitations on resident's working hours may be of benefit to both doctors and

354 their patients. There are many possible interventions that could potentially reduce the

355 identified risk, for example shorter shift times, enforced rest periods within shifts, or

356 encouragement to consider seeking extra help or deferring complex cases if it is safe

357 to do so during high-risk periods. An important area for further study is to evaluate

358 the potential of such interventions to lower the risk of adverse outcomes and to weigh

359 the advantages and disadvantages of each in practice. Many interventions may not be

360 feasible in diverse practice settings worldwide, but self-awareness of increased risk is

361 nonetheless valuable to any obstetrician contemplating a complex procedure.

362

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419

420   **Table 1** Characteristics of the maternal-fetal dyad and the delivery for the full cohort

Characteristic		All deliveries (n=24,506)		Deliveries by doctors (n=7,680)	
		OR (95% CI) (Day v. Night)	p value	OR (95% CI) (Day v. Night)	p value
Gestational age (weeks)		0.98 (0.96-0.99)	0.02*	0.98 (0.96-1.01)	0.25
Birth weight (g)		1.00 (0.99-1.01)	0.06	1.00 (0.99-1.00)	0.18
Maternal age		0.99 (0.98-1.00)	0.10	0.99 (0.99-1.00)	0.16
Maternal BMI		1.00 (0.99-1.01)	0.33	1.00 (0.99-1.01)	0.92
Onset of labour	Spontaneous	Ref			
	Induced	0.82 (0.77–0.87)	<0.01**	0.96 (0.87-1.05)	0.36
	No labour	1.17 (1.01-1.34)	0.04*	1.31 (1.12-1.54)	<0.01**
Obstetrician experience:	Midwife	Ref		N/A	N/A
	≤ 5 years obstetrician	1.40 (1.16-1.68)	<0.01**	Ref	
	> 5 years obstetrician	1.25 (1.02-1.52)	0.03*	0.90 (0.82-0.99)	0.04*
Parity:	0	Ref			
	1	0.94 (0.88-1.00)	0.04*	0.98 (0.89-1.07)	0.65
	≥2	0.88 (0.81-0.94)	<0.01**	0.86 (0.75-0.99)	0.04*
Delivery Type:	SVD	Ref			
	Caesarean section	0.89 (0.74-1.09)	0.26	0.86 (0.71-1.04)	0.13
	Forceps	0.97 (0.79-1.18)	0.04*	0.95 (0.77-1.16)	0.59
	Ventouse	0.95 (0.77-1.17)	<0.01**	0.94 (0.76-1.15)	0.54

421   and the deliveries performed by doctors comparing each characteristic between

422   deliveries occurring during day *versus* night shifts. *p<0.05, **p<0.01

423

424

425

426
427

428

429 **Table 2** Risk of adverse outcome for the full cohort and the deliveries performed by

430 doctors comparing each characteristic between deliveries occurring during day *versus*

431 night shifts. Model coefficients are expressed as odds ratios and 95% confidence

432 intervals (CI).

433

	All deliveries (n=24,506)		Deliveries by doctors (n=7,680)	
Adverse outcome	OR (95% CI) (Day v. Night)	p value	OR (95% CI) (Day v. Night)	p value
EBL ≥1.5 litres	1.04 (0.85-1.26)	0.72	0.99 (0.76-1.27)	0.91
$3^{rd}/4^{th}$ degree tear	1.02 (0.89-1.17)	0.79	1.07 (0.84-1.35)	0.59
Umbilical arterial pH ≤7.10	1.09 (0.90-1.32)	0.40	1.22 (0.98-1.53)	0.08
Delayed neonatal respiration	1.08 (0.96-1.23)	0.19	1.10 (0.94-1.29)	0.26
Failed instrumental delivery	1.13 (0.85-1.49)	0.41	1.13 (0.85-1.49)	0.41
Critical incident	0.89 (0.77-1.02)	0.10	0.94 (0.77-1.16)	0.58

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436

437   **Table 3** Risk of adverse outcome for deliveries performed by doctors with random

438   effect for delivering individual comparing each characteristic between deliveries

439   occurring during day *versus* night shifts. Model coefficients are expressed as odds

440   ratios and 95% confidence intervals (CI).

441

442

Adverse outcome	Deliveries by doctors (3032 deliveries by 28 individuals)	
	OR (night v. day) (95% CI)	p value
EBL ≥1.5 litres	1.18 (0.72-1.94)	0.52
3rd/4th degree tear	1.06 (0.71-1.59)	0.77
Umbilical arterial pH ≤7.10	1.44 (0.95-2.18)	0.09
Delayed neonatal respiration	0.95 (0.71-1.26)	0.69
Failed instrumental delivery	1.13 (0.84-1.53)	0.41
Critical incident	1.28 (0.92-1.77)	0.14

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444

445 **Figure Legends**

446 **Figure 1:** Risk of adverse outcomes dependent on hours worked prior to delivery (A)

447 Estimated maternal blood loss $\geq$1L ($p<0.05$) (B) Umbilical arterial pH $\leq$7.1 ($p<0.05$).

448 Dashed line represents the mean risk level for the outcome; risks that are negative

449 with respect to this line are therefore less likely than average, and those that are

450 positive are more likely than average.

451

452 **Figure 2:** Comparison of risk of adverse outcomes dependent on hours worked prior

453 to delivery between day and night shift (A) Estimated maternal blood loss $\geq$1L during

454 day shift 08.00-20.00 ($p = 0.07$) (B) Estimated maternal blood loss $\geq$1L during night

455 shift 20.00-08.00 (C) Umbilical arterial pH $\leq$7.1 during day shift 08.00-20.00 (D)

456 Umbilical arterial pH $\leq$7.1 during night shift 20.00-08.00 ($p<0.01$). Dashed line

457 represents the mean risk level for the outcome; risks that are negative with respect to

458 this line are therefore less likely than average, and those that are positive are more

459 likely than average.

460