

ORIGINAL RESEARCH ARTICLE

Early antenatal risk factors for births before arrival: An unmatched case-control study

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Abstract

Introduction: Birth before arrival is associated with maternal morbidity and neonatal morbidity and mortality. Yet, timely risk stratification remains challenging. Our objective was to identify risk factors for birth before arrival which may be determined at the first antenatal appointment.

Material and methods: This was an unmatched case-control study involving 37 348 persons who gave birth at a minimum of 22+0 weeks' gestation over a 5-year period from January 2014 to October 2019 (IRAS project ID 222260; REC reference: 17/SC/0374). The setting was a large UK university hospital. Data obtained on maternal characteristics at booking was examined for association with birth before arrival using a stepwise multivariable logistic regression analysis. Data are presented as adjusted odds ratios with 95% confidence intervals. Area under the receiver-operator characteristic curves (C-statistic) were employed to enable discriminant analysis assessing the risk prediction of the booking data on the outcome.

Results: Multivariable analysis identified significant independent predictors of birth before arrival that were detectable at booking: parity, ethnicity, multiple deprivation, employment status, timing of booking, distance from home to the nearest maternity unit, and safeguarding concerns raised at booking by clinical staff. Our model demonstrated good discrimination for birth before arrival; together, the predictors accounted for 77% of the data variance (95% confidence interval 0.74–0.80).

Conclusions: Information gathered routinely at booking may discriminate individuals at risk for birth before arrival. Better recognition of early factors may enable maternity staff to direct higher-risk women towards specialized care services at an early point in their pregnancy, enabling time for clinical and social interventions.

KEYWORDS

births before arrival, maternal health, social factors

Abbreviations: aOR, adjusted odds ratio; BBA, birth before arrival; CI, confidence interval; OR, odds ratio.

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1 | INTRODUCTION

Births before arrival (BBAs) occur unplanned away from their intended location. Compared to planned births, the risk of maternal morbidity and neonatal morbidity and mortality are increased.^{1,2} Infants are at a higher risk of infection,³ hypothermia,⁴ and neonatal intensive care admission.⁵ Although the prevalence of BBA in high-income countries is estimated at only 0.4%–0.8%,^{6–9} they remain an important determinant of maternal and neonatal health.

Effective risk stratification for BBA remains challenging. Previous studies have identified that risk is due to an interplay of demographic, obstetric, and social factors.^{10–12} The current literature's use of national databases to characterize this risk is, however, crude. First, the risk factors identified are inevitably general and lack the acuity possible with local surveillance. Second, this method obscures intranational variation in social disadvantage, which is critical when assessing its contribution to health inequity¹³; social risk factors often reflect the profile of locally marginalized communities.¹⁴ Furthermore, previous work has largely excluded missing data. This is despite emerging evidence that data in patient databases is often not missing at random, but instead may reflect health inequities.¹⁵ Finally, the data employed in previous studies is mostly collected at birth or postnatally. Whilst this may allow for identification of risk factors for BBA, it lacks pragmatic value in terms of preventing BBA. There is a need for early risk stratification: in high-risk individuals, this may afford time for the implementation of preventative measures such as patient education, individualized antenatal care planning, and social support solutions.¹⁶

The objective of this study was to identify risk factors for BBA using only routine data collected during the first antenatal appointment ("booking").¹⁷ We aimed to build a model for the prediction of BBA to ascertain if factors identifiable at booking may be used to assist clinical decision-making and risk stratification at the earliest stages of pregnancy.

2 | MATERIAL AND METHODS

2.1 | Study design

This unmatched case-control study used data routinely collected from individuals who were registered at Oxford University Hospitals NHS Foundation Trust with a delivery dated between January 01, 2014 and October 19, 2019. A case-control design was chosen to investigate whether, in pregnant people who experience BBA, factors identifiable at booking may differentiate them from those who do not experience this adverse outcome. The study population included singleton births that occurred at over 22+0 weeks' gestation. Individuals with postcodes outside of Oxfordshire were excluded as tertiary referrals. Terminations of pregnancy were also excluded, as were pregnancies where there was insufficient data on labor (Figure S1).

Key message

Birth before arrival is a cause of adverse obstetric outcomes. Its risk may be predicted by information provided by pregnant women in their first antenatal appointment.

Cases were individuals who had unplanned births outside of their intended location (BBAs) ($n = 216$). This included births that occurred unplanned at home or in transit to a maternity unit. Controls were institutional or planned home births ($n = 37\,132$). Cases and controls were identified from "Place of birth" reported in the core outcome set "Maternity Care."¹⁸ A random subgroup of controls was not selected due to the risk of introducing selection bias. Cases and controls were unmatched to avoid limiting the risk factors that could be examined in this exploratory work.

Maternal characteristics were identified either from the literature or from a pre-determined analysis of relevant factors from the maternity unit's booking proforma. This was guided by the World Health Organization's theoretical framework on social determinants of health, whereby social factors are categorized as distal, intermediate, or proximal¹⁹; proximal factors are primarily related to healthcare access, intermediate factors include adverse maternal behaviors, and distal social factors include ethnicity and lower socioeconomic status.^{3,4} A directed acyclic graph (DAG) was drawn to delineate the theoretical relationship between risk factors and BBA (Figure 1). The DAG was subsequently employed used as a guide for analysis of the dataset, to mitigate the risk of determining association with BBA by chance.

Demographic factors included age and parity. Age and parity were not normally distributed and therefore were coded as ordinal categorical variables.

The proximal social factors assessed were gestational age at booking ($\leq 12+0$ weeks or $>12+0$ weeks) and the distance from the patient's home to the nearest maternity unit. Distance was measured as the distance in a straight line between the outward codes of the patient's address and the closest maternity unit. Distance was not normally distributed and was coded as an ordinal categorical variable.

The intermediate social factors assessed at booking were substance misuse, smoking, psychiatric disorder, current or past social worker involvement, and documentation of safeguarding concerns raised by maternity staff.

The distal risk factors we assessed were ethnicity (White, Black or Black British, Asian or Asian British, and any other ethnicity) and two facets of socioeconomic status: multiple deprivation and employment status. Indices of multiple deprivation are small area based measures that may act as a proxy for socioeconomic status.²⁰ Here, we used the English indices of multiple deprivation 2019.²¹ The scores are presented as quintiles, with the fifth quintile reflecting the least deprived neighborhoods and the first reflecting the most deprived.

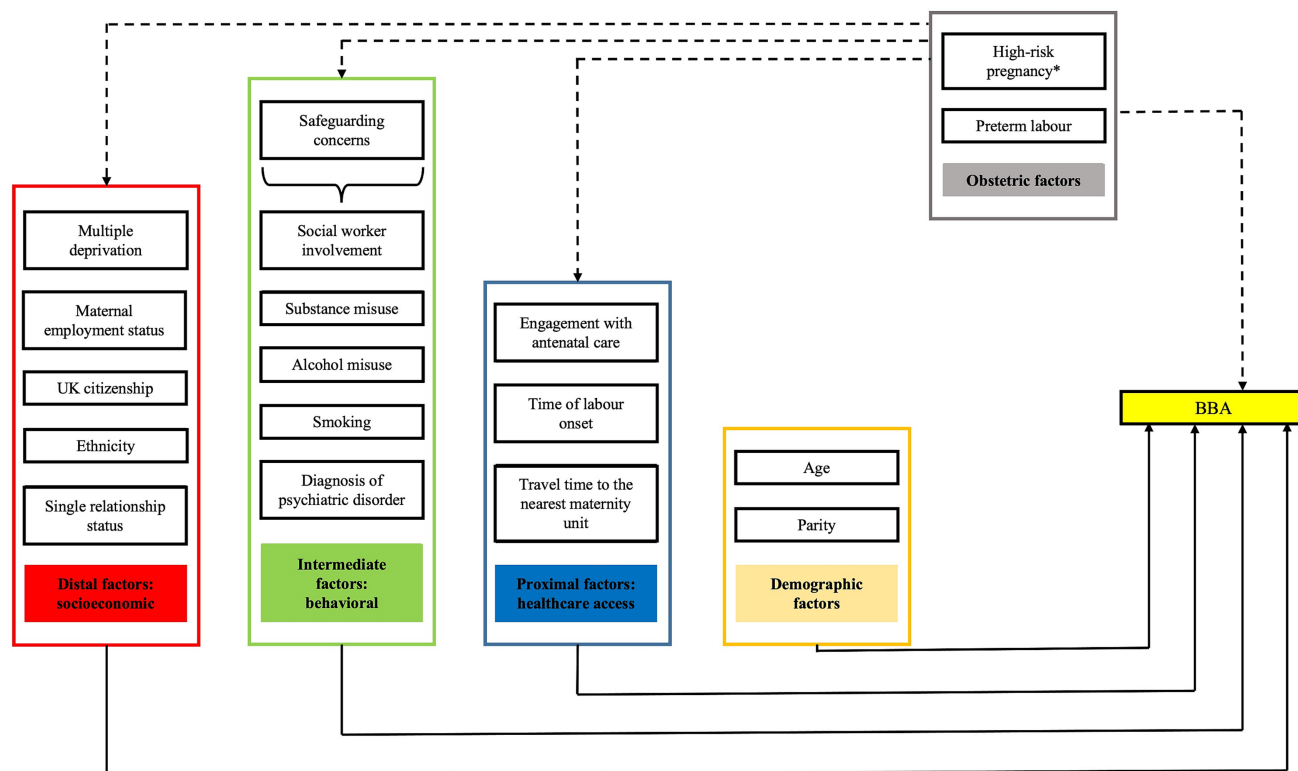


FIGURE 1 Directed acyclic graph (DAG): a theoretical framework for determinants of BBA. *High-risk pregnancy includes previous or current obstetric pathology and/or the need for the cesarean-section; dotted arrows denote confounding relationships. BBA, birth before arrival.

There was no direct patient or public involvement in this study. As this study retrospectively analyzed routinely collected patient data, informed consent was not sought. This study was reported in accordance with STROBE guidelines for case-control studies²² (Table S1).

2.2 | Statistical analyses

Maternal characteristics were compared for cases and controls using either the chi-squared test or, where the assumptions of chi-squared were violated, the Fisher-Freeman-Halton exact test. Categorical variables are presented as frequencies with percentages. Univariable logistic regression analysis was used to investigate the association between each risk factor and BBA; the results are presented as unadjusted odds ratios (OR) with 95% confidence intervals (CI). For the ordinal categorical variables that were significantly associated with BBA, we conducted a test for trend.

Before undertaking multivariable logistic regression analysis, multicollinearity between the independent variables was assessed using correlation coefficients. The variable “safeguarding concerns” was highly correlated with other intermediate social factors. This was likely to be related to high-risk behaviors (smoking and substance misuse), as well as social worker involvement and maternal psychiatric disorder. Therefore, to ensure model parsimony we only included “safeguarding concerns” in the multivariable model. The

association between each intermediate social factor and the risk of BBA was examined separately in a subgroup analysis.

We performed stepwise logistic regression analysis by adding variables according to the DAG in the following order: proximal social factors, intermediate social factors, and distal social factors. The final model also included demographic factors. Due to a high correlation between missing data for both multiple deprivation and distance as both reflect no known postcode, the “missing” category for the latter was excluded in the multivariable analyses to improve model convergence.

Each adjusted model accounted for confounding by obstetric factors which were postulated to be associated with both the social factors and the outcome. This included markers of high-risk pregnancy (hypertensive disorder, diabetes mellitus) and parturition (gestational age at birth, birthweight, time of birth). This is because the literature suggests that such maternal, fetal and labor characteristics are significantly associated with social and economic risk factors.²³ Furthermore, women with such high-risk pregnancies are encouraged to have planned births at a healthcare facility.²⁴ We therefore postulated that these variables would be likely confounders in the dataset.

Missing data were coded as a distinct category for each variable to interrogate their possible nonrandom pattern of distribution. As we hypothesized missingness in the dataset was unlikely to have occurred by chance, multiple imputation and complete case analysis were inappropriate.¹⁵ If the missing category of a variable was found

TABLE 1 Maternal characteristics identified at the first antenatal appointment.

Risk factor	BBA (%) <i>n</i> = 216	Non-BBA (%) <i>n</i> = 37 132	<i>p</i> -value ^a
Demographic factors			
Age (years)			
20–34	154 (71.3)	26 586 (71.6)	0.38
≤19	2 (4.9)	845 (2.3)	
≥35	60 (56.5)	9701 (26.1)	
Parity			
Nulliparous (0 births)	24 (11.1)	16 488 (44.4)	<0.001
Multiparous (1–4 births)	185 (85.6)	20 271 (54.6)	
Grand multiparous (≥5 births)	7 (3.2)	373 (1.0)	
Social factors: proximal			
Distance to the nearest maternity unit			
<5 miles	64 (29.6)	12 400 (33.4)	<0.001
5 ≤ <i>x</i> < 10 miles	37 (17.1)	7393 (19.9)	
10 < <i>x</i> ≤ 15 miles	71 (32.9)	12 411 (33.4)	
≥15 miles	39 (18.1)	4736 (12.8)	
Missing	5 (2.3)	192 (0.5)	
Timing of booking			
≤12+0 weeks' gestation	113 (52.3)	24 477 (65.9)	<0.001
>12+0 weeks' gestation	43 (19.9)	6413 (17.3)	
Missing	60 (27.8)	6242 (16.8)	
Social factors: intermediate			
Safeguarding concerns			
No	158 (73.1)	29 837 (80.4)	<0.001
Yes	13 (6.0)	694 (1.9)	
Missing	45 (20.8)	6601 (17.8)	
Social worker involvement			
No	110 (50.9)	18 661 (50.3)	<0.001
Yes	22 (10.2)	1386 (3.7)	
Missing	84 (38.9)	17 085 (46.0)	
Smoking			
Never smoked	121 (56.0)	21 719 (58.5)	0.02
Current smoker	32 (14.8)	3663 (9.9)	
Past smoker	56 (25.9)	11 144 (30.0)	
Missing	7 (3.2)	606 (1.6)	
Psychiatric disorder			
No	117 (54.2)	22 479 (60.5)	0.11
Yes	49 (22.7)	6677 (18.0)	
Missing	50 (23.1)	7976 (21.5)	
Substance misuse			
Never used	158 (73.1)	28 938 (77.9)	0.05 ^b
Current use	3 (1.4)	128 (0.3)	
Past use	14 (6.5)	2050 (5.5)	
Missing	41 (19.0)	6016 (16.2)	

(Continues)

TABLE 1 (Continued)

Risk factor	BBA (%) <i>n</i> = 216	Non-BBA (%) <i>n</i> = 37 132	<i>p</i> -value ^a
Social factors: distal			
Ethnicity			
White	179 (82.9)	29 949 (80.7)	0.01
Black or Black British	9 (4.2)	880 (2.4)	
Asian or Asian British	5 (2.3)	3205 (8.6)	
Any other ethnicity	10 (4.6)	1185 (3.2)	
Missing	13 (6.0)	1913 (5.2)	
Multiple deprivation			
Fifth quintile (least deprived)	67 (31.0)	15 252 (41.1)	<0.001
Fourth quintile	69 (31.9)	10 088 (27.2)	
Third quintile	32 (14.8)	5864 (15.8)	
Second quintile	29 (13.4)	3686 (9.9)	
First quintile (most deprived)	14 (6.5)	2050 (5.5)	
Missing	5 (2.3)	192 (0.5)	
Employment status			
In paid employment	127 (58.8)	26 413 (71.1)	<0.001
Outside of paid employment	70 (32.4)	7186 (19.4)	
Missing	19 (8.8)	3533 (9.5)	

Abbreviation: BBA, birth before arrival.

^a*p*-values calculated using chi-squared independence test, except where indicated otherwise.^b*p*-values calculated using Fisher–Freeman–Halton exact test.

to be significantly associated with the outcome, a sensitivity analysis was undertaken by reclassifying the missing data into the extreme categories of the variable and rerunning the final logistic regression analysis.

Results are presented as adjusted odds ratios (aOR) with 95% CI. All associations were considered significant at a two-tailed *p*-value of 0.05. Analyses were undertaken using SPSS (IBM Corp. Released 2019. IBM SPSS Statistics for Macintosh, version 27.0. ArmonWhik, NY, USA).

3 | RESULTS

A comparison of maternal characteristics of cases (*n* = 216) and controls (*n* = 37 132) is presented in Table 1. The demographic risk factor significantly associated with BBA was parity (*p* < 0.001); maternal age had no significant association (*p* = 0.38). By contrast, both proximal social factors (distance to the nearest maternity unit and timing of booking) were significantly associated with BBA (*p* < 0.001). Similarly, the intermediate social factors safeguarding concerns, social worker involvement, smoking, and psychiatric disorder had a significant relationship with BBA at *p* < 0.05; the association between substance misuse and BBA was at *p* = 0.05. Distal social

factors included ethnicity, multiple deprivation, and employment status: the three factors were all significantly associated with BBA at ($p = 0.01$, $p < 0.001$, and $p < 0.001$, respectively). Further exploration using serial logistic regression is shown in [Table 2](#).

3.1 | Proximal social factors and BBA

Distance showed an increasing linear trend of association with BBA (linear-by-linear association = 4.00, $p = 0.045$). Living at the longest distances (≥ 15 miles) was associated with significant increased crude odds of BBA (OR 1.60, 95% CI: 1.07–2.38). This association was maintained with serial adjustment ([Table 2](#)). Of note, individuals with missing data had the greatest odds of BBA. Sensitivity analysis, performed by redistributing the missing group into the shortest or longest distances, did not materially change the results ([Table S2](#)).

Late gestational age at booking ($>12+0$ weeks) was associated with increased crude odds of BBA (OR 1.45, 95% CI: 1.02–2.07). The effect size of the OR was attenuated with serial adjustment ([Table 2](#)). If the booking time was unknown, there was increased odds of BBA that remained significant with serial adjustment (aOR 1.42; 95% CI: 1.01–2.01). Redistribution of missing data for sensitivity analysis did not substantially change the results ([Table S2](#)).

3.2 | Intermediate social factors and BBA

Safeguarding concerns raised at booking was associated with increased odds of BBA. The association remained significant with adjustment (aOR 2.30, 95% CI: 1.26–4.22). Subgroup analysis of the other intermediate social factors identified that smoking and substance misuse at booking, involvement of social workers at the time of booking, and the presence of psychiatric disorder were associated with increased crude odds of BBA ([Table S3](#)). Assessment of multicollinearity identified that these factors correlated with the intermediate risk factor safeguarding concerns; they were therefore excluded from the logistic regression.

3.3 | Distal social factors and BBA

There was a significant association between ethnicity and BBA: cases included a higher proportion of Black or Black British and a lower proportion of Asian or Asian British individuals compared with the control group ([Table 1](#)). Asian or Asian British individuals had significantly lower odds of BBA relative to those of white ethnicity (aOR 0.25, 95% CI: 0.10–0.62) ([Table 2](#)).

There was a significant linear trend of association between multiple deprivation and odds of BBA (linear-by-linear association = 5.54, $p = 0.019$). The odds of BBA were higher in the lower four quintiles compared with the highest (least deprived) quintile ([Table 2](#)). The missing category was significantly associated with BBA; sensitivity analysis by redistributing the missing cases into the

most and least deprived quintiles did not substantially change the results ([Table S2](#)).

Besides socioeconomic deprivation, not being in paid employment was also associated with increased odds of BBA. This association remained significant after adjusting for other factors, although the effect size of the aOR decreased (aOR 1.42, 95% CI: 1.03–1.95).

3.4 | Demographic factors and BBA

Extremes of age were not significantly associated with BBA in our population; however, parity was a strong independent predictor of BBA and was only minimally affected by other factors on serial adjustments ([Table 2](#)). We observed a significant linear trend (linear-by-linear association 102.02, p -value < 0.001). Grand multiparity (five or more previous births) had almost nine-times higher odds of BBA after adjusting for other factors (aOR 8.66, 95% CI: 3.51–21.37).

3.5 | Prediction of BBA

The social factors investigated had an incremental effect on the area under the curve (AUC) ([Figure 2](#)). The final model accounted for 77% (95% CI: 0.74–0.80) of the variance in our sample population. This was not different from a model that did not control for obstetric confounders (AUC = 0.75, 95% CI: 0.72–0.78) ([Table S4](#); [Figure S2](#)).

4 | DISCUSSION

In this case-control study, data collected routinely at the first antenatal appointment had good discriminatory ability to predict BBA. As anticipated by our DAG, progressive addition of social and demographic factors increased the efficacy of the model. Furthermore, the model was not materially affected by exclusion of obstetric confounders (such as preterm birth, low birthweight, and maternal disease in pregnancy). Thus, the predictive power of the model in our study population was driven by the information gathered at booking and not obstetric complications identified later in pregnancy. Our model should therefore enable clinicians to better risk-stratify for BBA early in pregnancy using only the pregnant person's booking data.

Significant early predictors of BBA were demographic (multiparity) and social factors. Proximal social determinants included the timing of booking, and the distance from home to the nearest maternity unit. The former is internal to the individual's locus of control as it reflects active engagement with maternity services; the latter is external and depends on local resource allocation. Intermediate social risk factors included high-risk behaviors and safeguarding concerns raised at booking. No previous literature has identified that individuals already known to have safeguarding concerns at booking are at increased risk of BBA. This is particularly important. First, it supports the hypothesis that risk of BBA

TABLE 2 Association between BBA and maternal characteristics identified at the first antenatal appointment. Crude and adjusted odds ratios calculated using logistic regression.

Risk factor	Unadjusted OR (95% CI)	Adjusted for proximal social factors aOR (95% CI) ^a	Adjusted for proximal and intermediate social factors	Adjusted for proximal, intermediate, and distal social factors	Adjusted for all social and demographic factors
Distance to the nearest maternity unit					
<5 miles	1.00	1.00	1.00	1.00	1.00
5 ≤ x < 10 miles	0.97 (0.65–1.46)	0.97 (0.64–1.45)	0.98 (0.65–1.47)	1.03 (0.67–1.58)	0.98 (0.64–1.51)
10 < x ≤ 15 miles	1.11 (0.79–1.56)	1.12 (0.80–1.58)	1.13 (0.81–1.59)	1.18 (0.82–1.70)	1.14 (0.79–1.64)
≥15 miles	1.60 (1.07–2.38)	1.58 (1.06–2.35)	1.56 (1.05–2.34)	1.55 (1.03–2.34)	1.50 (0.99–2.28)
Missing	5.05 (2.01–12.68)	5.24 (2.08–13.20)	4.79 (1.89–12.12)	^b	^b
Timing of booking					
≤12+0 weeks' gestation	1.00	1.00	1.00	1.00	1.00
>12+0 weeks' gestation	1.45 (1.02–2.07)	1.47 (1.03–2.09)	1.41 (0.99–2.01)	1.32 (0.92–1.88)	1.33 (0.93–1.91)
Missing	2.08 (1.52–2.85)	2.03 (1.48–2.78)	1.98 (1.45–2.72)	2.14 (1.52–3.02)	1.42 (1.01–2.01)
Safeguarding concerns					
No	1.00	-	1.00	1.00	1.00
Yes	3.54 (2.00–6.26)		3.27 (1.84–5.82)	2.20 (1.21–4.00)	2.30 (1.26–4.22)
Missing	1.29 (0.92–1.80)		1.19 (0.86–1.67)	1.32 (0.93–1.89)	1.50 (1.05–2.15)
Ethnicity					
White	1.00	-	-	1.00	1.00
Black or Black British	1.71 (0.87–3.35)			1.66 (0.84–3.31)	1.51 (0.76–3.01)
Asian or Asian British	0.26 (0.11–0.64)			0.25 (0.10–0.61)	0.25 (0.10–0.62)
Any other ethnicity	1.41 (0.75–2.68)			1.30 (0.68–2.49)	1.33 (0.69–2.54)
Missing	1.14 (0.65–2.00)			0.70 (0.35–1.38)	0.69 (0.35–1.35)
Multiple deprivation					
Fifth quintile (least deprived)	1.00	-	-	1.00	1.00
Fourth quintile	1.56 (1.11–2.18)			1.52 (1.09–2.14)	1.54 (1.09–2.15)
Third quintile	1.24 (0.81–1.90)			1.25 (0.81–1.92)	1.26 (0.82–1.94)
Second quintile	1.79 (1.15–2.77)			1.66 (1.05–2.62)	1.58 (0.99–2.50)
First quintile (most deprived)	1.56 (0.87–2.77)			1.32 (0.71–2.44)	1.26 (0.68–2.34)
Missing	5.93 (2.26–14.87)			5.95 (2.26–15.64)	6.44 (2.42–17.16)
Employment status					
In paid employment	1.00	-	-	1.00	1.00
Outside of paid employment	2.03 (1.51–2.72)			1.91 (1.40–2.61)	1.42 (1.03–1.95)
Missing	1.12 (0.69–1.81)			0.91 (0.53–1.55)	0.85 (0.50–1.44)
Age (years)					
20–34	1.00	-	-	-	1.00
≤19	0.41 (0.10–1.65)				0.59 (0.14–2.48)
≥35	1.07 (0.79–1.44)				0.96 (0.70–1.30)
Parity					
Nulliparous (0 births)	1.00	-	-	-	1.00
Multiparous (1–4 births)	6.27 (4.10–9.60)				5.48 (3.51–8.55)

TABLE 2 (Continued)

	Unadjusted	Adjusted for proximal social factors	Adjusted for proximal and intermediate social factors	Adjusted for proximal, intermediate, and distal social factors	Adjusted for all social and demographic factors
Risk factor	OR (95% CI)	aOR (95% CI) ^a			
Grand multiparous (≥5 births)	12.89 (5.52–30.11)				8.66 (3.51–21.37)

Abbreviations: aOR, adjusted odds ratio; BBA, birth before arrival; CI, confidence interval; OR, odds ratio.

^aAdjusted models also account for the obstetric factors that were considered to be known confounders.

^bMissing data for both multiple deprivation and distance are equivalent; as such, missing data for distance was excluded from the logistic regression when multiple deprivation was added.

is associated with social vulnerability. Yet it also indicates that maternity staff are already able to recognize patients at risk, implying that there is ready potential in maternity services to reduce the incidence of BBAs.

Distal risk factors identified were ethnicity, multiple deprivation, and employment status. The relationship between ethnicity and risk of BBA in our sample population is noteworthy. Whilst Black individuals were at increased odds of BBA, this was not statistically significant at $p < 0.05$. By contrast, Asian individuals were at significantly decreased odds of BBA. This could not be explained by adjustment for maternal complications. This implies that there is either a biological confounder that we failed to measure or a unique sociocultural feature of this Asian community that positively affects their healthcare-seeking behavior. Given the current focus on racial health inequity in maternity care, particularly for Black individuals,²⁵ it would be critical for others to evaluate whether and how ethnicity impacts risk for BBA in their community. Along with ethnicity, our work provides further evidence that clinicians should contemplate the social and economic context of their patients when considering their risk of adverse health outcomes.

A major strength of this study is that the inclusion criteria were purposefully broad. This was to ensure that the study had maximum real-world applicability. Furthermore, no previous studies in the field have employed serial regression analyses, whereby factors are added in a predetermined hierarchical fashion. This served two purposes. First, it identified the progressive influence of risk factors on the prediction of BBA. Second, it exposed the interplay between determinants. This inter-relationship is partly captured by the DAG; however, it is likely to be even more complex. We postulate that the predictors of BBA act as a network of biological and sociocultural vulnerability. Our statistical technique has demonstrated that the predictors for BBA cannot be siloed.

This study was not without limitations. First, it depended on both accurate self-reporting by patients and accurate documentation by clinical staff. It is therefore possible that there were inaccuracies in the data gathered. Second, our BBA population was inevitably heterogenous: the definition includes births occurring with no healthcare professionals present, with untrained paramedics, or with trained paramedics or emergency midwives.²⁶

Whilst we define BBA as any birth occurring in an inappropriate and unplanned location, future work should explore whether the predictors for BBA vary depending on these subgroups. Third, as socioeconomic disadvantage remains difficult to quantify, we had to use indirect measures. Although indices of multiple deprivation are a validated measure of socioeconomic status,²⁷ it cannot compute social vulnerability at the individual level. It is therefore inevitable that we lost some acuity. A further limitation is that our study was only based in one region. As BBAs are rare events, this meant that there was only a small number of cases. This limits the study power, which can be observed in the wide confidence intervals for some of the variables included here.²⁸ Yet, this limitation should be balanced against the ability of a smaller-scale study to identify nuanced risk factors not recorded in national databases. This was evident with our analysis of intermediate social risk factors such as safeguarding concerns. Furthermore, the novel findings identified here are in keeping with the conclusions of other studies in high-income countries^{4,11,12}: principally, that BBAs are observed most commonly amongst the more socially and economically vulnerable individuals in any locality. This supports the assumption that our study has good external validity, despite its smaller study size.

Missing data may be considered a further limitation; it arguably reduces the statistical merits of a study. However, missingness is informative. For example, missing data may identify individuals who did not have a formal booking in pregnancy, but instead their data was inputted during other interactions with maternity services. This cannot be ruled out by the retrospective design of our study, and indeed may be supported by the increased odds of BBA when the timing of booking was unknown. Furthermore, missing data for multiple deprivation may reflect individuals who either do not have stable housing or are unwilling to declare their home address. Our interpretation of “missingness” as a significant finding is supported by previous work, which has identified a correlation between missing data, economic deprivation, and adverse obstetric outcomes.¹⁵ As such, the absence of information in patient records is deserving of both research and clinical attention.

Despite state-funded healthcare systems in many high-income countries, social determinants of health remain hugely

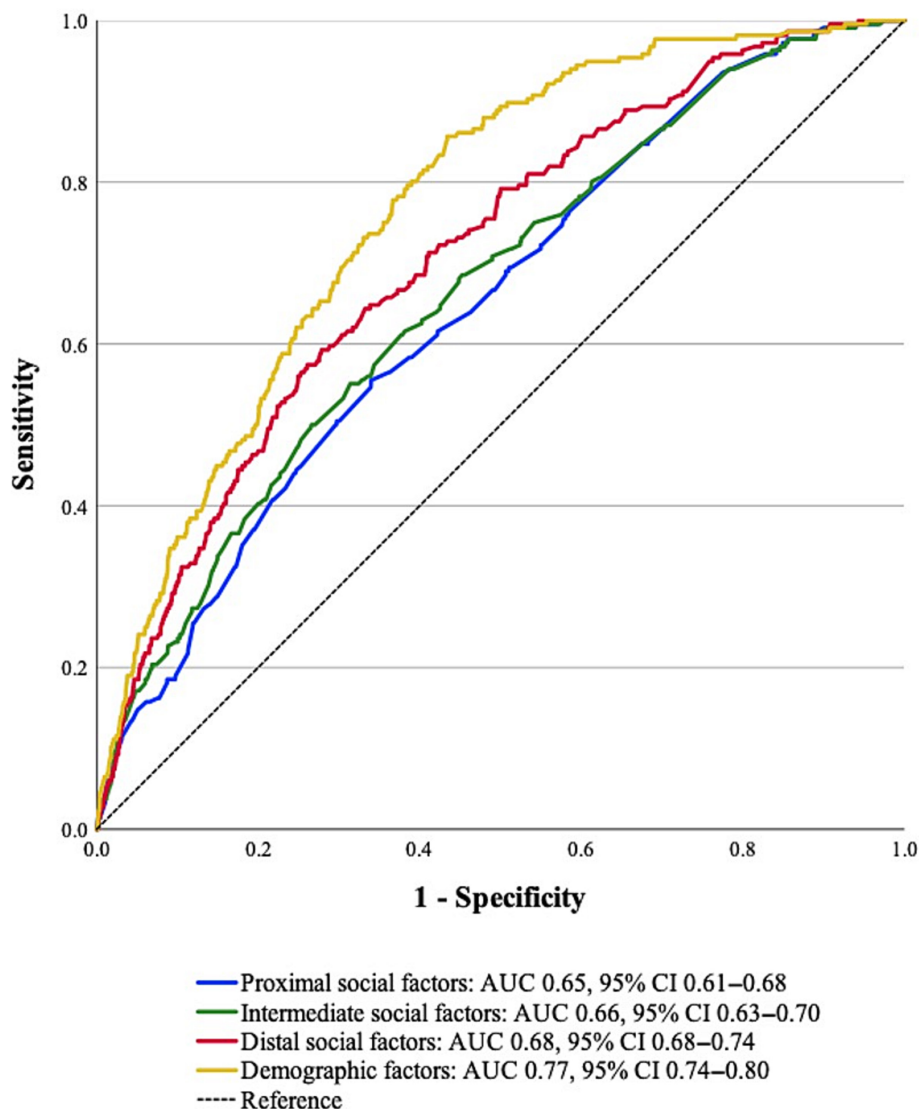


FIGURE 2 Area under the curve with serial adjustments for distal, proximal, and intermediate social factors, and demographic factors. All curves were also adjusted for obstetric confounders.

significant.²⁹ We advocate for the creation of clinical pathways through which vulnerable women may access coordinated support from health and social care.³⁰ This first requires early risk stratification. Here, the viability of using booking information to predict BBA has been shown. Future studies should therefore consider whether a screening tool for BBA could be developed using data collected at the first antenatal appointment. Yet, screening programs also necessitate effective interventions to prevent the adverse outcome. Such interventions for persons at high-risk of BBA may include antenatal education programs, early involvement of social workers or perinatal psychiatry, or continuity-of-care pathways with specialist midwives.³¹ To best identify how teams may support high-risk women, future studies should also include qualitative research involving the relevant stakeholders: obstetricians, midwives, paramedics, and women who have experienced BBA. Whilst such work has been undertaken in the field,^{32–34} the patient sample populations have been largely

skewed towards women of higher socioeconomic status; they do not reflect the high-risk population identified here. Future studies should therefore carefully consider study design and involve a recruitment process which elevates the voices of those most vulnerable to BBA.

5 | CONCLUSION

Our findings align with existing research that implicates socioeconomic vulnerability as a root cause of BBA.¹² We demonstrate that routine information gathered at booking has good discriminatory ability to predict the risk of BBA. This should assist with timely risk stratification for this adverse event. Future studies may consider whether screening tools may be developed to enable rapid identification of high-risk persons at the booking appointment. For individuals identified as having complex social needs with an associated

higher risk of BBA, targeted interventions should then be implemented to reduce the risk of unplanned births outside of a health facility.

AUTHOR CONTRIBUTIONS

CM and LI conceived the project idea. TRH, CYLA, and LI planned the project. TRH and SM coded the data, and TRH and MN conducted the data analysis. TRH wrote the original manuscript, which was revised by MN, CYLA, and LI. The manuscript was approved by all authors before submission.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

Ethical approval was first granted on July 27, 2017 and updated on September 20, 2021 (IRAS project ID 222260; REC reference: 17/SC/0374).

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REFERENCES

- Örtqvist AK, Haas J, Ahlberg M, Norman M, Stephansson O. Association between travel time to delivery unit and unplanned out-of-hospital birth, infant morbidity and mortality: a population-based cohort study. *Acta Obstet Gynecol Scand*. 2021;100:1478-1489.
- Thornton CE, Dahlen HG. Born before arrival in NSW, Australia (2000–2011): a linked population data study of incidence, location, associated factors and maternal and neonatal outcomes. *BMJ Open*. 2018;8:e019328.
- Gunnarsson B, Smáráson AK, Skogvoll E, Fastang S. Characteristics and outcome of unplanned out-of-institution births in Norway from 1999 to 2013: a cross-sectional study. *Acta Obstet Gynecol Scand*. 2014;93:1003-1010.
- Scott T, Esen UI. Unplanned out of hospital births—who delivers the babies? *Ir Med J*. 2005;98:70-72.
- Northern Region Perinatal Mortality Survey Coordinating Group. Collaborative survey of perinatal loss in planned and unplanned home births. *BMJ*. 1996;313:1306-1309.
- Renesme L, Garlantézec R, Anouilh F, Bertschy F, Carpentier M, Sizun J. Accidental out-of-hospital deliveries: a case-control study. *Acta Paediatr*. 2013;102:e174-e177.
- Rodie VA, Thomson AJ, Norman JE. Accidental out-of-hospital deliveries: an obstetric and neonatal case control study. *Acta Obstet Gynecol Scand*. 2002;81:50-54.
- Haloob R, Thein A. Born before arrival. A five year retrospective controlled study. *J Obstet Gynaecol*. 1992;12:100-104.
- Jones D. Babies born before arrival (BBA) in Newham, London during 2007–2008: a retrospective audit and commentary. *Midwifery Dig*. 2009;19:219-224.
- Ovaskainen K, Ojala R, Gissler M, Luukkaala T, Tammela O. Out-of-hospital deliveries have risen involving greater neonatal morbidity. *Acta Paediatr*. 2015;104:1248-1252.
- Ovaskainen K, Ojala R, Tihtonen K, Gissler M, Luukkaala T, Tammela O. Unplanned out-of-hospital deliveries in Finland: a national register study on incidence, characteristics and maternal and infant outcomes. *Acta Obstet Gynecol Scand*. 2020;99:1691-1699.
- Comber E, Roussot A, Chabernaud JL, Cottenet J, Rozenberg P, Quantin C. Out-of-maternity deliveries in France: a nationwide population-based study. *PLoS One*. 2020;15:e0228785.
- Marmot M, Friel S, Bell R, Houweling TA, Taylor S. Closing the gap in a generation: health equity through action on the social determinants of health. *Lancet*. 2008;372:1661-1669.
- Sheiner E, HersHKovitz R, Shoham-Vardi I, Erez O, Hadar A, Mazor M. Accidental out-of-hospital delivery as an independent risk factor for perinatal mortality. *Arch Gynecol Obstet*. 2004;269:85-88.
- Lindquist A, Knight M, Kurinczuk JJ. Variation in severe maternal morbidity according to socioeconomic position: a UK national case-control study. *BMJ Open*. 2013;3:e002742.
- National Maternity Review. *Better Births: Improving Outcomes of Maternity Services in England* [Internet]. <https://www.england.nhs.uk/wp-content/uploads/2016/02/national-maternity-review-report.pdf>
- National Institute for Health and Care Excellence [NICE Guideline No. 201]. *Antenatal Care* [Internet]. 2021. <https://www.nice.org.uk/guidance/ng201>
- Devane D, Begley CM, Clarke M, Horey D, OBoyle C. Evaluating maternity care: a core set of outcome measures. *Birth*. 2007;34:164-172.
- World Health Organization. *Closing the Gap: Policy into Practice on Social Determinants of Health: Discussion Paper* [Internet]. World Health Organization; 2011 <https://apps.who.int/iris/handle/10665/44731>
- Noble M, Wright G, Smith G, Dibben C. Measuring multiple deprivation at the small-area level. *Environ Plan Econ Space*. 2006;38:169-185.
- Ministry of Housing Communities & Local Government. *The English Indices of Deprivation 2019* [Internet]. UK Government; 2019:31 <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>
- von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ*. 2007;335:806-808.
- Jones GL, Mitchell CA, Hirst JE, Anumba DOC, the Royal College of Obstetricians and Gynaecologists. Understanding the relationship between social determinants of health and maternal mortality. *BJOG*. 2022;129:1211-1228.
- Royal College of Obstetricians and Gynaecologists/Royal College of Midwives. *Joint Statement No. 2* [Internet]. 2007. https://birthguidechicago.com/wp-content/uploads/2018/07/home_births_rcog_rcm0607.pdf
- Knight M, Bunch K, Tuffnell D, et al., eds. *Saving Lives, Improving Mothers' Care—Lessons Learned to Inform Maternity Care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2017–19* [Internet]. National Perinatal Epidemiology Unit, University of Oxford; 2021 <https://www.npeu.ox.ac.uk/mbrace-uk>

26. McLelland GE, Morgans AE, McKenna LG. Involvement of emergency medical services at unplanned births before arrival to hospital: a structured review. *Emerg Med J*. 2014;31:345-350.
27. Spencer N, Bambang S, Logan S, Gill L. Socioeconomic status and birth weight: comparison of an area-based measure with the Registrar General's social class. *J Epidemiol Community Health*. 1999;53:495-498.
28. Dziaj JJ, Dierker LC, Abar B. The interpretation of statistical power after the data have been gathered. *Curr Psychol*. 2020;39:870-877.
29. Lindquist A, Kurinczuk JJ, Redshaw M, Knight M. Experiences, utilisation and outcomes of maternity care in England among women from different socio-economic groups: findings from the 2010 National Maternity Survey. *BJOG*. 2015;122:1610-1617.
30. Reeves S, Lewin S, Epsin S, Zwarenstein M. Interprofessional teamwork: key concepts and issues. *Interprofessional Teamwork for Health and Social Care [Internet]*. John Wiley & Sons, Ltd; 2010:39-56. doi:[10.1002/9781444325027.ch3](https://doi.org/10.1002/9781444325027.ch3)
31. Sandall J, Soltani H, Gates S, Shennan A, Devane D. Midwife-led continuity models versus other models of care for childbearing women. *Cochrane Database Syst Rev*. 2016;4:CD004667.
32. Vik ES, Haukeland GT, Dahl B. Women's experiences with giving birth before arrival. *Midwifery*. 2016;42:10-15.
33. Flanagan B, Lord B, Reed R, Crimmins G. Listening to women's voices: the experience of giving birth with paramedic care in Queensland, Australia. *BMC Pregnancy Childbirth*. 2019;19:490.
34. Svedberg E, Strömbäck U, Engström Å. Women's experiences of unplanned pre-hospital births: a pilot study. *Int Emerg Nurs*. 2020;51:100868.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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