

Early detection of six-week post-discharge mortality and readmission among postpartum women and newborns in Uganda: development and temporal validation of multivariable prediction models

Supplementary Material

S0. Maternal readmission conditions included in modelling	2
Table S0. Maternal outcome classification, using matrix reported by Chou et al. 2016 [2]	3
Table S1. Candidate variables used in modelling	4
Table S2. Performance metrics across 10 folds of cross-validation in the intermediate model for readmission due to obstetric infections in postpartum women.	5
Table S3. Average rank of variable importance and the number of times selected in the top eight variables across 10 folds of cross-validation for the intermediate model for readmission due to obstetric infections in postpartum women.	6
Table S4. Coefficients of the final maternal model for readmission due to obstetric infections.	7
Table S5. Performance metrics across 10 folds of cross-validation in the final maternal model for readmission due to obstetric infections in postpartum women.	8
Table S6. Performance metrics across all 100 bootstraps for the intermediate and final multinomial models for newborn readmission and mortality.	9
Table S7. Average rank of variable importance and number of times selected in the top 8 variables across 100 bootstraps from the intermediate model for newborn readmission or mortality.	10
Table S8. Coefficients of the final newborn multinomial model for readmission or mortality.	11
Figure S1. Days until post-discharge readmission and care-seeking in postpartum women.	12
Figure S2. Days until post-discharge readmission or mortality in newborns.	13
Figure S3. Performance metrics of the final maternal model for readmission due to obstetric infections in postpartum women on the full dataset.	14
Figure S4. Performance metrics of the final newborn multinomial model for the readmission outcome in newborns on the full dataset.	15
Figure S5. Performance metrics of the final newborn multinomial model for the death outcome in newborns on the full dataset.	16
Figure S6. Distribution of predictor variables selected in the final maternal model for readmission outcome.	17

S0. Maternal readmission conditions included in modelling

Data Collection: Post-discharge outcome data were collected through structured maternal self- or proxy-report, capturing symptoms and conditions at follow-up. Reported diagnoses were not mutually exclusive. Full details of study design, sampling, and data collection procedures are reported in the primary publication. Ambiguous cases or those classified as “other” were sent to at least two clinical investigators to assist with classification based on reported symptoms, conditions, duration of admission, time from discharge to admission and labour and delivery-related variables.

Outcome Classification: Maternal post-discharge admission outcomes were classified using two complementary frameworks. The conceptual basis followed Filippi *et al.* [1], which defines maternal morbidity as any health condition attributed to and/or complicating pregnancy and childbirth that has a negative impact on the woman's wellbeing or functioning, and organises conditions based on timing; the pre-reproductive cycle, pregnancy, labour and delivery, the postnatal period and post-reproductive cycle. Given that the models aimed to predict outcomes following discharge from facility delivery, we focussed on conditions in the postnatal period.

Operational grouping of direct obstetric conditions followed the maternal morbidity matrix described by Chou *et al.* [2]. Self-reported conditions were grouped into three domains: direct obstetric, indirect obstetric and infection related (**Table S0 below**). Although the classification framework encompasses all morbidity domains captured in the self-report instrument, the predictive model was restricted to obstetric infections as the outcome of interest on a clinical, epidemiological, and methodological basis.

Epidemiology: Puerperal sepsis and surgical site infection accounted for 34.8% and 28.3% of post-discharge readmissions respectively [3]. Together they represented the majority of the infection burden and were the conditions most directly attributable to the delivery episode itself, making them the most clinically relevant targets for a discharge-focused prediction model.

Clinical and etiological pathways: Although malaria, vomiting, diarrhea and other infections are important causes of morbidity in Uganda, post-discharge occurrence is driven by post-discharge exposure and vector burden rather than by clinical factors present at the time of delivery. Predictors available at discharge including delivery mode, vital signs, length of stay, intrapartum complications, are unlikely to predict acquisition of malaria and other infections. Mastitis was similarly excluded on the basis that it represents a distinct clinical pathway and temporal profile. Mastitis arises from milk stasis and bacterial colonisation during lactation. Occurrence is driven by breastfeeding practices, nipple trauma, and engorgement rather than by intrapartum or perioperative factors. While clinically significant, mastitis carries a different severity profile and care pathway from puerperal sepsis and surgical site infection, both of which are associated with systemic illness, readmission, and risk of maternal mortality. A model targeting puerperal sepsis and surgical site infection, by contrast, is anchored in mechanisms directly related to the delivery and postnatal period.

Restricting to surgical site infection and puerperal sepsis ensures the model targets conditions with the highest burden in our cohort with clear clinical pathways, shared aetiological mechanisms, and direct actionable implications for discharge planning and postnatal care.

References

1. Filippi V, Chou D, Barreix M, Say L. A new conceptual framework for maternal morbidity. *Int J Gynecol Obstet.* 2018;141: 4–9. doi:10.1002/ijgo.12463
2. Chou D, Tunçalp Ö, Firoz T, Barreix M, Filippi V, von Dadelszen P, et al. Constructing maternal morbidity – towards a standard tool to measure and monitor maternal health beyond mortality. *BMC Pregnancy Childbirth.* 2016;16: 45. doi:10.1186/s12884-015-0789-4
3. Pillay Y, Nguyen V, Komugisha C, Lavoie PM, Bebell LM, Vidler M, et al. Post-discharge mortality, readmission and care seeking among postpartum women and their newborns following facility-based delivery in Uganda: a prospective observational study. *BMJ Open.* 2026;16: e108734. doi:10.1136/bmjopen-2025-108734

Table S0. **Maternal outcome classification, using matrix reported by Chou et al. 2016 [2]**

Admission Condition	High-level category: direct or indirect maternal morbidity	Subcategory	Infection related to pregnancy or delivery	Include in modelling
Eclampsia	Direct	Hypertensive disorders of pregnancy	N	N
Diabetes	Indirect	Pre-existing diseases complicating pregnancy, childbirth and the puerperium	N	N
Fistula	Indirect	Diseases of the genitourinary system complicating pregnancy, childbirth and the puerperium	N	N
HIV related illness	Indirect	Maternal infections that complicate pregnancy childbirth and puerperium	Y	N
Malaria	Indirect	Maternal infections that complicate pregnancy childbirth and puerperium	Y	N
Retained placenta	Direct	Delivery related complications	N	N
Heavy bleeding	Direct	Obstetric hemorrhage	N	N
Anemia	Indirect	Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium	N	N
Surgical site infection	Direct	Unanticipated complications	Y	Y
Puerperal sepsis	Direct	Pregnancy related infection	Y	Y
Other infection	Indirect	Maternal infections that complicate pregnancy childbirth and puerperium	Y	N
Diarrhea	Indirect	Maternal infections that complicate pregnancy childbirth and puerperium	Y	N
Vomiting	Indirect	Maternal infections that complicate pregnancy childbirth and puerperium	Y	N
PPD/psychosis	Indirect	Mental disorders or diseases of the nervous system complicating pregnancy, childbirth and the puerperium	N	N
Needed another surgery	Direct	Unanticipated complications	N	N
Needed blood transfusion	Direct	Obstetric hemorrhage	N	N
Needed oxygen	Direct	Unanticipated complications	N	N
Dehiscence	Direct	Unanticipated complications	N	N
Constipation	Can be direct or indirect	Unanticipated complications or Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium	N	N
Dehydration	Can be direct or indirect	Unanticipated complications or Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium	N	N
Mastitis & other related concerns	Direct	Pregnancy related infection	Y	N
Musculoskeletal complaint	Indirect	Diseases of the Musculoskeletal system and connective tissue	N	N
Peptic ulcer disease	Indirect	Diseases of the digestive system complicating pregnancy, childbirth and the puerperium	Possible	N
Perineal laceration	Direct	Unanticipated complications	N	N
Pulmonary embolism	Indirect	Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium	N	N
Varicose veins	Direct	Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium	N	N

Table S1. Candidate variables used in modelling

Maternal Demographics and Social Variables		
- Maternal age - Number of people living in house, including mother and baby - Lives with father of the baby - Current Marital status	- Education level - Mother or household member had less food than needed - Had any children who have died - Socioeconomic index	- Transport time - Delayed by >1 hour coming to the hospital - Transport mode
Pregnancy and Health History		
- Referral visit - Mother at hospital for elective caesarean section - Vitals were measured - Systolic blood pressure - Diastolic blood pressure - Temperature - Heart rate	- Mother in distress upon arrival - Diagnosed with pregnancy-related illness during pregnancy ^a - Due date known - Gravidity - Parity - Pregnancy loss - Previous caesarean section	- Known or suspected placental disorder - Currently taking medication for blood pressure - Diagnosed with HIV - Admitted to hospital during pregnancy ≥4 antenatal care visits - Antenatal care provider
Maternal Delivery		
- Delivery mode, vaginal or caesarean - Caesarean section delayed or timely, if applicable - Gestation period <37, 37-40, >40 wks - Episiotomy - Degree of vaginal or perineal tearing	- Type of induced labor, if any - Units of blood required for blood transfusion, if any - Post-partum hemorrhage - Obstruction of labor - Meconium in amniotic fluid	- Number of vaginal exams <3, 3-5, >5 - Rupture of membranes more than 24 hours before delivery - Placental complications - Manual removal of placenta - Number of babies delivered
Newborn Delivery		
- Baby was born alive ^b - Stillbirth ^b - Congenital malformation of stillbirth ^b - Sex of the baby	- Weight >2.5kg - Length - Apgar at 1 minute	- Apgar at 5 minutes - Delayed cord clamping - Resuscitation at birth
Maternal Discharge		
- Admitted to higher level of care for post-delivery complications - Discharge systolic blood pressure - Discharge diastolic blood pressure - Respiratory rate	- Temporal artery temperature - Best SpO₂ - Best heart rate - Hematocrit	- Discharge destination - Support at home after discharge - Prior history of poor milk production - Antibiotics during admission
Newborn Discharge		
- Disposition of the newborn ^b - Baby discharged home with mother ^b - Newborn diagnosis if admitted ^{b, c} - Baby defecated - Baby made urine	- Latching/suckling well breastfeeding - Jaundice - Discharge in their eyes - Neonatal temporal artery temperature	- Neonatal SpO₂ - Neonatal respiratory rate - Neonatal best heart rate - Newborn discharged on antibiotics
Duration of Hospital Stay		
- Time admission – delivery - Time admission – discharge	- Time admission – labor - Time labor – discharge	- Time labor – delivery - Time delivery – discharge

^a Includes gestational diabetes, pre-eclampsia, eclampsia, gestational hypertension, antepartum hemorrhage/vaginal bleeding, PROM, preterm labour, malaria, HIV, urinary tract infection, tuberculosis, anemia, or other infections. Each individual illness was evaluated as a separate predictor, with another predictor for having at least one of these illnesses.

^b Only applicable to the maternal model

^c Includes sepsis, birth asphyxia, congenital, jaundice, and prematurity/low birth weight. Each individual diagnosis was evaluated as a separate predictor.

Table S2. Performance metrics across 10 folds of cross-validation in the intermediate model for readmission due to obstetric infections in postpartum women.

Uses the probability threshold that gave 80% sensitivity.

Fold	Specificity	Sensitivity	AUROC	PPV	NPV	PRAUC	F1 Score	Brier Score
1	0.716	0.786	0.796	0.052	0.994	0.056	0.097	0.02
2	0.843	0.769	0.84	0.083	0.995	0.067	0.149	0.017
3	0.681	0.769	0.738	0.042	0.994	0.05	0.08	0.018
4	0.717	0.769	0.767	0.047	0.994	0.061	0.089	0.018
5	0.694	0.769	0.771	0.044	0.994	0.048	0.083	0.019
6	0.729	0.769	0.827	0.05	0.994	0.066	0.093	0.019
7	0.828	0.769	0.851	0.076	0.995	0.108	0.138	0.017
8	0.541	0.769	0.745	0.03	0.992	0.072	0.057	0.017
9	0.653	0.786	0.77	0.043	0.994	0.077	0.081	0.019
10	0.656	0.769	0.754	0.039	0.994	0.148	0.075	0.017
Average	0.706	0.773	0.786	0.051	0.994	0.075	0.094	0.018

AUROC = area under the receiver operating characteristic curve; PPV = positive predictive value; NPV = negative predictive value; PRAUC = area under the precision-recall curve

Table S3. Average rank of variable importance and the number of times selected in the top eight variables across 10 folds of cross-validation for the intermediate model for readmission due to obstetric infections in postpartum women.

Only the top 20 variables are reported. Eight variables were included in the final model and selected based on frequency of selection in the top eight across the folds, and prioritization of clinical variables over socio-economic variables (e.g., marital status).

Variable	Average Rank	Folds Selected in Top Eight	Included in Final Model
Delivery Mode: Caesarian, Vaginal	1	10	✓
Best Maternal Heart Rate	3.3	9	✓
Socioeconomic Index	5	9	
Current Marital Status	14.7	8	
UTI Diagnosis During Pregnancy	20.4	7	✓
Resuscitation of Newborn at Birth	19.4	6	✓
Discharged Against Medical Advice	18.6	4	✓
Known or Suspected Placental Disorder	13	4	
Malaria Diagnosis During Pregnancy	46.4	4	✓
HIV Diagnosis Before Pregnancy	31.2	3	✓
Gestation Period: <37, 37-40, >40 weeks	16.7	2	✓
Referral Visit	28.8	2	
Stillbirth	29.8	2	
Hepatitis B/C Diagnosis During Pregnancy	30	2	
Apgar Score After 1 Minute	44.5	2	
Sepsis Diagnosis in Newborn	66.7	1	
Maternal Age, years	54.2	1	
Disposition of the Newborn	27.5	1	
Manual Removal of the Placenta	88.6	1	
Kidney Disease Diagnosis Before Pregnancy	31.6	1	

Abbreviations: HIV = human immunodeficiency virus; UTI = urinary tract infection

Table S4. Coefficients of the final maternal model for readmission due to obstetric infections.

Variable	Coefficient
Intercept	-4.329
Delivery Mode: Caesarean	0.192
Best Maternal Heart Rate	0.142
UTI Diagnosis During Pregnancy	0.069
Discharge Against Medical Advice	0.002
Malaria Diagnosis During Pregnancy	0.027
HIV Diagnosis Before Pregnancy	-0.098
Gestation Period: 37 - 40 weeks	-0.036
Caesarean Delivery × Best Maternal Heart Rate	0.278
Caesarean Delivery × UTI Diagnosis During Pregnancy	0.084
Caesarean Delivery × Resuscitation of Newborn at Birth	0.164
Caesarean Delivery × Discharge Against Medical Advice	0.041
Caesarean Delivery × Malaria	0.138
Caesarean Delivery × HIV+	-0.066
Caesarean Delivery × Gestation Period: <37 weeks	0.016
Caesarean Delivery × Gestation Period: >40 weeks	0.11

Abbreviations: HIV = human immunodeficiency virus; UTI = urinary tract infection

Table S5. Performance metrics across 10 folds of cross-validation in the final maternal model for readmission due to obstetric infections in postpartum women.

Uses the probability threshold that gave 80% sensitivity.

Fold	Specificity	Sensitivity	AUROC	PPV	NPV	PRAUC	F1 Score	Brier Score
1	0.648	0.786	0.759	0.042	0.994	0.053	0.08	0.019
2	0.672	0.769	0.811	0.041	0.994	0.094	0.078	0.017
3	0.794	0.769	0.775	0.064	0.995	0.06	0.118	0.017
4	0.717	0.769	0.793	0.047	0.994	0.054	0.089	0.017
5	0.586	0.769	0.738	0.033	0.993	0.054	0.063	0.017
6	0.759	0.769	0.822	0.055	0.994	0.071	0.103	0.017
7	0.808	0.769	0.824	0.068	0.995	0.08	0.126	0.017
8	0.631	0.769	0.759	0.037	0.993	0.086	0.07	0.017
9	0.612	0.786	0.767	0.038	0.993	0.17	0.073	0.018
10	0.74	0.769	0.794	0.052	0.994	0.263	0.097	0.017
Average	0.697	0.773	0.784	0.048	0.994	0.099	0.09	0.017

Abbreviations: AUROC = area under the receiver operating characteristic curve; PPV = positive predictive value; NPV = negative predictive value; PRAUC = area under the precision-recall curve

Table S6. Performance metrics across all 100 bootstraps for the intermediate and final multinomial models for newborn readmission and mortality.

Bootstrapped performance metric, mean (2.5th, 97.5th percentiles)	Intermediate		Final	
	Readmission	Mortality	Readmission	Mortality
Specificity	0.484 (0.380, 0.570)	0.489 (0.202, 0.763)	0.532 (0.438, 0.600)	0.539 (0.207, 0.832)
Sensitivity	0.800 (0.795, 0.805)	0.796 (0.769, 0.833)	0.800 (0.786, 0.812)	0.806 (0.769, 0.846)
Area under the receiver operating characteristic curve (AUROC)	0.689 (0.654, 0.723)	0.693 (0.587, 0.786)	0.712 (0.672, 0.747)	0.731 (0.600, 0.854)
Positive predictive value (PPV)	0.058 (0.047, 0.070)	0.009 (0.005, 0.017)	0.063 (0.052, 0.075)	0.011 (0.005, 0.025)
Negative predictive value (NPV)	0.984 (0.980, 0.987)	0.997 (0.994, 0.999)	0.985 (0.982, 0.988)	0.998 (0.995, 0.999)
Area under the precision-recall curve (PRAUC)	0.076 (0.061, 0.096)	0.022 (0.007, 0.072)	0.080 (0.065, 0.109)	0.029 (0.010, 0.071)
F1 score	0.108 (0.088, 0.129)	0.019 (0.011, 0.033)	0.118 (0.097, 0.138)	0.022 (0.010, 0.048)
Brier score	0.037 (0.032, 0.041)	0.006 (0.004, 0.008)	0.036 (0.031, 0.039)	0.006 (0.004, 0.007)

Table S7. Average rank of variable importance and number of times selected in the top 8 variables across 100 bootstraps from the intermediate model for newborn readmission or mortality.

Only the top 10 variables are reported for each outcome. The top four variables for newborn readmission and mortality (excluding delivery mode) were selected based on frequency of selection in the top eight across the bootstraps, and prioritization of clinical variables over socio-economic variables (e.g., maternal education). Delivery mode was included as the ninth variable as it was joint most important for both outcomes.

Readmission			
Variable	Average Rank	Bootstraps Selected in Top 8	Included in Final Model
Delivery Mode: Caesarian, Vaginal	1.0	99	✓
Mother Given Antibiotics During Admission	24.3	67	✓
Number of Vaginal Exams: <3, 3-5, >5	11.3	66	✓
Time to Hospital: <30 mins, 30 mins to 1 hr, > 1 hr	12.4	51	✓
Any Condition Diagnosed During Pregnancy	28.9	47	✓
Resuscitation at Birth	22.1	46	
Referral Visit	22.3	40	
Prior Maternal Admission During Pregnancy	21.6	37	
Maternal Temperature	18.4	36	
Mean Neonatal Heart Rate ^a	32.7	31	
Mortality			
Variable	Average Rank	Bootstraps Selected in Top 8	Included in Final Model
Delivery Mode: Caesarian, Vaginal	6.4	92	✓
Weight of Newborn: ≤2.5 kg, >2.5 kg	8.2	85	✓
HIV Diagnosis During Pregnancy	25.4	46	✓
Maternal Education Level	32.0	41	
Prior History of Poor Milk Production: Yes, No, N/A	37.5	40	✓
Transport Mode	35.7	33	
Antepartum Hemorrhage During Pregnancy	39.2	33	✓
Prior Maternal Admission During Pregnancy	34.4	30	
Number of Vaginal Exams: <3, 3-5, >5	51.1	29	
Obstruction of Labor	50.1	21	

^a Mean of right hand and foot

Table S8. **Coefficients of the final newborn multinomial model for readmission or mortality.**

Variable	Coefficient	
	Readmission	Mortality
Intercept	-0.57	-2.344
Delivery Mode: Caesarean	-0.092	0
Antibiotics During Admission	0.25	-0.113
Vaginal Exams: 3-5	-0.01	-0.001
Vaginal Exams: >5	0.027	0
Any Condition Diagnosed During Pregnancy	-0.287	0.137
Time to Hospital: 30 minutes - 1 hour	0	-0.003
Time to Hospital: >1 hour	-0.13	0.002
Weight of Newborn: >2.5kg	0.023	-0.248
HIV Diagnosis During Pregnancy	-0.009	0.162
No Prior History of Poor Milk Production	0.017	-0.037
Prior History of Poor Milk Production Not Applicable (first baby)	0	0.046
Antepartum Hemorrhage	-0.04	0
Caesarean Delivery × Antibiotics During Admission	0.041	0
Caesarean Delivery × Vaginal Exams: >5	-0.044	0
Caesarean Delivery × Any Condition Diagnosed During Pregnancy	-0.002	0.035
Caesarean Delivery × Time to Hospital: 30 minutes - 1 hr	0	0
Caesarean Delivery × Weight of Newborn: >2.5kg	-0.021	0
Caesarean Delivery × HIV Diagnosis During Pregnancy	0	0
Caesarean Delivery × No Prior History of Poor Milk Production	-0.078	0
Caesarean Delivery × Antepartum Hemorrhage	0	0.068

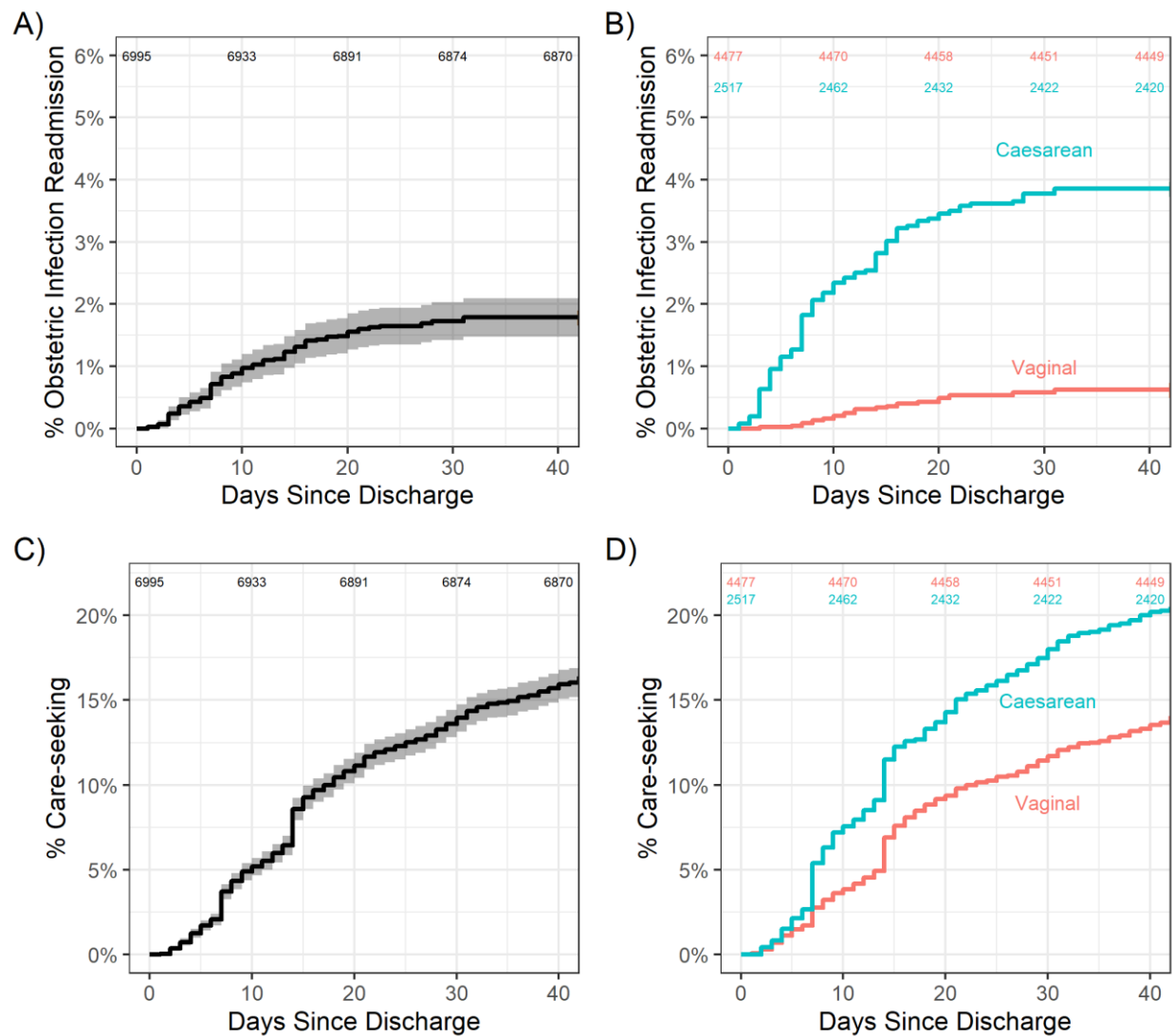


Figure S1. Days until post-discharge readmission and care-seeking in postpartum women. A) readmission due to obstetric infection overall; B) readmission stratified by delivery mode; C) post-natal care-seeking overall; D) care-seeking stratified by delivery mode. Numbers at risk are reported at the top of each plot.

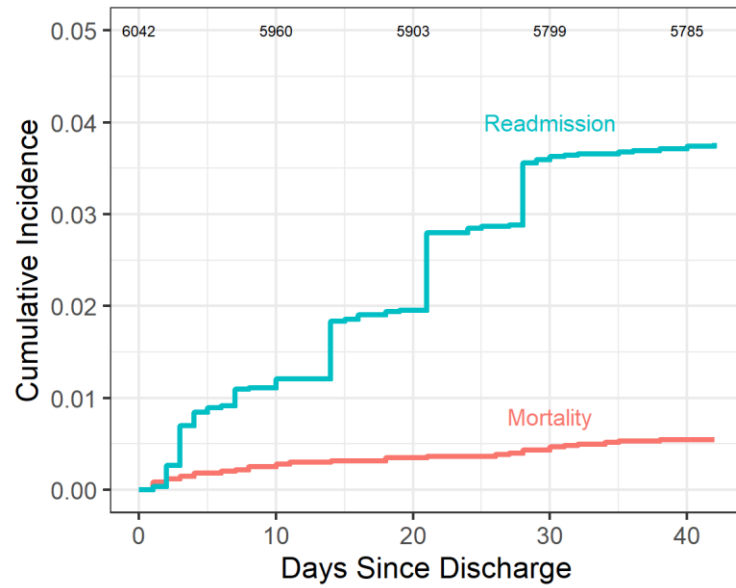


Figure S2. Days until post-discharge readmission or mortality in newborns.
Survival curves were created using a competing risks model for readmission vs. mortality.
Numbers at risk are reported at the top of the figure.

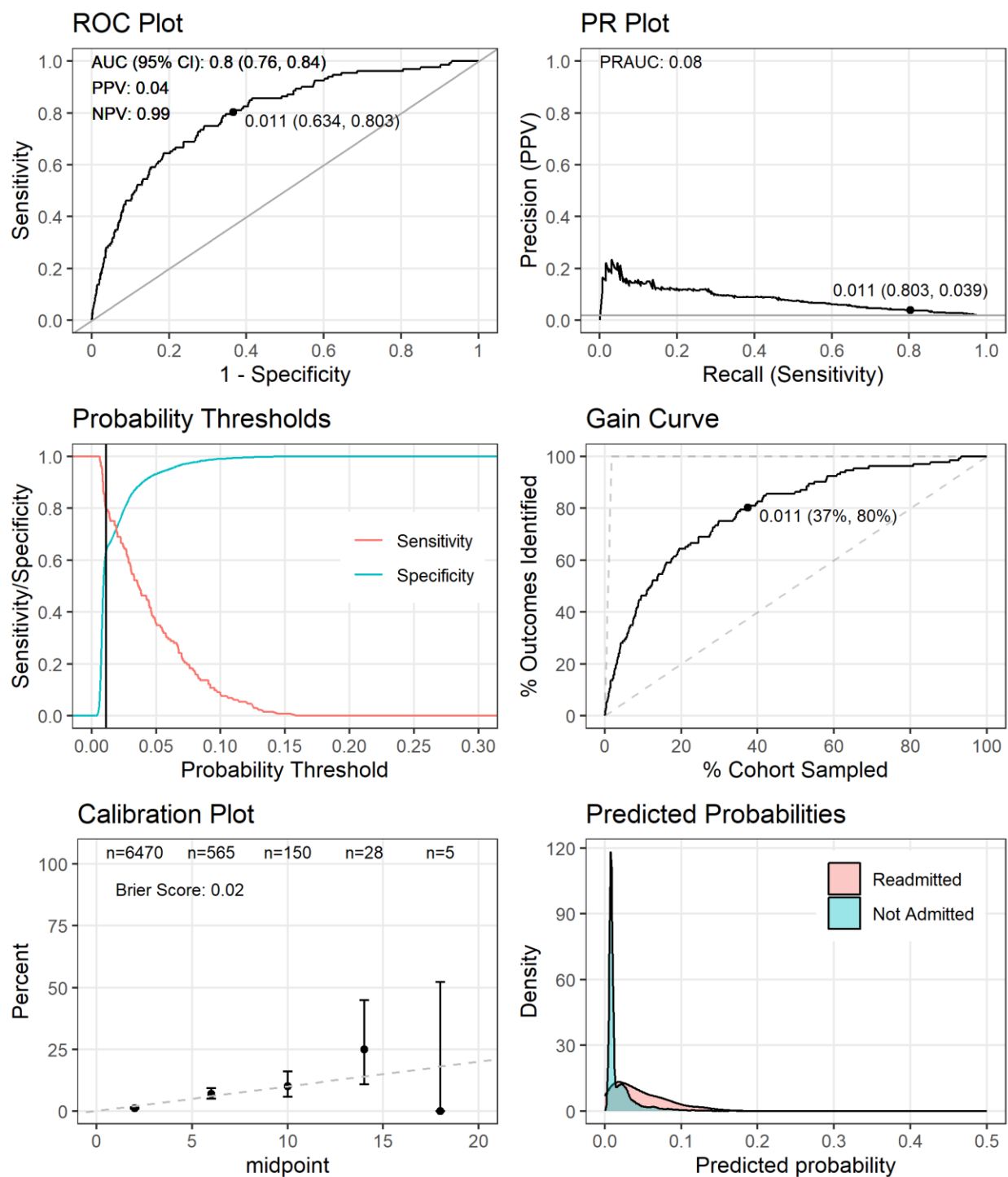


Figure S3. **Performance metrics of the final maternal model for readmission due to obstetric infections in postpartum women on the full dataset.**

The points on the receiver operating characteristic (ROC), precision-recall (PR), and gain curve plots indicate co-ordinates for the probability threshold at sensitivity = 80%. Positive predictive values (PPV) and negative predictive value (NPV) are reported at this threshold.

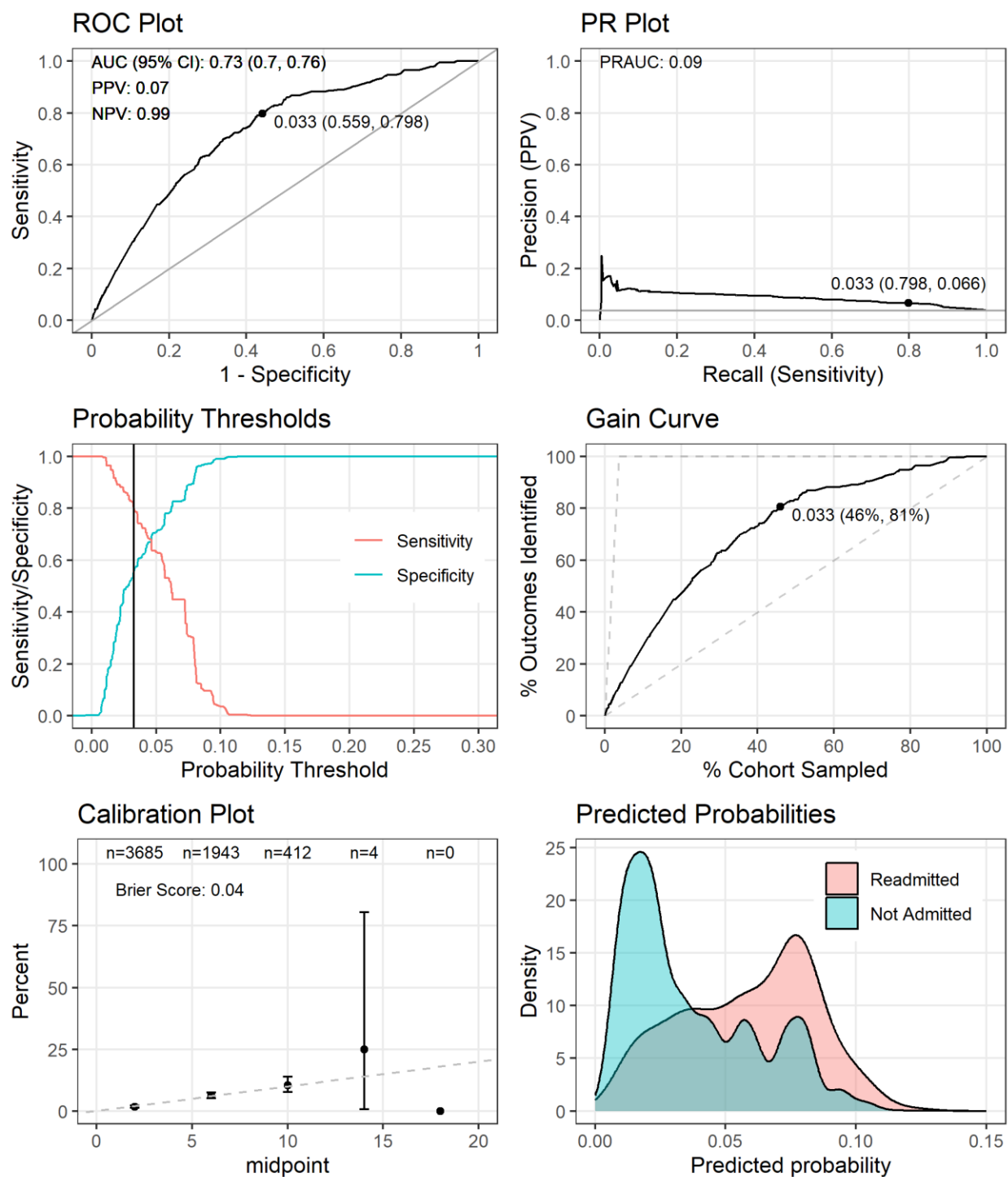


Figure S4. **Performance metrics of the final newborn multinomial model for the readmission outcome in newborns on the full dataset.**

The points on the receiver operating characteristic (ROC), precision-recall (PR), and gain curve plots indicate co-ordinates for the probability threshold at sensitivity = 80%. Positive predictive values (PPV) and negative predictive value (NPV) are reported at this threshold.

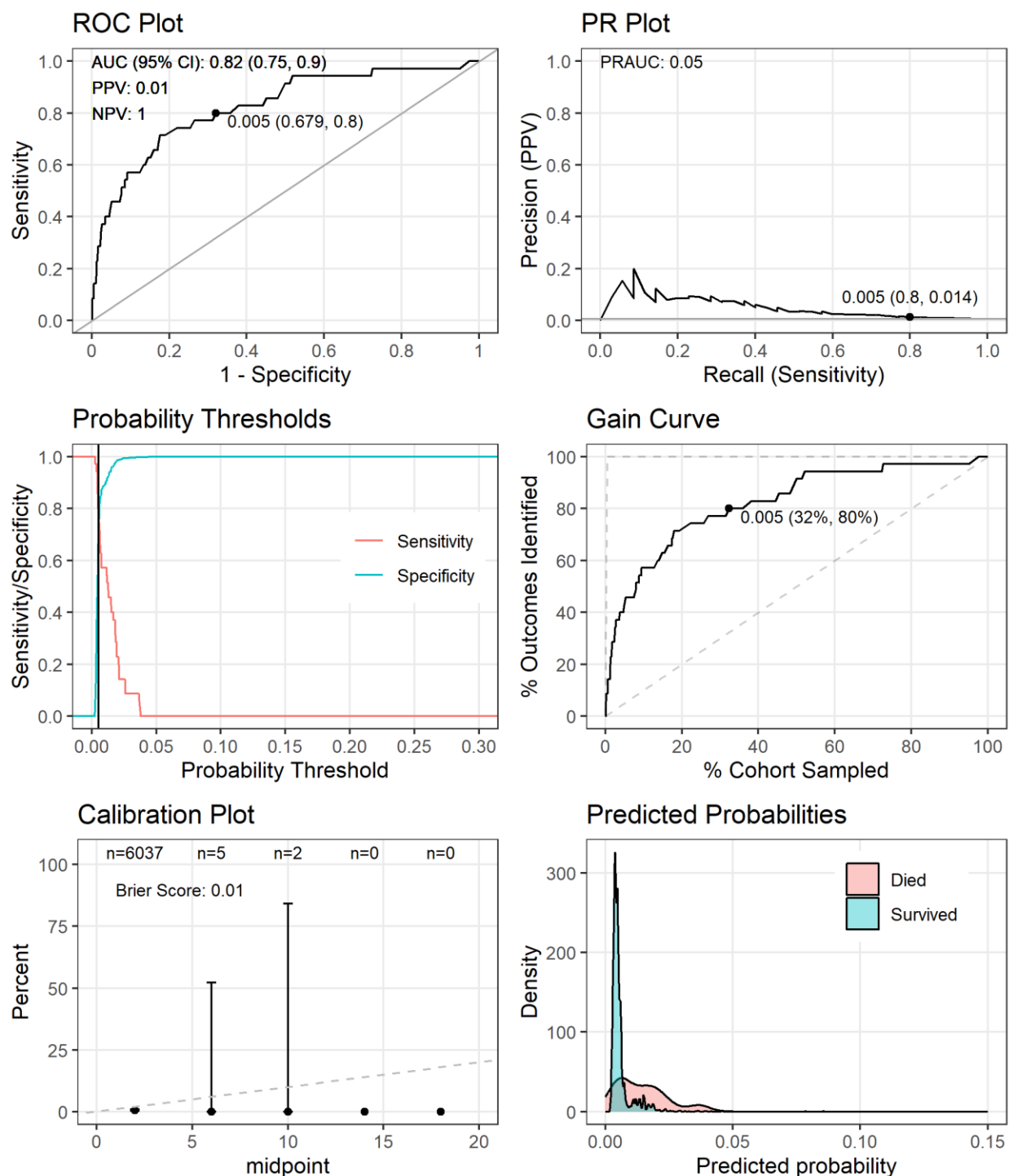


Figure S5. **Performance metrics of the final newborn multinomial model for the death outcome in newborns on the full dataset.**

The points on the receiver operating characteristic (ROC), precision-recall (PR), and gain curve plots indicate co-ordinates for the probability threshold at sensitivity = 80%. Positive predictive values (PPV) and negative predictive value (NPV) are reported at this threshold.

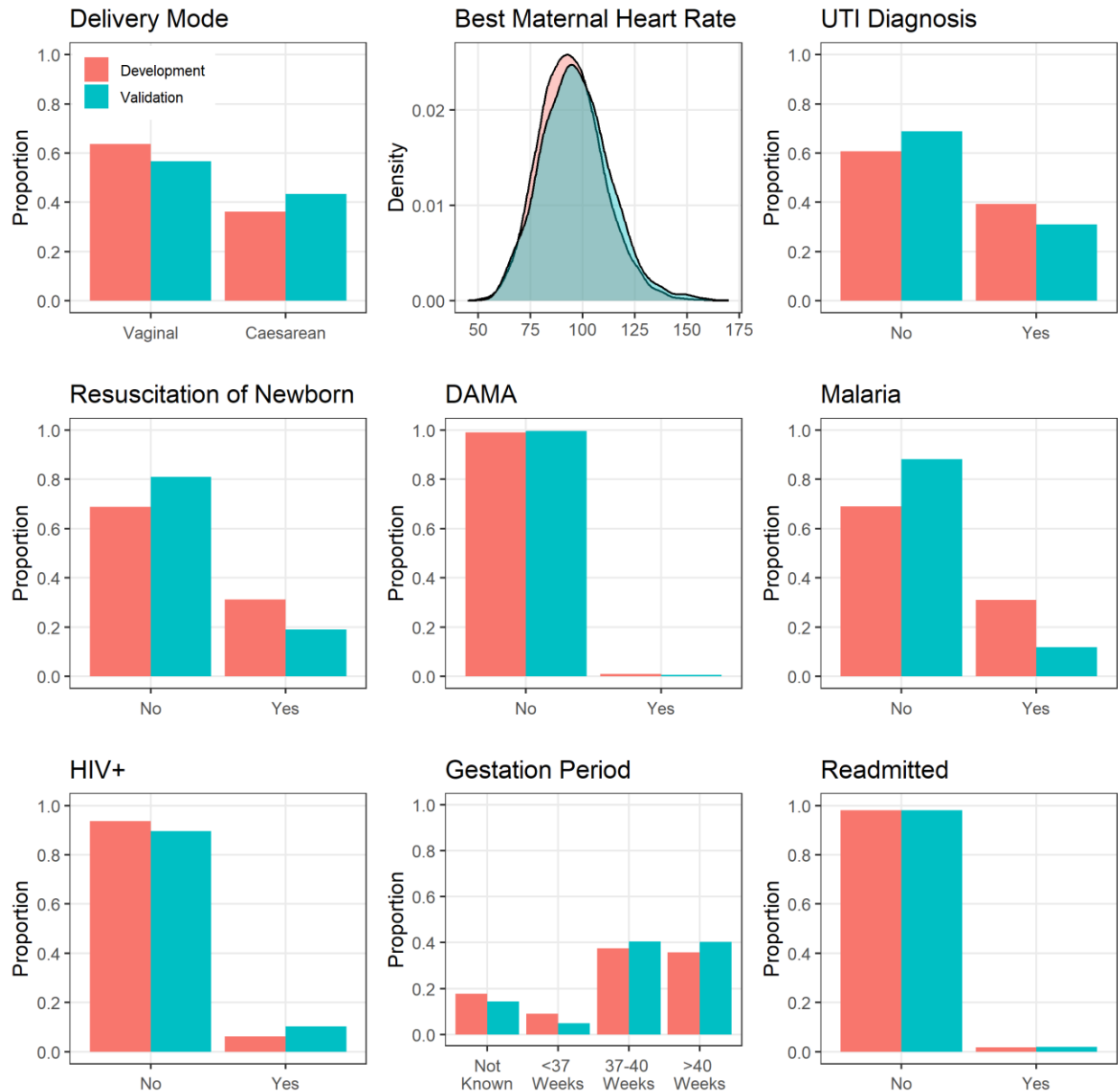


Figure S6. **Distribution of predictor variables selected in the final maternal model for readmission outcome.**

Comparison between the development dataset (red) and the temporal validation dataset (green). Abbreviations: DAMA = discharged against medical advice; HIV = human immunodeficiency virus; UTI = urinary tract infection