Risk calculator for advanced neonatal resuscitation

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ABSTRACT
In order to predict which newborns will require advanced resuscitation (ANR), we developed an ANR risk calculator (calculator) using a bootstrap sample size of 52,973 from a case-control study of newborns ≥34 weeks gestation. Multivariable logistic regression coefficients were obtained for the 10 original risk factors and two interaction terms. The area under the receiving operating characteristic curve predicting ANR was 0.9243. ANR prediction is improved by accounting for perinatal variables, beyond factors known prenatally. Prospective validation of this model is warranted in a clinical setting.

INTRODUCTION
Very few newborns will require advanced neonatal resuscitation (ANR) procedures, such as tracheal intubation or emergency vascular access, at birth.1,2 If ANR procedures are required, they must be initiated without delay.3 Currently, there is little information allowing providers to estimate the risk of requiring ANR.4 Isolated risk factors do not accurately predict the risk of ANR.5

Based on Berazategui’s original data set, we sought to construct a prediction model that could be incorporated into a user-friendly tool to help providers to better estimate this risk of ANR.5

METHODS
Using data from Berazategui,5 we implemented bootstrap resampling to generate an empirical data distribution reflective of the population prevalence of ANR. We focused on infants born ≥34 weeks gestational age. All cases were kept in the new distribution, while control subjects were resampled with replacement until the distribution reached a prevalence of 0.37%. Ten risk factors and two interaction terms were analyzed. Multivariable logistic regression coefficients were obtained for the 10 original risk factors and two interaction terms on the bootstrap data. Leave-one-out cross-validation confirmed that the model coefficient estimates were stable across the resampled values (SD of log odds estimates of the leave-one-out models were all less than 0.18). Figure 1 displays the receiving-operating characteristic curve showing the sensitivity and specificity at various cut-off points for the computed probability.

PATIENT AND PUBLIC INVOLVEMENT
Neither patients nor public were involved in this study’s development.

DISCUSSION
We created a risk calculator that may be useful for resource allocation in the delivery room. Although individual risk factors are not useful for identifying newborns at risk of ANR, combining a small number of variables provides a more precise prediction.

While the original case-control study could not estimate an individual newborn’s risk, our model used a resampling method to construct a large bootstrap sample that was reflective of the original population. Although the bootstrap sample may exacerbate bias from the original controls due to extensive resampling, this bias will primarily affect the model’s specificity. Bias is
unlikely to affect the model’s sensitivity. As a screening tool, sensitivity is most relevant to users who must determine when to call a team with ANR skills to the delivery room.

This study confirmed the previously validated logistic regression model, but the risk calculation needs to be validated clinically. We developed a prototype mobile app that allows users to choose the local ANR prevalence and calculate a newborn’s ANR risk by clicking each variable and selecting the appropriate option. (View the calculator by clicking here: calculator.) Once validated in a clinical setting, the app may help providers to determine their local threshold for allocating skilled personnel to the delivery room.

In conclusion, we demonstrated feasibility of developing an ANR risk calculator that may allow more rational allocation of delivery room personnel. A clinical validation study is planned.

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### Table 1  Descriptive statistics of the original and bootstrap data sets

| Variable(s)* | Original sample | Bootstrap sample |
|--------------|-----------------|------------------|
|              | N | ANR no, n=784† | ANR yes, n=196† | P value‡ | N | ANR no, n=52777† | ANR yes, n=196† | P value‡ |
| Gestational age 34–37 weeks | 980 | 130 (17%) | 63 (32%) | <0.001 | 52973 | 8790 (17%) | 63 (32%) | <0.001 |
| Growth restriction | 980 | 12 (1.5%) | 11 (5.6%) | 0.002 | 52973 | 788 (1.5%) | 11 (5.6%) | <0.001 |
| Gestational diabetes | 975 | 13 (1.7%) | 4 (2.1%) | 0.8 | 52769 | 849 (1.6%) | 4 (2.1%) | 0.6 |
| Meconium stained amniotic fluid | 980 | 38 (4.8%) | 72 (37%) | <0.001 | 52973 | 2598 (4.9%) | 72 (37%) | <0.001 |
| Forceps or vacuum delivery | 980 | 10 (1.3%) | 13 (6.6%) | <0.001 | 52973 | 673 (1.3%) | 13 (6.6%) | <0.001 |
| Chorioamnionitis | 980 | 4 (0.5%) | 6 (3.1%) | 0.006 | 52973 | 301 (0.6%) | 6 (3.1%) | 0.001 |
| Fetal bradycardia | 980 | 14 (1.8%) | 54 (28%) | <0.001 | 52973 | 1004 (1.9%) | 54 (28%) | <0.001 |
| Placental abruption | 980 | 5 (0.6%) | 24 (12%) | <0.001 | 52973 | 323 (0.6%) | 24 (12%) | <0.001 |
| General anaesthesia | 980 | 6 (0.8%) | 23 (12%) | <0.001 | 52973 | 465 (0.9%) | 23 (12%) | <0.001 |
| Emergency caesarean section | 980 | 26 (3.3%) | 64 (33%) | <0.001 | 52973 | 1816 (3.4%) | 64 (33%) | <0.001 |
| Fetal bradycardia*Emergency c-section | 980 | 7 (0.9%) | 31 (16%) | <0.001 | 52973 | 524 (1.0%) | 31 (16%) | <0.001 |
| Abruption*Emergency c-section | 980 | 2 (0.3%) | 22 (11%) | <0.001 | 52973 | 131 (0.2%) | 22 (11%) | <0.001 |

Ten covariates from the original cohort including three antepartum and seven intrapartum factors, along with last two interaction terms which were not included in the original cohort.

†n (%).

‡Pearson’s χ² test; Fisher’s exact test.

ANR, advanced neonatal resuscitation.

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Figure 1  ROC curve of infants needing ANR from the multivariable logistic regression model based on the bootstrapped data set. Illustrated in the figure is a threshold value of 0.002 for the computed risk of ANR using the model that yields a sensitivity of 0.856 and a specificity of 0.751. ANR, advanced neonatal resuscitation; ROC, receiving-operating characteristic.
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