Updated PRAiS logistic regression risk model: August 2024

We have recalibrated the PRAiS v2 [1] logistic regression model and updated the inclusion criteria and one risk factor. This is the PRAiS v4 risk model and is implemented PRAiS v4 of the Excel software.

NOTE: there is no PRAiS3 risk model – we chose to call both the risk model and the Excel software by the same version number to avoid confusion.

PRAiS v4 risk model

Probability of death within 30 days following paediatric cardiac surgery $= \frac{1}{1+e^{-Z}}$ where

$$Z = -1.140 - 0.332 * \sqrt{age} + 0.271 * age - 1.564 * \sqrt{weight} + 0.093 * weight + \sum_{i=1}^{34} B_i X_i.$$

Parameters *i* =1 to 34 are tabulated below along with their corresponding regression coefficients, B_i, and the condition that must be satisfied for $X_i = 1$ ($X_i = 0$ otherwise). Note that patient age must be in units of years and patient weight in units of kilograms. The model was developed using records for patients **under 18 years old**.

All allocations of EPCC codes and NCHDA specific procedure categories to these broader risk factor groupings are given in "**Important Mappings Used For PRAiS v4.xlsx**".

i	$X_i = 1$ if condition satisfied ($X_i = 0$ otherwise)	B_i
1	Diagnosis grouping 1	0.000
2	Diagnosis grouping 2	-0.237
3	Diagnosis grouping 3	-0.157
4	Diagnosis grouping 4	-1.090
5	Diagnosis grouping 5	-0.290
6	Diagnosis grouping 6	0.401
7	Diagnosis grouping 7	-0.271
8	Diagnosis grouping 8	-0.596
9	Diagnosis grouping 9	-1.742
10	Diagnosis grouping 10	-2.116
11	Diagnosis grouping 11	-1.121
12	Specific procedure grouping 1	0.000
13	Specific procedure grouping 2	0.594
14	Specific procedure grouping 3	0.462
15	Specific procedure grouping 4	-0.101
16	Specific procedure grouping 5	-0.685
17	Specific procedure grouping 6	-0.764
18	Specific procedure grouping 7	0.135
19	Specific procedure grouping 8	0.064
20	Specific procedure grouping 9	-0.627
21	Specific procedure grouping 10	-0.403
22	Specific procedure grouping 11	-0.282
23	Specific procedure grouping 12	-0.661
24	Specific procedure grouping 13	-1.491
25	Specific procedure grouping 14	-0.769
26	Specific procedure grouping 15	-1.016
27	Specific procedure grouping 20 (no specific procedure)	0.290
28	Bypass procedure	-0.064
29	Definite indication of univentricular heart	0.849
30	Additional Cardiac Risk factor	0.812
31	Acquired Comorbidity	0.312
32	Congenital Comorbidity	0.260
33	Severity of Illness Indicator	1.014
34	Prematurity indicator	0.386

We note that caution is needed when interpreting individual coefficients as these are not clinically meaningful when taken in isolation of the other risk factors. The predicted risk comes from the *combination* of procedure, age, weight, severity of diagnosis and additional risk factor information.

Original PRAiS risk model development

The original PRAiS risk model was developed on a subset of the National Congenital Heart Disease Audit (NCHDA) data from 2000-2010 and then tested on a pristine validation set. It was developed using the 2010 NCHDA specific procedure algorithm. The original risk model was published in Crowe et al [2].

Version 1.0 of the PRAiS software [3] used an updated version of the PRAiS risk model developed by recalibrating the model parameters on the full 2007-2010 NCHDA data set and using the 2012 NCHDA specific procedure algorithm.

In response to a step change in the completeness of reporting of comorbidity and diagnosis and an apparent improvement in outcomes, and at the request of the NICOR congenital steering group, we recalibrated the PRAiS risk model again in June 2013 (version 2.0) and April 2014 (version 2.2) both on the 2009-2012 national dataset. [(NOTE: there is no version 2.1 of the PRAiS model calibration, but there is a version 2.1 of the software used to implement PRAiS.)].

Development of PRAiS v2 implemented in PRAiS v3.0 of the software

With the continued improvement in short term survival outcomes and more complete reporting of diagnoses and additional risk factors, we revisited the risk factors within the PRAiS model. This was a 15 month long project from April 2015 to June 2016 where, together with an expert panel of clinicians and data managers, we added more detailed information about additional risk factors (congenital comorbidity; acquired comorbidity; severity of illness and additional cardiac risk factors), more detailed information about diagnosis (11 diagnostic groups instead of 3 previously), less information about specific procedure (we now have 16 procedure groupings) and moved to a non-linear treatment of age and weight to better capture the higher risk for small babies.

The risk factors were developed and different options extensively tested using cross-validation techniques in the 2009-2014 NCHDA dataset. Once a final set of risk factors was chosen from this process, we successfully tested the final model in a new validation set of 2014-15 NCHDA data. The coefficients of the PRAiS2 model in this document and implemented in the PRAiS v3.0 software come from the final model calibrated over the whole 2009-15 dataset [1].

Development of PRAiS v4 implemented in PRAiS v4.0 of the software

In 2024, we recalibrated PRAiS using NCHDA data from 2015-2022 and updated the software with some changes to keep up to date with NCHDA current practice – this is PRAiS v4.0 and the PRAiS software v4.0. NOTE: there is no PRAiS model v3, but we have gone directly to PRAiS v4.0 to be in sync with the version number of the software.

<u>Changes to risk factors:</u>

Age: We now include all children under 18 years of age (instead of under 16)

We have added a new additional risk factor (Prematurity).

We have implemented the latest NCHDA Specific Procedure algorithm as of July 2024 (v8.5). Note, that following discussions with NICOR, there are slight some changes to allocations in terms of not using the “allowed only with” codes and using separate groupings for HLHS Hybrid and Tracheal procedures.

Procedure types “11 – EP surgery” and “7. Hybrid” are now included within PRAiS, and are assigned a transformed procedure type of “Non-bypass” for the model.

We have updated the allowed procedure, diagnosis and comorbidity codes in line with latest NCHDA code lists (as of July 2024) and their allocation to one of more of: broad procedure groups, broad diagnosis groups and additional risk factors.

Performance of the PRAiS v4 risk model

Using cross validation (25 times 5-fold), the model showed excellent performance in out-of-sample subsets. The median (range) Area Under the ROC curve was 0.85 (0.80,0.89)[ideal 1] , the median (range) slope was 0.93 (0.71,1.30) [ideal 1], the median (range) intercept was -0.22 (-1.09, 1.02) [ideal 0].

When PRAiS v2 was applied to data from 2015-2022 it overestimated deaths significantly, highlighting the need for this recalibration.

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Team

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References

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