Title	Development and validation of a novel computer-aided score to predict the risk of in-hospital mortality for acutely ill medical admissions in two acute hospitals using their first electronically recorded blood test results and vital signs: a cross-sectional study
Authors	Faisal, Muhammad;Scally, Andrew;Jackson, Natalie;Richardson, Donald;Beatson, Kevin;Howes, Robin;Speed, Kevin;Menon, Madhav;Daws, Jeremey;Dyson, Judith;Marsh, Claire;Mohammed, Mohammed A.
Publication date	2018-12-06
Original Citation	Faisal, M., Scally, A.J., Jackson, N., Richardson, D., Beatson, K., Howes, R., Speed, K., Menon, M., Daws, J., Dyson, J. and Marsh, C., 2018. Development and validation of a novel computer-aided score to predict the risk of in-hospital mortality for acutely ill medical admissions in two acute hospitals using their first electronically recorded blood test results and vital signs: a cross-sectional study. BMJ open, 8(12): e022939, (8pp.) DOI: 10.1136/bmjopen-2018-022939
Type of publication	Article (peer-reviewed)
Link to publisher's version	https://bmjopen.bmj.com/content/8/12/e022939 - 10.1136/bmjopen-2018-022939
Rights	© Author(s) (or their employer(s)) 2018. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ. This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/. - http://creativecommons.org/licenses/by-nc/4.0/
Download date	2025-07-04 14:02:47

Supplementary Material

The NEWS [https://www.rcplondon.ac.uk/projects/outputs/national-early-warning-score-news] is based on a scoring system in which a score is allocated to vital signs physiological measurements already undertaken when patients present to, or are being monitored in hospital. Six physiological parameters form the basis of the scoring system:

Physiological Parameters	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51-90	91 - 110	111 - 130	≥131
Level of Consciousness				Alert			Voice, Pain, or Unconscious

A score is allocated to each as they are measured, the magnitude of the score reflecting how extreme the parameter varies from the norm. This score is then aggregated, and uplifted for people requiring oxygen.

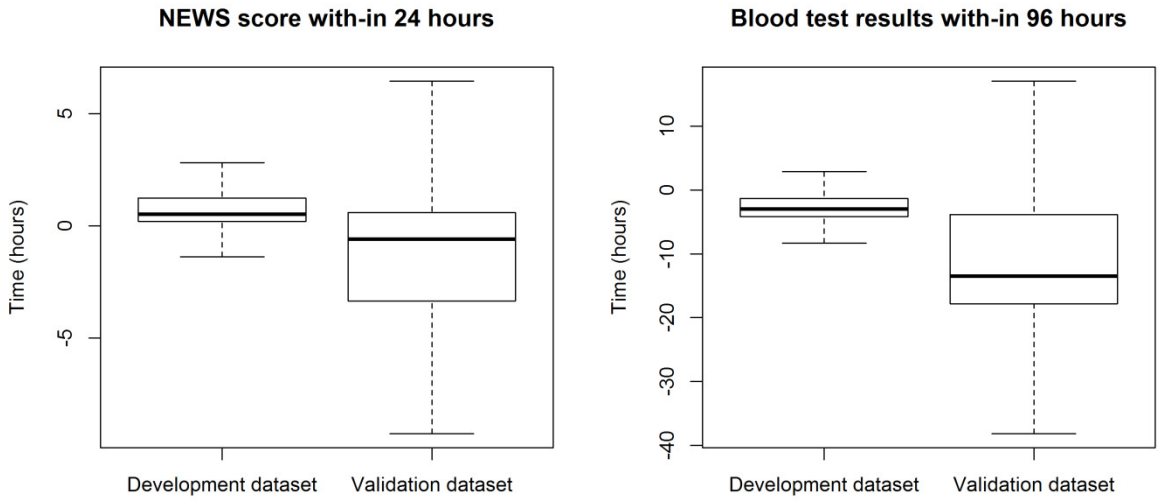

Figure S1 Distribution of time to first NEWS score and Blood test results for development and validation datasets.

Blood tests results recorded	Development dataset N(%)	Validation dataset N(%)
within 24 hours	29255 (94.4)	24341 (92.7)
within 48 hours	894 (2.9)	1098 (4.2)
within 72 hours	512 (1.6)	495 (1.9)
within 96 hours	335 (1.1)	313 (1.2)

Table S1 Distribution of time to the first set of Blood test results recorded within 4 days for development and validation datasets.

Characteristic	Development dataset	Validation dataset
N	6104	10504
Male (%)	3008 (49.3)	4875 (46.4)
Mean Age (SD)	61.4 (20.2)	64.7 (21.4)
Median Length of Stay (days) (IQR)	1.1 (4.0)	1.4 (4.4)
In-hospital mortality (%)	405 (6.6)	434 (4.1)

Table S2 Characteristics of emergency admissions with incomplete data in development and validation datasets.

		Example 1 (Discharged alive)			Example 2 (Discharged dead)		
Variable Name	Coefficient	Values	Transformed	Log(Odds)	Values	Transformed	Log(Odds)
Intercept	-3.22	1	1	-3.22	1	1	-3.22
Male	0.14	1	1	0.14	0	0	0
Age	0.077	51	51	3.927	44	44	3.388
Albumin	-0.104	36	36	-3.744	11	11	-1.144
1/sqrt(Creatinine)	9.883	86	0.107832773	1.065711	153	0.080845	0.798993
Haemoglobin	0.002	148	148	0.296	48	48	0.096
Log(Potassium)	-0.024	3.4	1.223775354	-0.02937	6.9	1.931521	-0.04636
Sodium	-0.023	111	111	-2.553	130	130	-2.99
Log(White Blood Count)	1.167	12	2.484906493	2.899886	34.7	3.546739	4.139045
Log(Urea)	1.211	7.8	2.054123604	2.487544	28.6	3.353407	4.060975
AKI (reference 0)	0	0	0	0	0	0	0
AKI stage 1	0.131	0	0	0	0	0	0
AKI stage 2	0.443	0	0	0	1	1	0.443
AKI stage 3	-0.388	0	0	0	0	0	0
NEWS	0.093	2	2	0.186	9	9	0.837
Log(Respiratory)	0.569	16	2.772588547	1.577603	22	3.091042	1.758803
Temperature	-0.145	36	36	-5.22	36.5	36.5	-5.2925
Log(Systolic)	-0.919	133	4.89034882	-4.49423	112	4.718499	-4.3363
Log(Diastolic)	0.777	79	4.369447577	3.395061	74	4.304065	3.344258
Log(Pulse)	0.511	63	4.143134465	2.117142	149	5.003946	2.557016
Oxygen Saturation	-0.016	94	94	-1.504	95	95	-1.52
Oxygen supplementation	0.606	0	0	0	0	0	0
Alert	0	0	0	0	0	0	0
Pain	0.716	0	0	0	0	0	0
Voice	0.395	0	0	0	0	0	0
Unconscious	1.925	0	0	0	1	1	1.925
Age * Log(White Cell Count)	-0.015	-	126.7302311	-1.90095	-	156.0565	-2.34085
1/sqrt(Creatinine)* Log(White Cell Count)	1.481	-	0.267954358	0.39684	-	0.286737	0.424657
AKI stage 3 * 1/sqrt(Creatinine)	15.551	-	0	0	-	0	0
Sum of Log(Odds)		-	-	**-4.17677**	-	-	**2.882744**
Probability of dying		-	-	**0.015116**	-	-	**0.946987**

Table S3 Coefficient of CARM model to predict in-hospital mortality with two examples (one discharged alive and one discharged died).

We accounted a baseline difference in risk of death in the external validation data by adding 0.52 to the CARM logit model using an iterative procedure described elsewhere[1].

1 Faisal M, Howes R, Steyerberg EW, *et al.* Using routine blood test results to predict the risk of death for emergency medical admissions to hospital: an external model validation study. *QJM* 2017;**110**:27–31. doi:10.1093/qjmed/hcw110

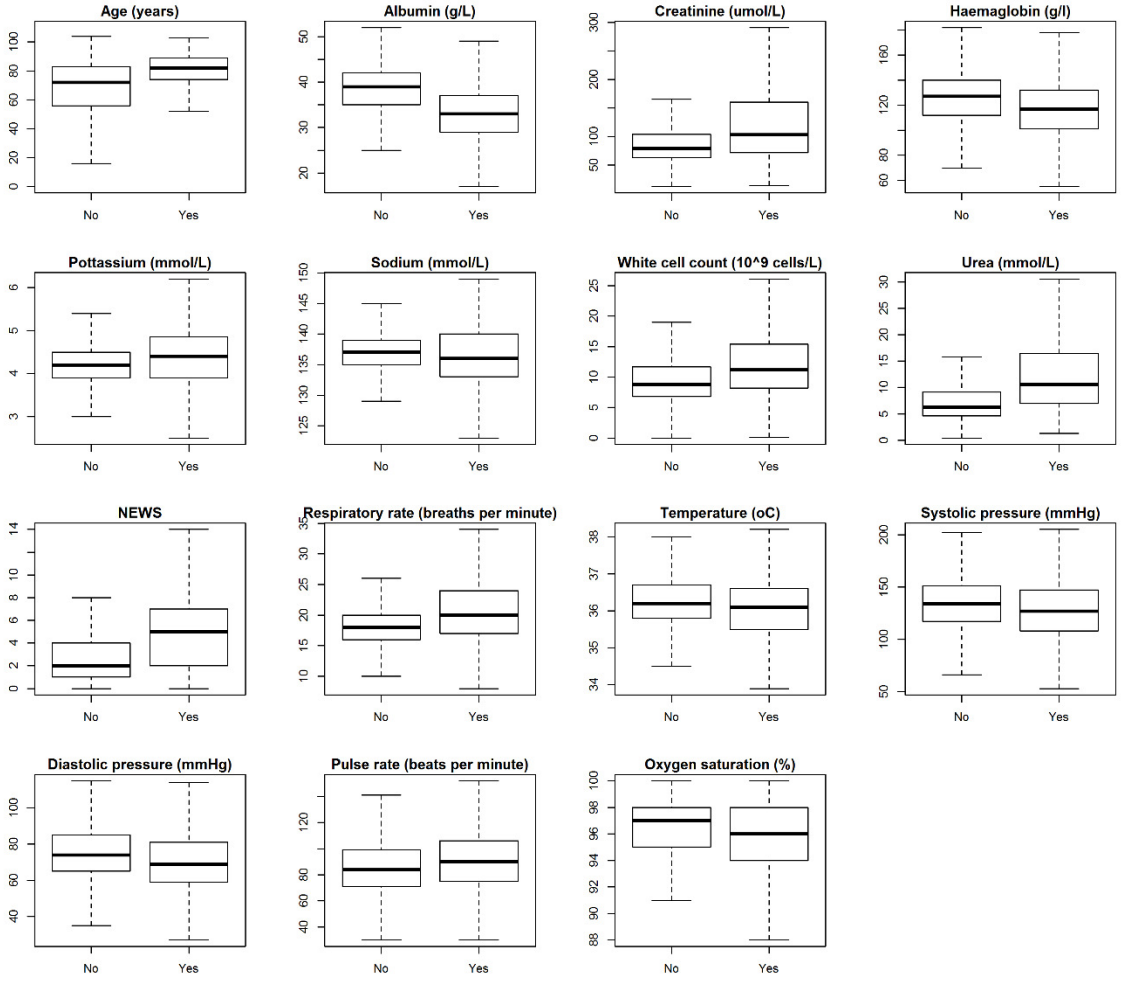

Figure S2 Boxplot without outliers for continuous covariates with respect to patient's discharge status (Alive/Died) for NLAG hospitals

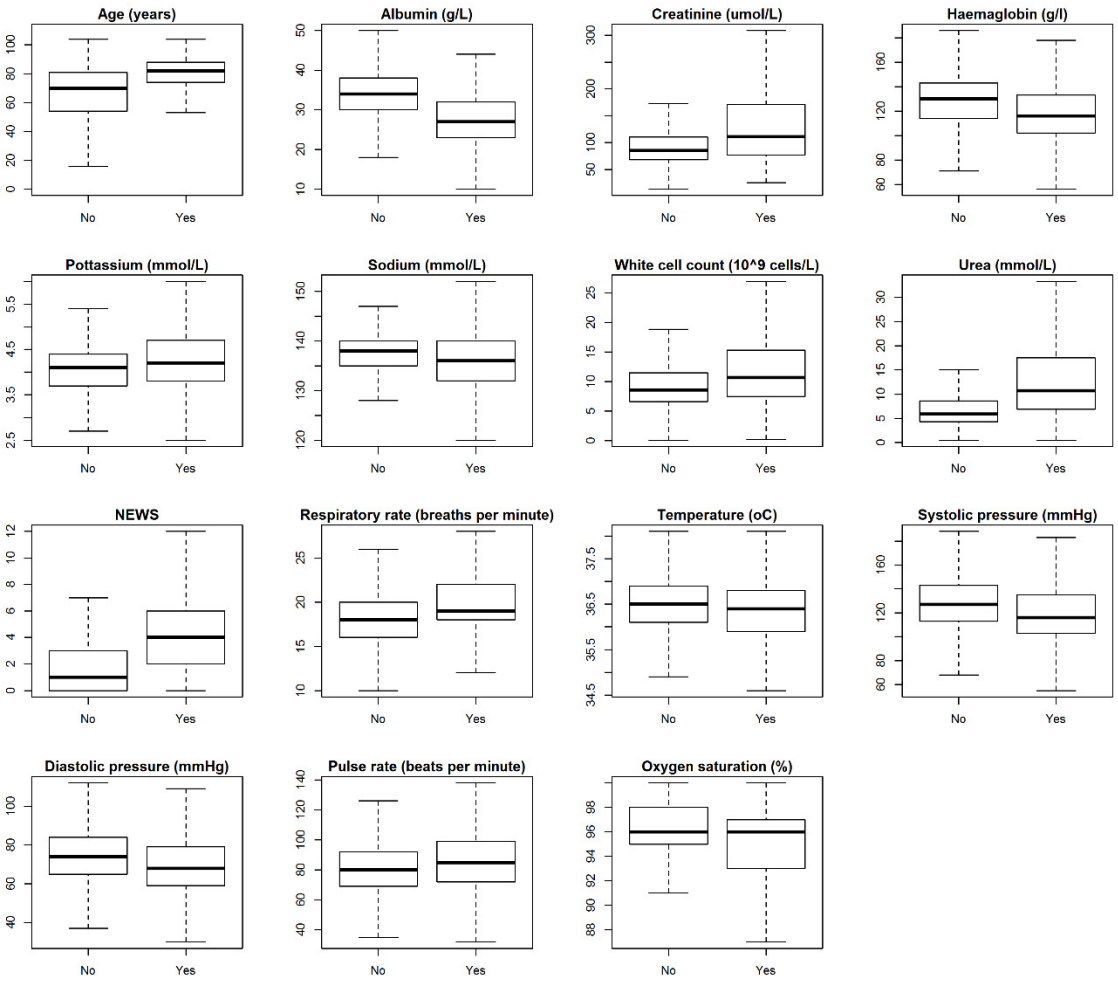

Figure S3 Boxplot without outliers for continuous covariates with respect to patient's discharge status (Alive/Died) for York hospital

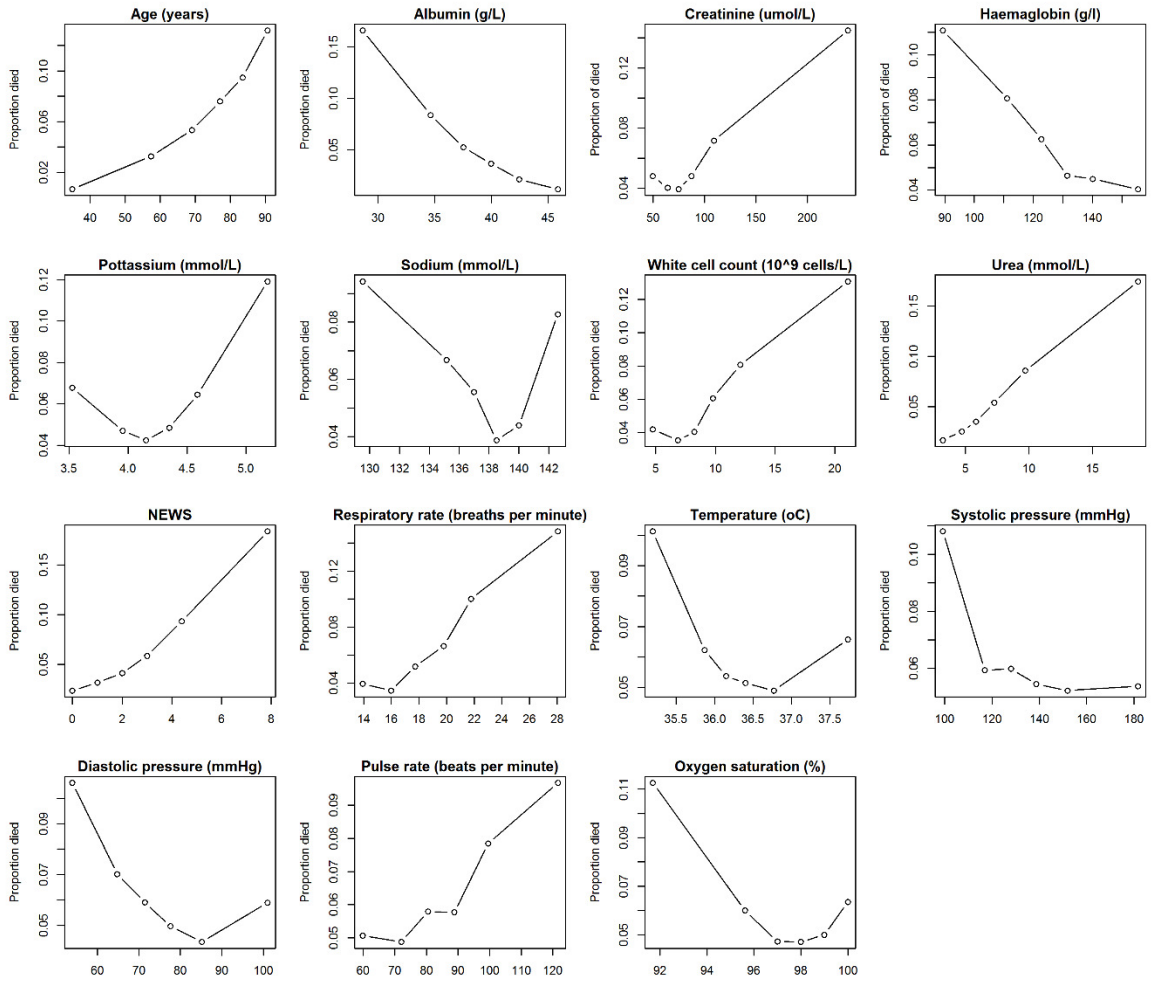

Figure S4 Line plots showing the observed risk of death with continuous covariates for NLAG hospitals

NB: y-axis range changes in each plot.

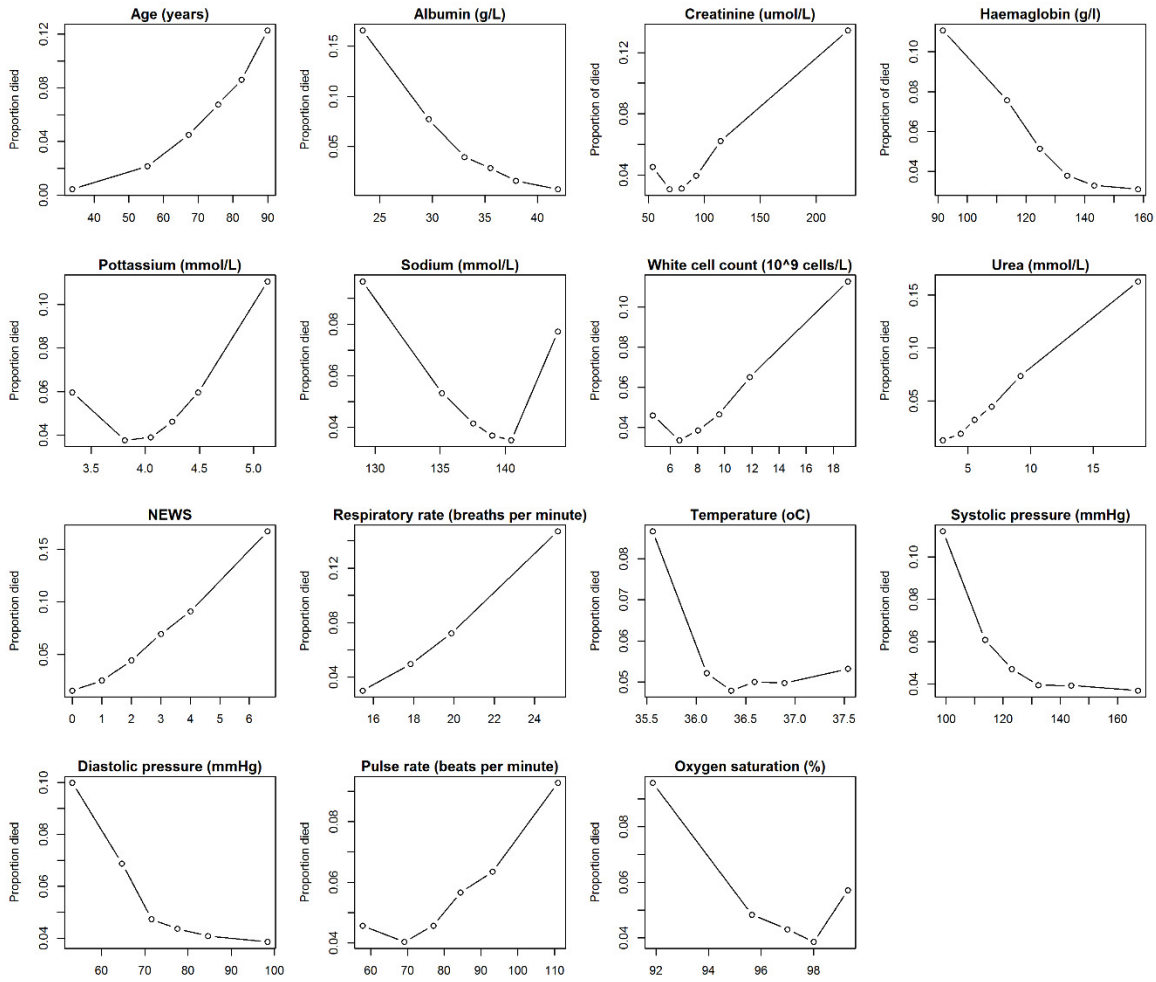

Figure S5 Line plots showing the observed risk of death with continuous covariates for York hospital.

NB: y-axis range changes in each plot.

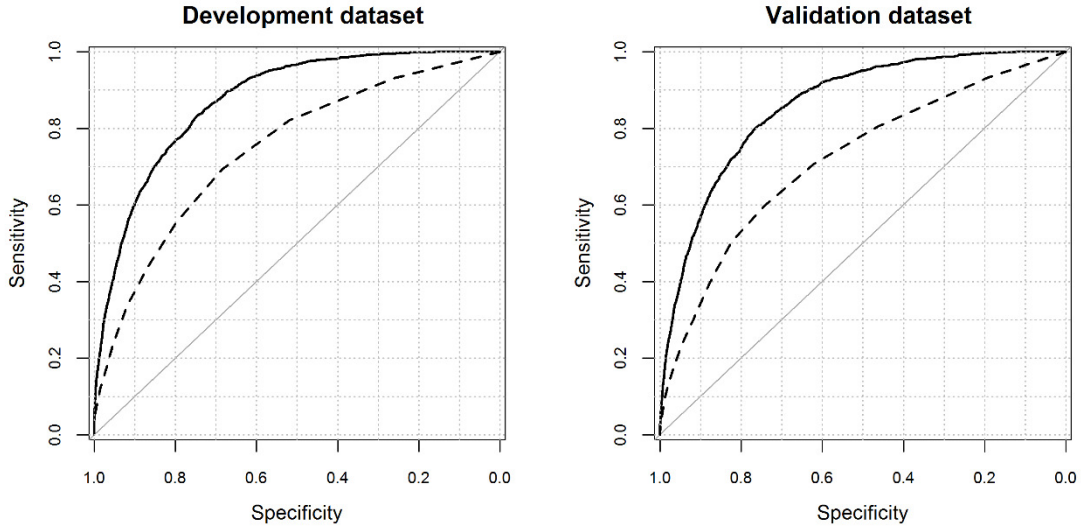

Figure S6 Area under the Receiver Operating Characteristic curve for development dataset (NEWS =0.75, CARM=0.87) and validation dataset (NEWS=0.72, CARM=0.86).

Black dashed line for NEWS and black solid line for CARM

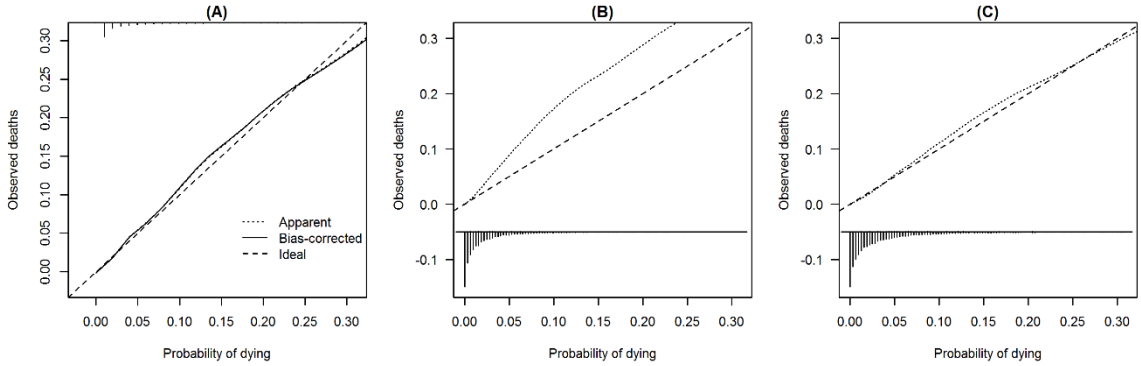

Figure S7 Internal and external validation with and without re-calibration of CARM model

(A) Internal validation of development dataset only using bootstrap method (B) performance of CARM model on external validation dataset without any re-calibration (C) performance of CARM model on external validation dataset after correcting for baseline mortality difference (5.7% vs 6.5%).

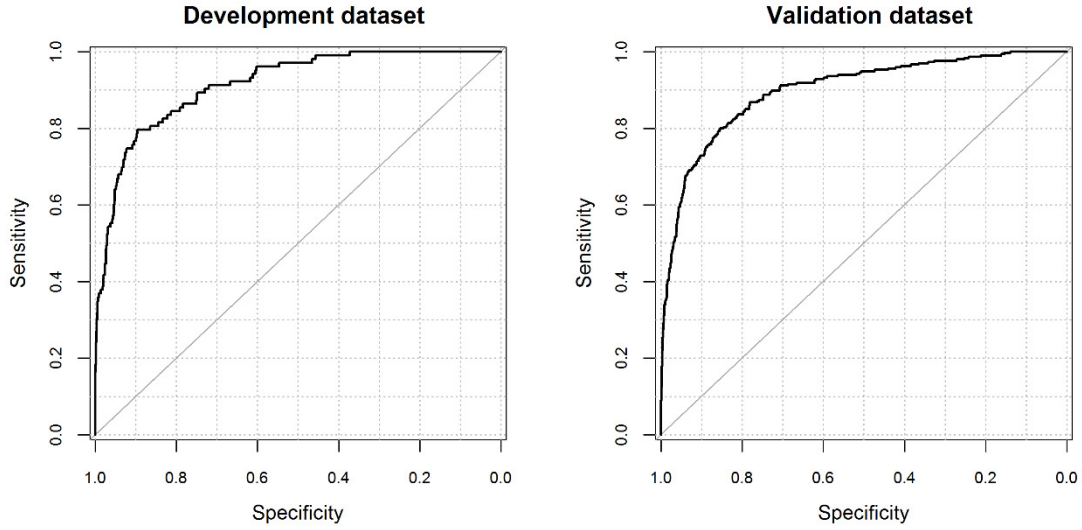

Figure S8 Receiver Operating Characteristic curve of (median) imputed blood tests results on development dataset and validation dataset.

NB: patients with imputed values were omitted during model development and validation.

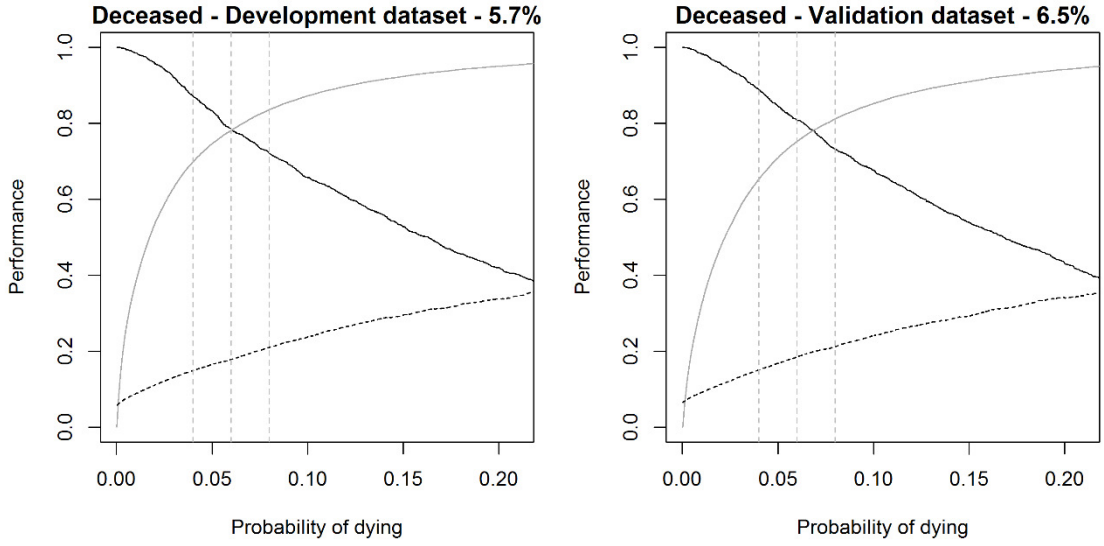

Figure S9: Sensitivity analysis of CARM model at various thresholds of probability of dying (0.0, 0.01, …, 0.20) on development dataset and validation dataset.

Black solid line is for sensitivity and black dashed line is for positive predictive value (PPV). Grey solid line is specificity and grey dashed vertical lines are at thresholds (0.04, 0.06, and 0.08).

NB: We selected thresholds exclusively based on development dataset.

Characteristics	NLAG AUC (95% CI)	York AUC (95% CI)
Overall	0.87 (0.87 to 0.88)	0.86 (0.85 to 0.87)
Sex		
Male	0.87 (0.86 to 0.88)	0.85 (0.84 to 0.86)
Female	0.88 (0.87 to 0.89)	0.87 (0.86 to 0.88)
Age		
Age>=75	0.81 (0.80 to 0.82)	0.81 (0.79 to 0.82)
Age<75	0.91 (0.90 to 0.92)	0.89 (0.88 to 0.91)
Seasons		
Spring	0.87 (0.86 to 0.89)	0.86 (0.84 to 0.88)
Summer	0.88 (0.87 to 0.90)	0.85 (0.83 to 0.87)
Autumn	0.87 (0.86 to 0.89)	0.87 (0.86 to 0.89)
Winter	0.87 (0.85 to 0.88)	0.86 (0.84 to 0.87)
Length of Stay (LoS)		
LoS>=5 days	0.77 (0.76 to 0.79)	0.75 (0.73 to 0.76)
Los<5 days	0.95 (0.94 to 0.96)	0.94 (0.93 to 0.95)
Day of the Week		
Sunday	0.93 (0.91 to 0.94)	0.93 (0.92 to 0.95)
Monday	0.87 (0.85 to 0.89)	0.87 (0.84 to 0.89)
Tuesday	0.87 (0.85 to 0.89)	0.83 (0.81 to 0.85)
Wednesday	0.86 (0.84 to 0.88)	0.84 (0.82 to 0.86)
Thursday	0.86 (0.84 to 0.88)	0.86 (0.84 to 0.88)
Friday	0.88 (0.86 to 0.90)	0.87 (0.85 to 0.89)
Saturday	0.90 (0.88 to 0.92)	0.91 (0.89 to 0.92)
Charlson Comorbidity Index		
Acute Myocardial	0.84 (0.82 to 0.86)	0.81 (0.78 to 0.84)
Congestive Heart	0.77 (0.75 to 0.79)	0.75 (0.73 to 0.78)
Peripheral Vascular	0.78 (0.74 to 0.82)	0.82 (0.79 to 0.86)
Cerebrovascular	0.78 (0.73 to 0.83)	0.78 (0.75 to 0.81)
Dementia	0.78 (0.75 to 0.81)	0.77 (0.73 to 0.80)
COPD	0.85 (0.84 to 0.87)	0.85 (0.83 to 0.86)
Rheumatoid Disease	0.87 (0.84 to 0.90)	0.83 (0.79 to 0.88)
Peptic Ulcer	0.88 (0.83 to 0.93)	0.83 (0.74 to 0.91)
Mild LD (Liver)	0.86 (0.82 to 0.90)	0.83 (0.76 to 0.90)
Diabetes	0.85 (0.83 to 0.87)	0.84 (0.82 to 0.86)
Diabetes+Complications	0.79 (0.69 to 0.89)	0.90 (0.85 to 0.95)
Hemiplegia/Paraplegia	0.80 (0.75 to 0.85)	0.74 (0.67 to 0.81)
RD (Renal)	0.80 (0.78 to 0.82)	0.81 (0.78 to 0.83)
Cancer	0.80 (0.78 to 0.83)	0.81 (0.78 to 0.84)
Moderate/Severe LD (Liver)	0.80 (0.73 to 0.87)	0.78 (0.71 to 0.84)
Metastatic Cancer	0.77 (0.74 to 0.80)	0.77 (0.74 to 0.81)

Table S4: The c-statistics (95% CI) is showing for CARM model in each hospital by Sex, Age, Seasons, Longer vs. shorter length of stay subjects, Day of the week, and 16 CCI disease groups.