

Decision Tree Early Warning Scores based on common laboratory test results discriminate patients at risk of hospital mortality

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Aim
To determine whether it is feasible to build an early warning score (EWS) based exclusively on laboratory data collected early in the hospital stay to predict patients at risk of hospital mortality.

Introduction
In the UK, most hospitals use an EWS to identify at risk patients and to provide appropriate care. These are based on measurements of vital signs (e.g., pulse rate, blood pressure, breathing rate and conscious level).

Although measured less often than vital signs, laboratory tests are subject to strict quality control and have independently been identified as risk factors for poor patient outcome¹. Therefore, an EWS based exclusively on laboratory test results may offer an additional opportunity to identify sick or 'at risk' patients.

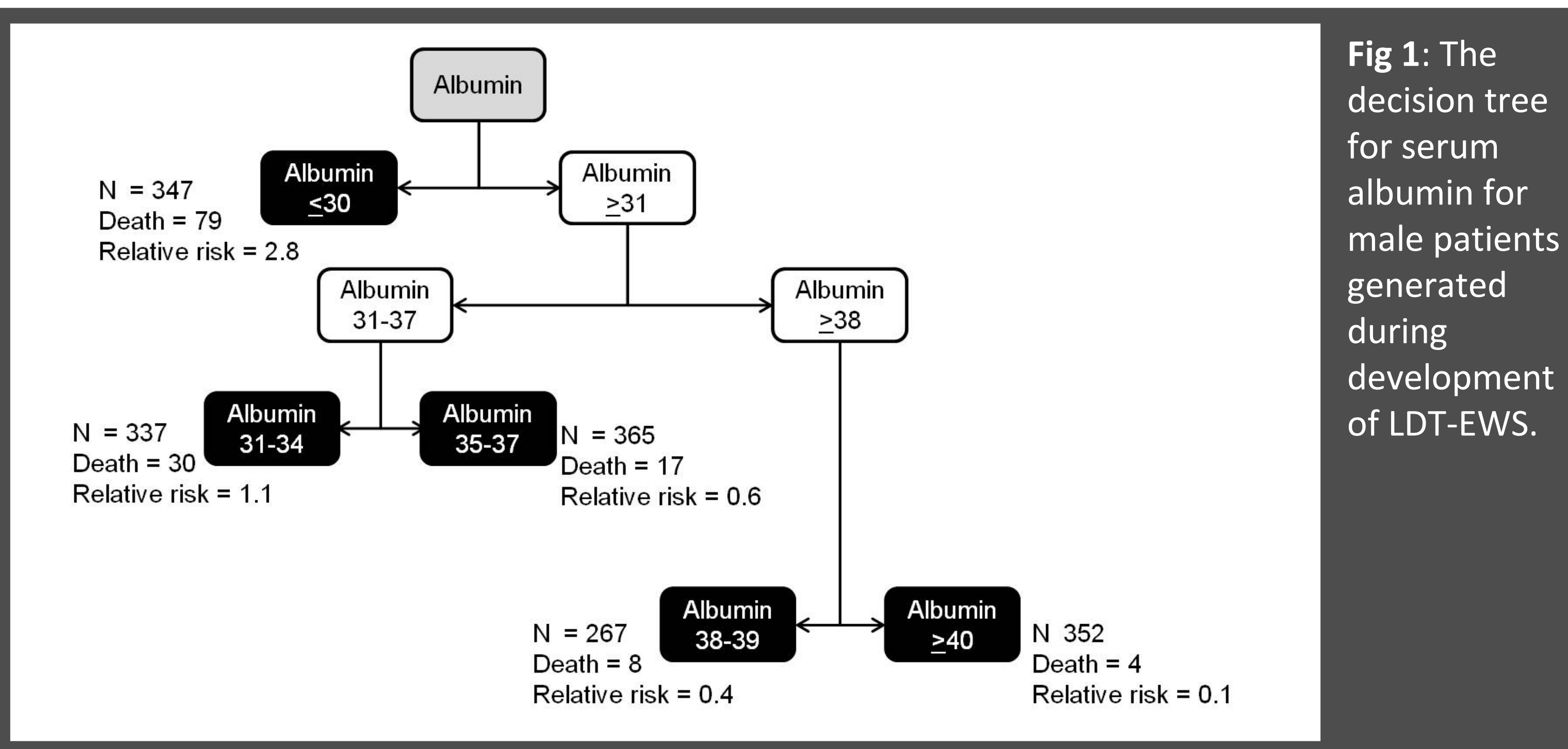


Fig 1: The decision tree for serum albumin for male patients generated during development of LDT-EWS.

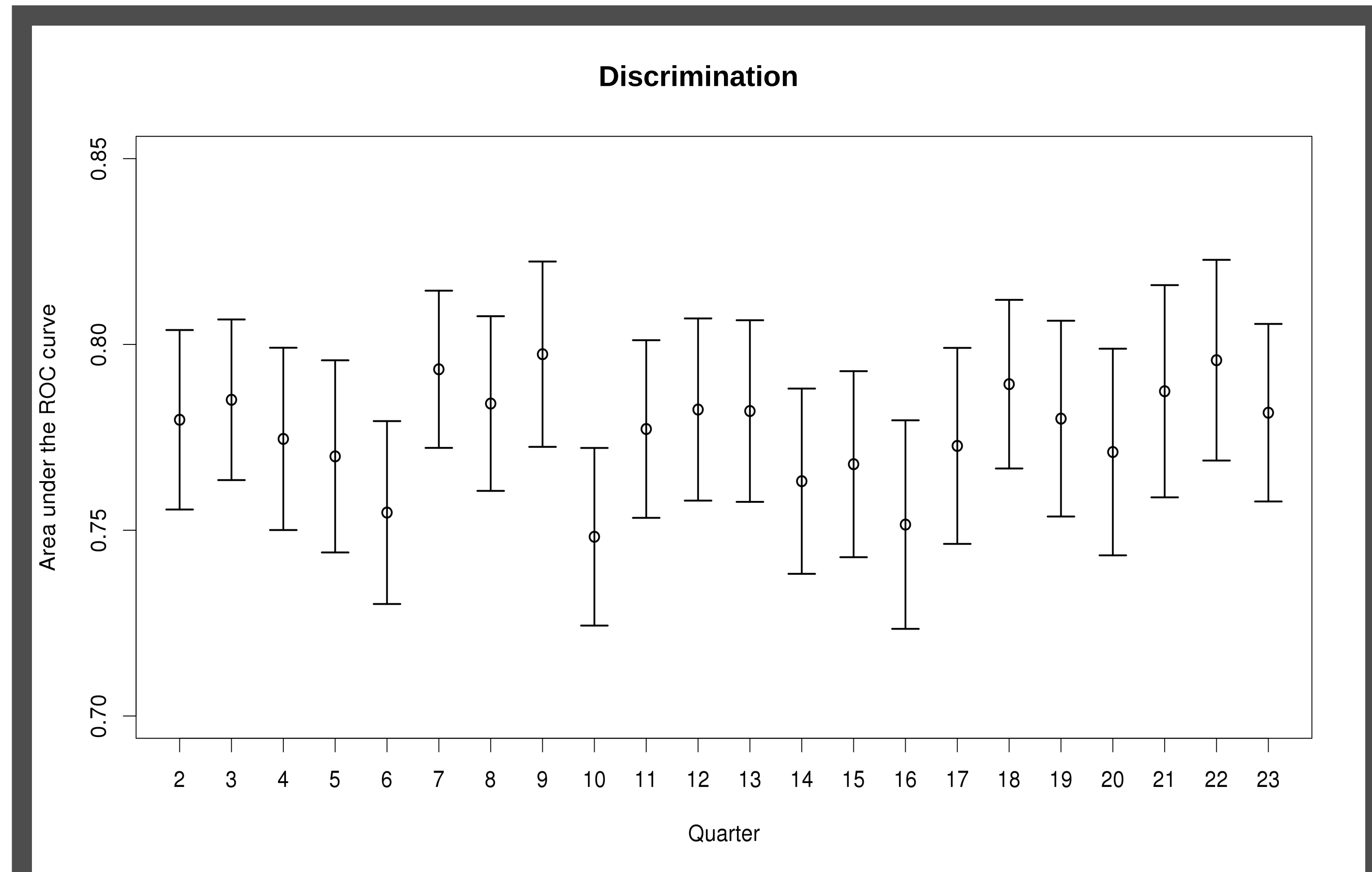


Fig. 2: Area under the receiver operating curve for LDT-EWS applied to 22 test data sets.

Results

The data generated slightly different EWS for males and females (Table 1). The area under the ROC curve values (95% CI) for LDTEWS in all patients, irrespective of gender, with in-hospital death as the outcome, ranged from 0.748 (0.723 to 0.772) (Q10) to 0.797 (0.772 to 0.823) (Q9) for the 22 validation sets Q2-Q23 (Fig. 2). These compare well with areas under the curve of 0.657 (0.636-0.678) to 0.782 (0.767-0.797) for vital signs based EWS^{3,4}.

EWS efficiency curves for male and female patients were generated for the 22 test data sets combined (Fig. 3). Whilst the curves are very similar in shape, the position of LDT-EWS scores differs for males and females. In clinical practice, it might be appropriate to have a different trigger point for male and female patients.

Methods
Decision Tree (DT) analysis is a data mining classification technique for splitting or partitioning of data sets into homogeneous groups. This partitioning is based on derived associations between the chosen outcome – in our case, in-hospital death – and one or more covariates.

Our modelling strategy assessed the following covariates individually: haemoglobin, white cell count, serum urea, serum albumin, serum creatinine, serum sodium, and serum potassium results. An example tree (serum albumin for male patients) is shown in Fig. 1.

To replicate the classic approach used by most EWS we chose to develop our EWS, LDT-EWS², with a 0, 1, 2 and 3 weighting system for the risk bands. The risk bands were set as follows: where the risk generated by the DT analysis for any given parameter was < mean risk of in-hospital death (relative risk<1), a value of 0 was ascribed; if the risk was \ge mean risk and < 2 times mean risk, a value of 1 was ascribed; if the risk was \ge 2 times mean risk and < 3 times mean risk, a value of 2 was ascribed; and if the risk was \ge 3 times mean risk, a value of 3 was ascribed.

LDT-EWS was developed for a single set (n= 3762) (Q1). It was validated in 22 other discrete sets each of three months long (Q2-Q23; range of n = 3590 to 4341). The ability of LDT-EWS to discriminate in-hospital death was assessed using the area under the receiver-operating characteristic (AUROC) curve and by plotting an EWS efficiency curve. The efficiency curves provide a relative measure, for a given trigger value in an EWS, of the number of triggers and number of patients subsequently dying that would be visited.

MALE	3	2	1	0	1	2	3
Hb		≤ 11.1	11.2-12.8	≥ 12.9			
WCC				≤ 9.3	9.4-16.6	≥ 16.7	
U				≤ 9.4	9.5-13.7		≥ 13.8
Cr				≤ 114	115-179	≥ 180	
Na		≤ 132		133-140	≥ 141		
K			≤ 3.7	3.8-4.4	4.5-4.7	≥ 4.8	
Alb		≤ 30	31-34	≥ 35			

FEMALE	3	2	1	0	1	2	3
Hb			≤ 12.0	12.1-14.8	≥ 14.9		
WCC				≤ 12.6	12.7-14.8	≥ 14.9	
U				≤ 8.4	8.5-13.8		≥ 13.9
Cr				≤ 91	92-157	≥ 158	
Na			≤ 134	135-140	≥ 141		
K			≤ 3.3	3.4-4.5	≥ 4.6		
Alb		≤ 28	29-34	≥ 35			

Table 1: LDT-EWS for males (top) and females (bottom).

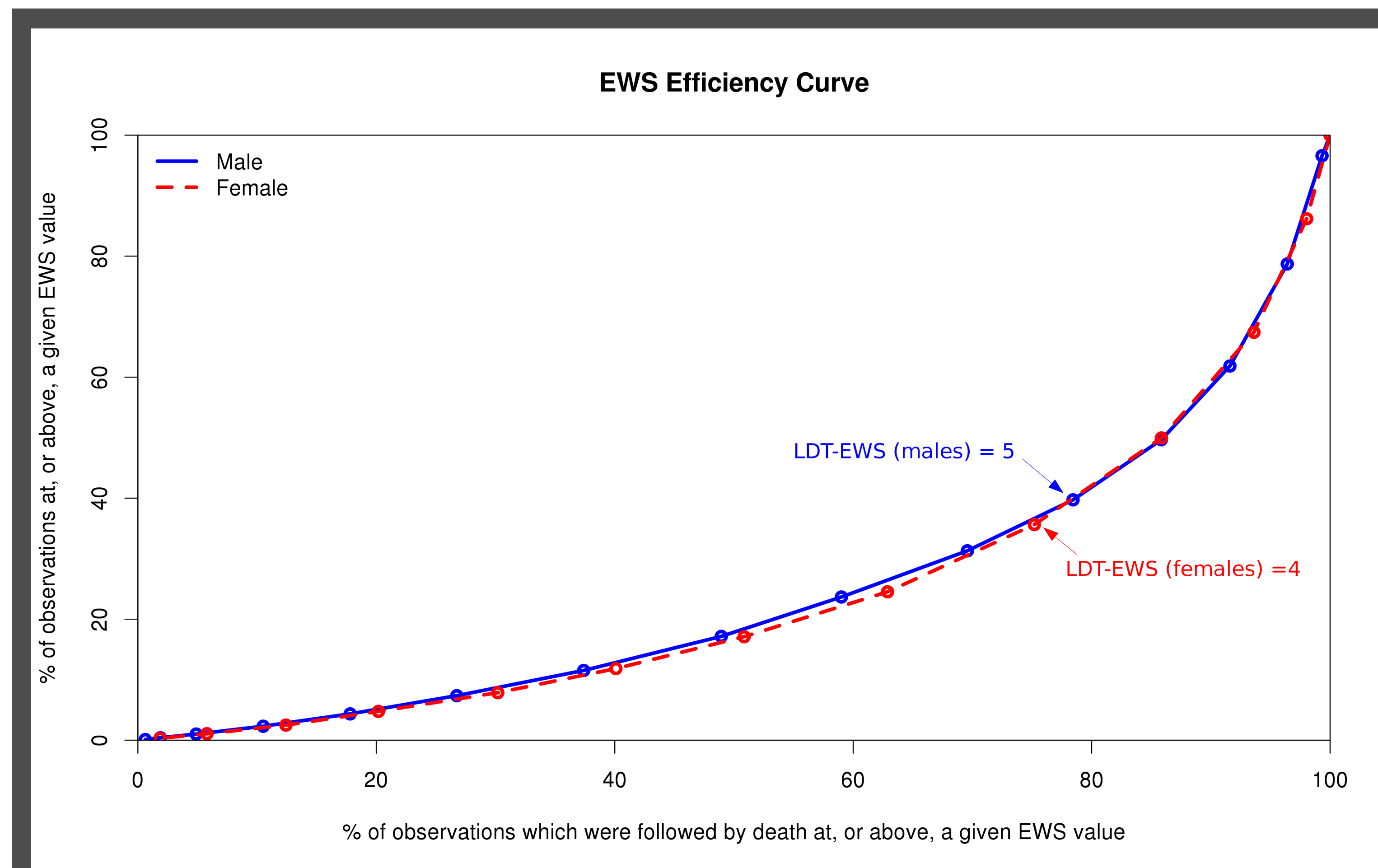


Fig. 3: LDT-EWS efficiency curves for males and females (performance over 22 test data sets combined).

Conclusions

This study provides evidence that the results of commonly measured laboratory tests collected soon after hospital admission can be used in a simple paper or computer-based early warning score (LDT-EWS) to discriminate in-hospital mortality. We hypothesise that, with appropriate modification, it might be possible to extend the use of LDT-EWS for use on an ongoing basis throughout the patient's hospital stay.

References

- Prytherch D, Sirl J, Schmidt P, Featherstone P, Weaver PC, Smith GB. The use of routine laboratory data to predict in-hospital death in medical admission. Resuscitation 2005;66:203-207
- Jarvis S, Kovacs C, Badriyah T, Briggs J, Mohammed M, Meredith P, Schmidt P, Featherstone P, Prytherch D, Smith GB. Development and validation of a decision tree early warning score based on routine laboratory test results for the discrimination of hospital mortality. Submitted to Resuscitation
- Smith GB, Prytherch DR, Schmidt P, Featherstone PI. Review and performance evaluation of aggregate weighted 'track and trigger' systems. Resuscitation 2008;77:170-179
- Jarvis S, Kovacs C, Badriyah T, Briggs J, Mohammed M, Meredith P, Schmidt P, Featherstone P, Prytherch D, Smith GB. Combining the National Early Warning Score with an early warning score based on common laboratory test results better discriminates patients at risk of hospital mortality. 8th International Rapid Response Conference, 13-14 May, 2013, Royal College of Physicians, London