Barts and The London
School of Medicine and Dentistry

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Queen Mary
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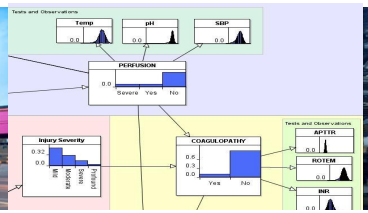
Causal Modelling Using Bayesian Networks

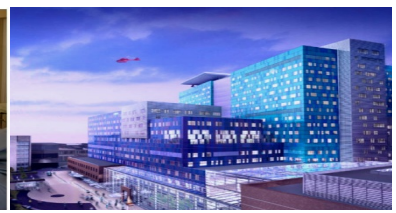
Barts and The London TRAUMA SCIENCES

RADAR

Risk Assessment and Decision Analysis Research Group

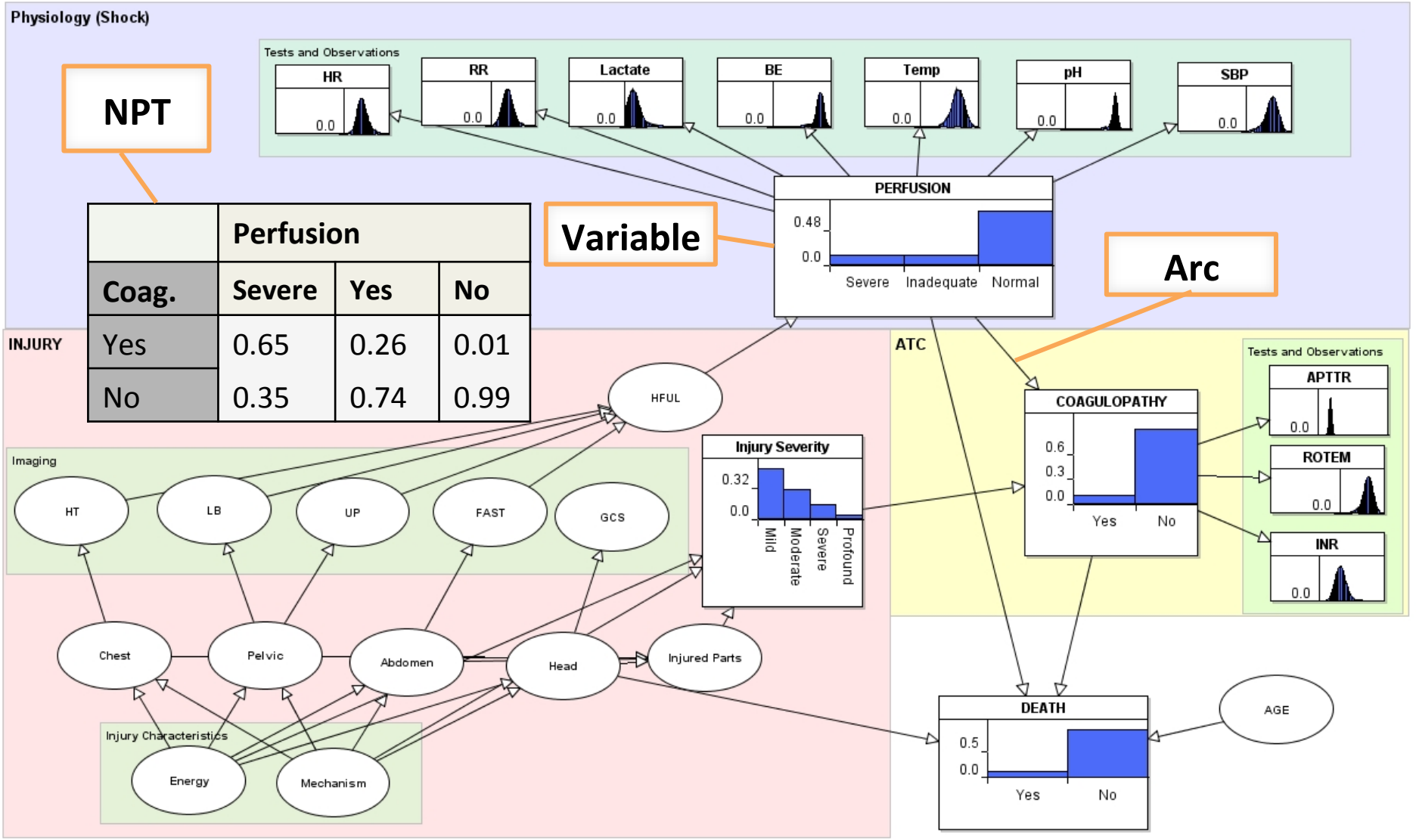




Outline

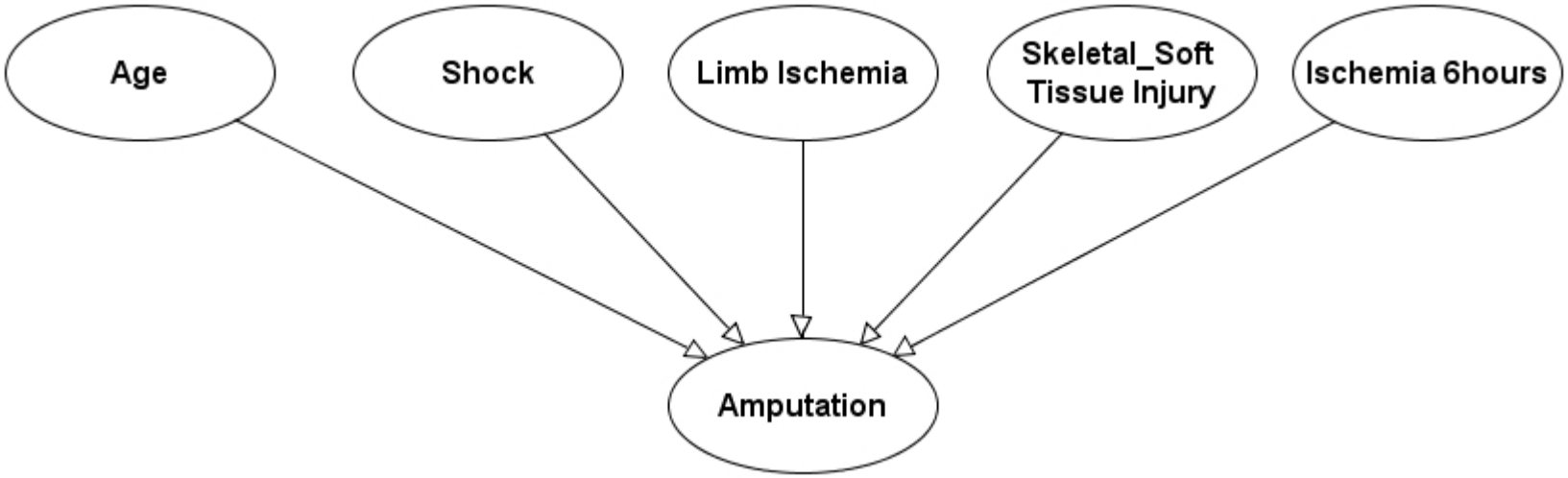
- Methodology:
  - Bayesian Networks
  - Challenges for Useful Decision Support
- Trauma Models:
  - Clinical Relevance
  - Results

ATC Bayesian Network



	Perfusion		
Coag.	Severe	Yes	No
Yes	0.65	0.26	0.01
No	0.35	0.74	0.99

BN v MESS Score

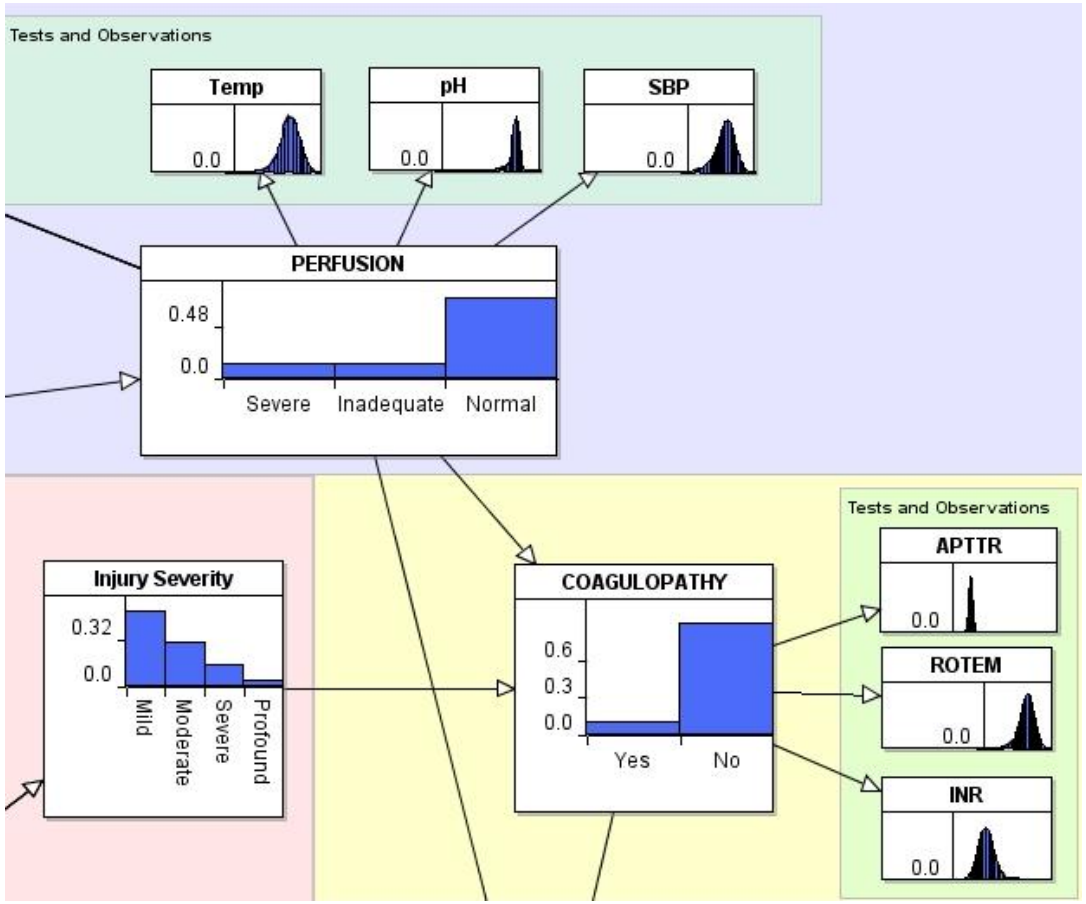


How the BN Model Differs

- Prediction: coagulopathy, death (c.f. GCS, TRISS)
- Flexible inputs
- Patient's physiological state
  - Causal modelling: informed by knowledge

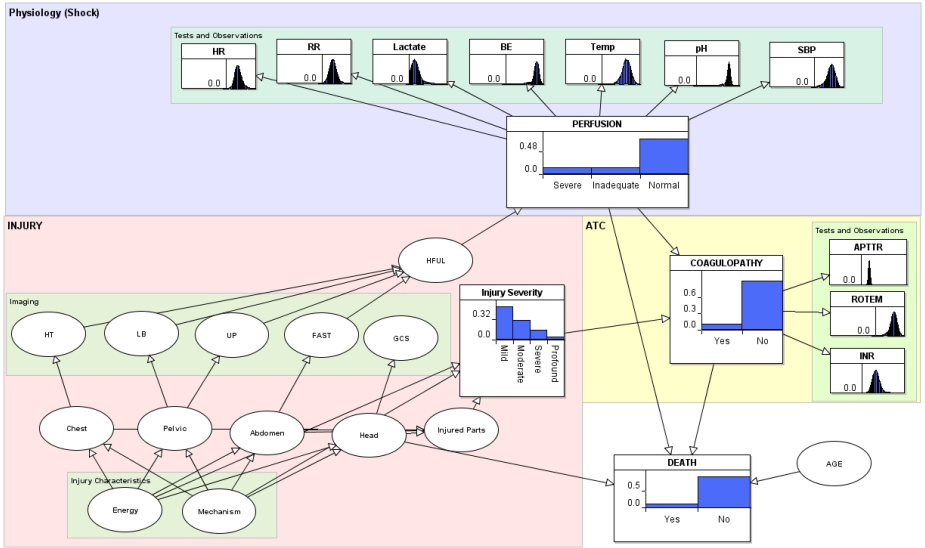
Modelling the Physiological State

- Not directly observed
- Tests available late
- No data
  - Measurements
  - Guided review
  - Learning



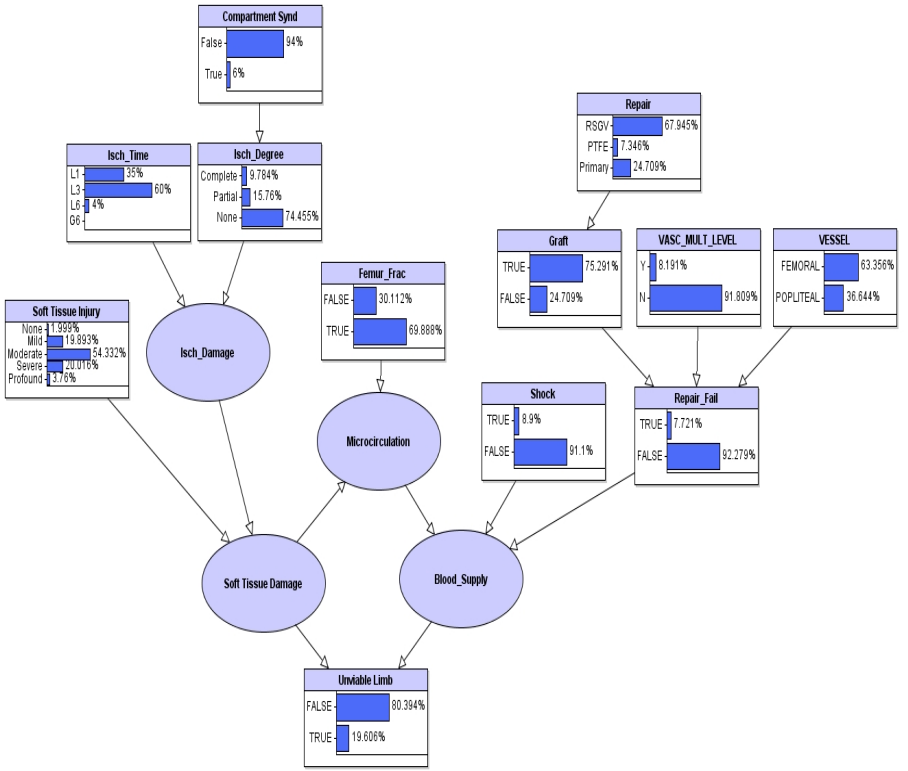
ATC Model Development: Summary

- Structure from
  - Expert panel
  - Literature review
- Parameters estimated from data
- Unobserved variables estimated
  - Clinical knowledge
  - Measurement data



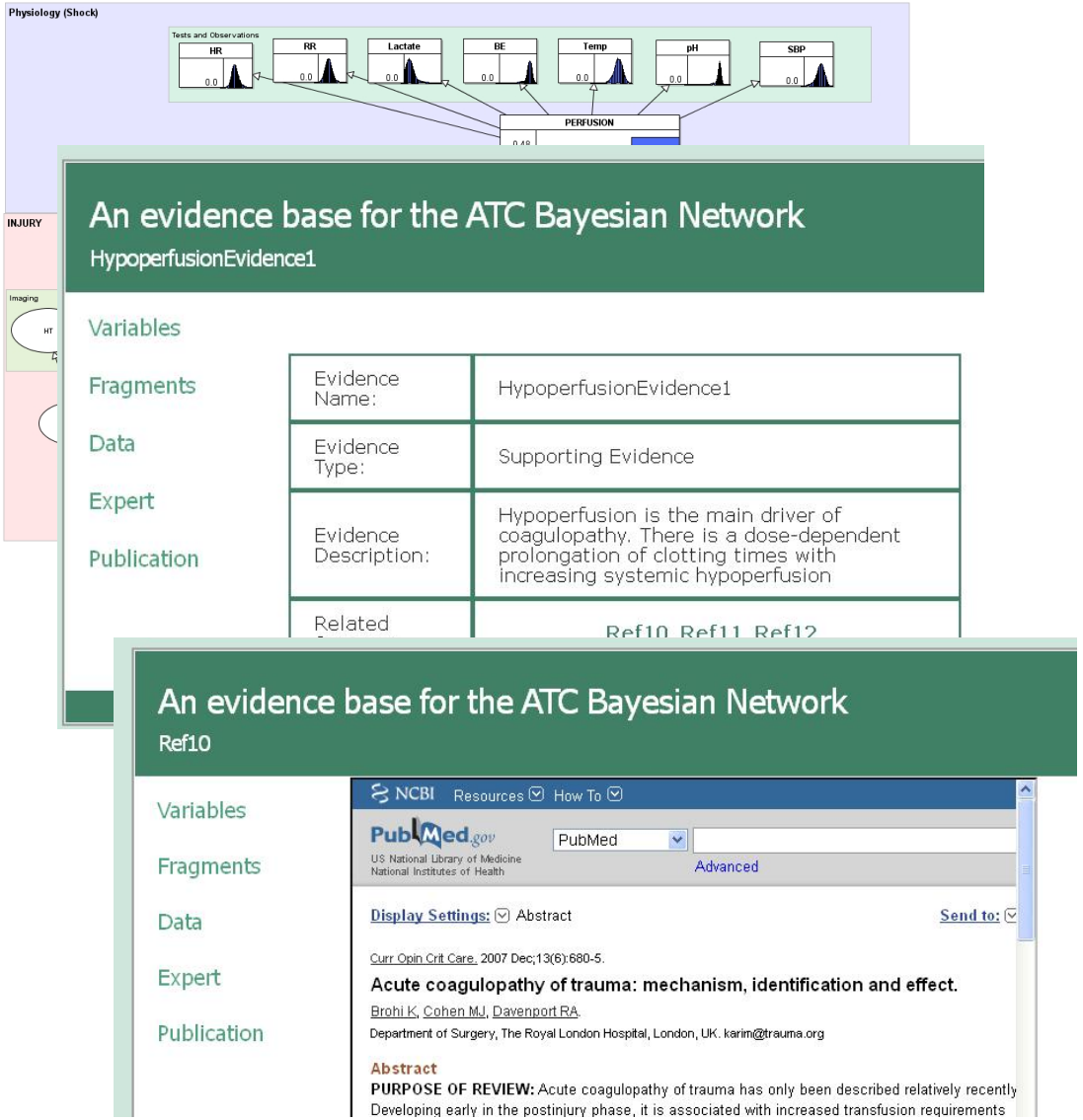
Lower Limb Vascular Injury BN: Summary

- Decision support by predicting the risks and outcomes
- Amount of data differs for different parts of the model:
  - Learn from data
  - Use meta-analysis results and clinical knowledge for parts lacking data



Evidence Behind the Model

- A browser to present the link to clinical evidence supporting or conflicting with the model.



DECISION-SUPPORT FOR SEVERE LOWER LIMB INJURIES

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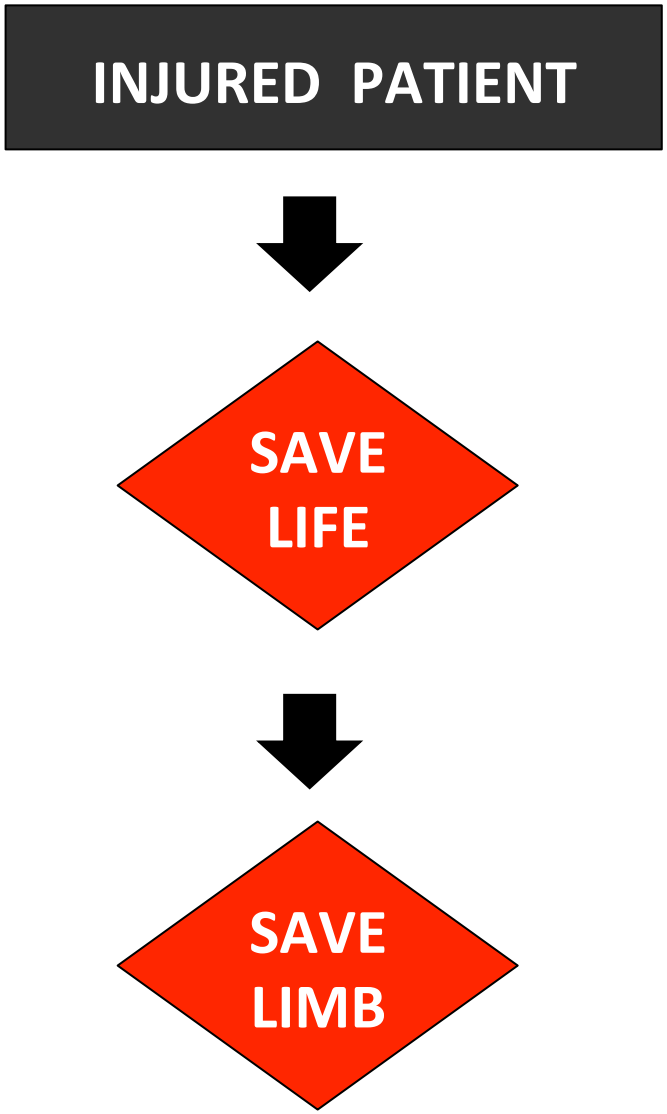
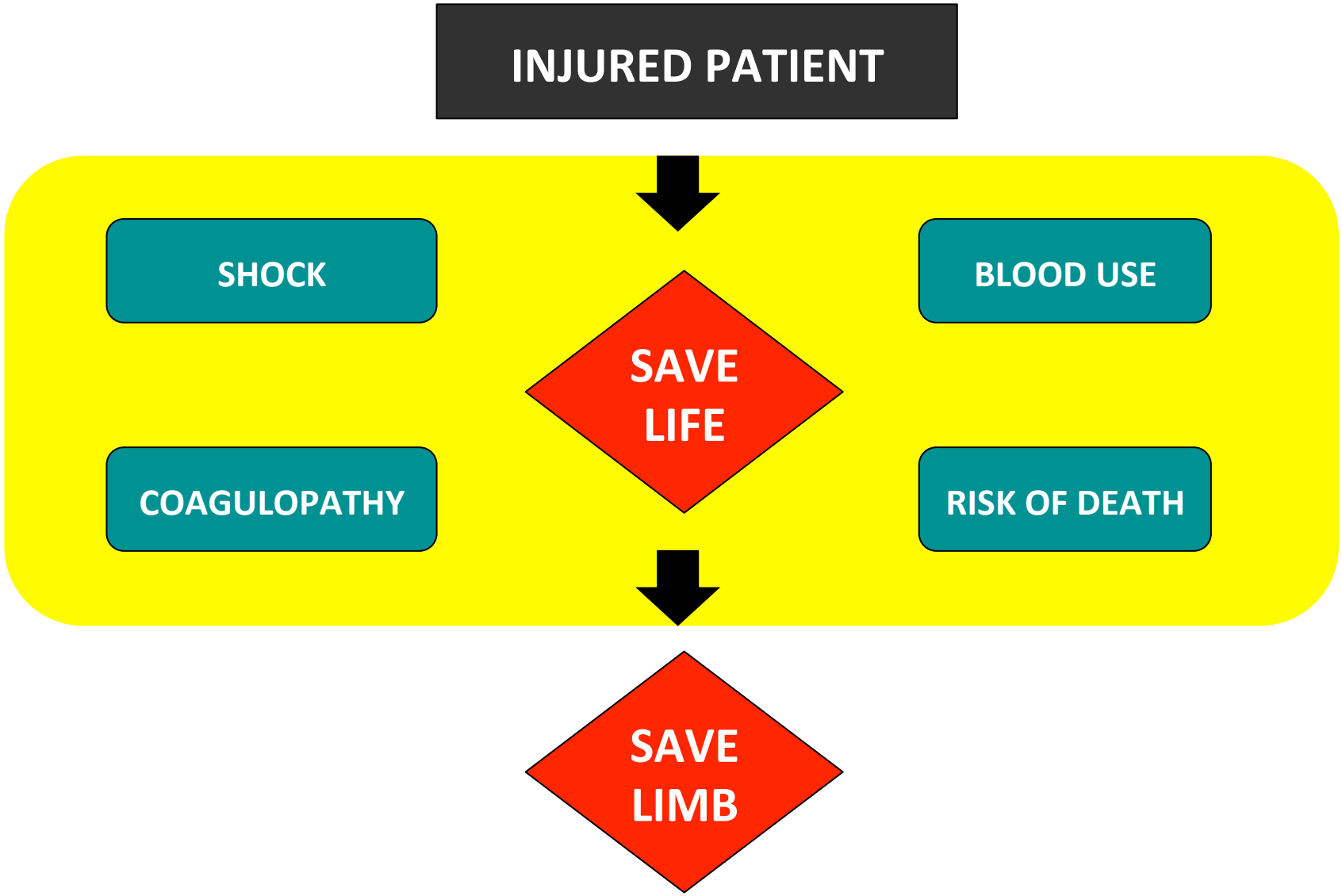

INJURED PATIENT
SAVE LIFE
SAVE LIMB

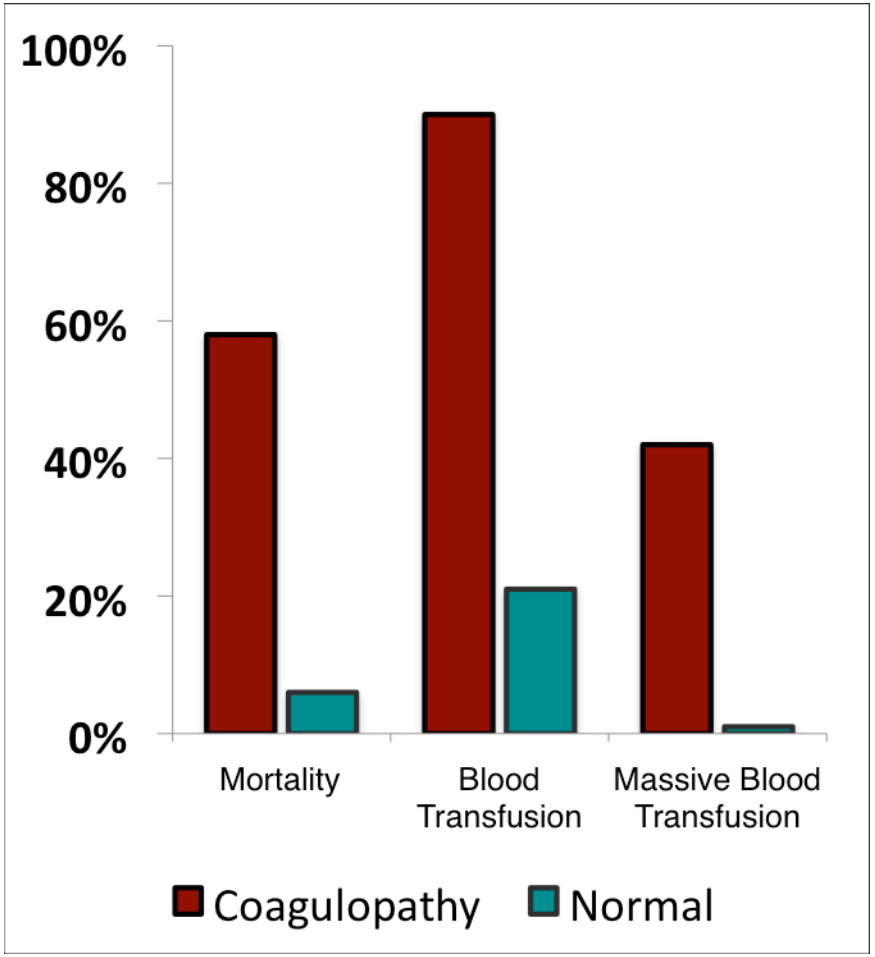

INJURED PATIENT
SHOCK
BLOOD USE
SAVE LIFE
COAGULOPATHY
RISK OF DEATH
SAVE LIMB

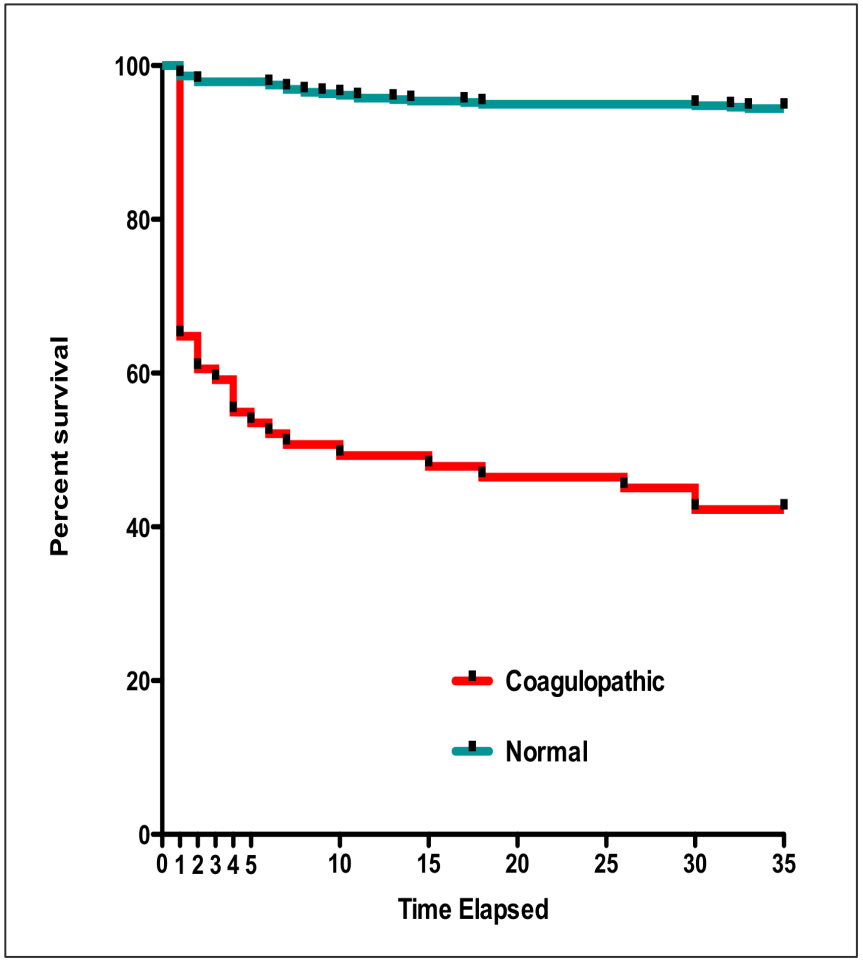
METHODOLOGY

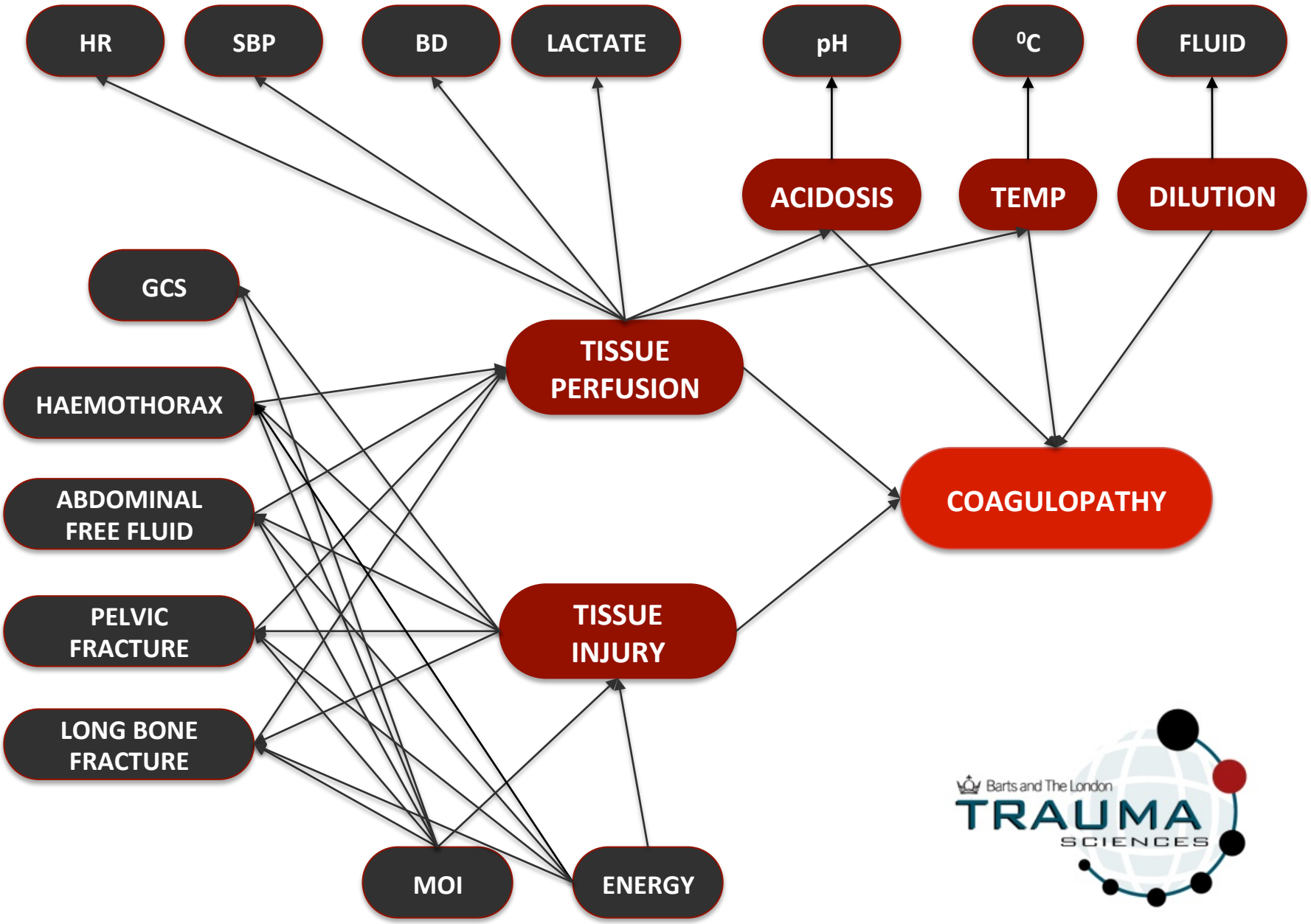
Classification of coagulopathy

1. Clinical criteria
2. Machine learning
3. Expert review

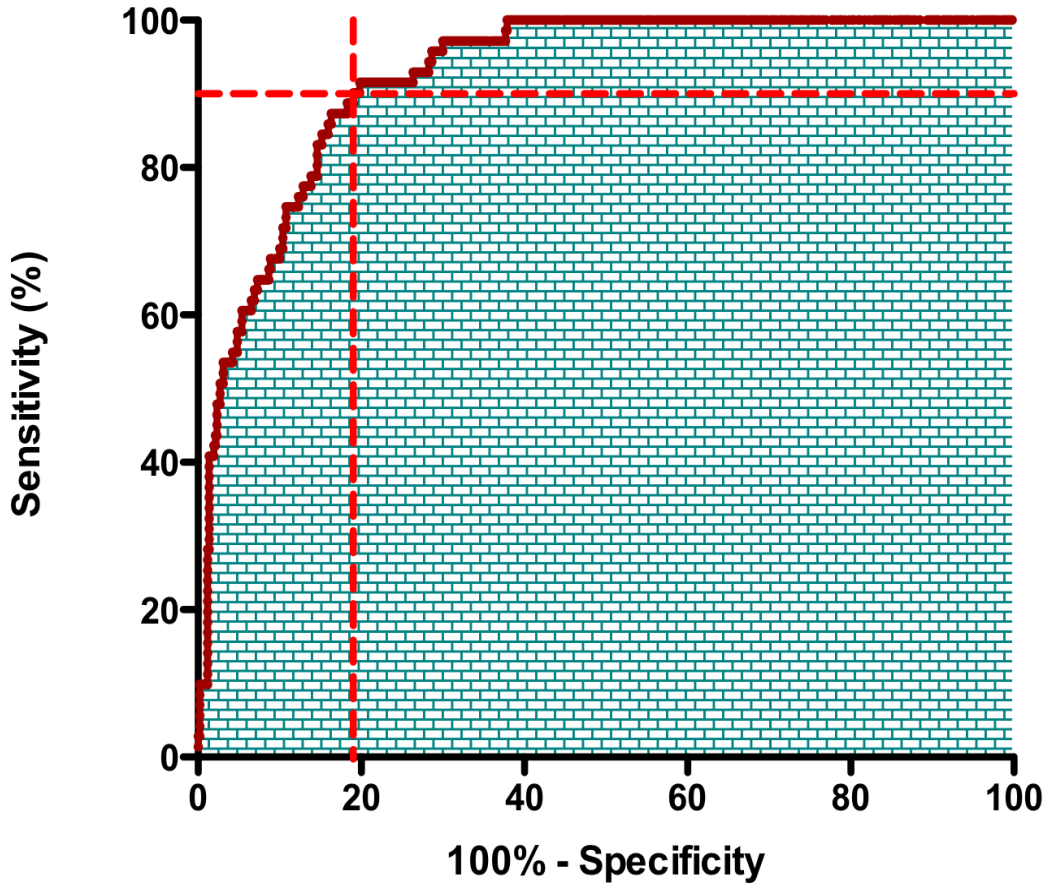
Clinical relevance






HR
SBP
BD
LACTATE
pH
⁰C
FLUID
ACIDOSIS
TEMP
DILUTION
GCS
HAEMOTHORAX
ABDOMINAL FREE FLUID
PELVIC FRACTURE
LONG BONE FRACTURE
TISSUE PERFUSION
TISSUE INJURY
COAGULOPATHY
MOI
ENERGY

Performance



AUROC:

0.924 (0.90 – 0.95)

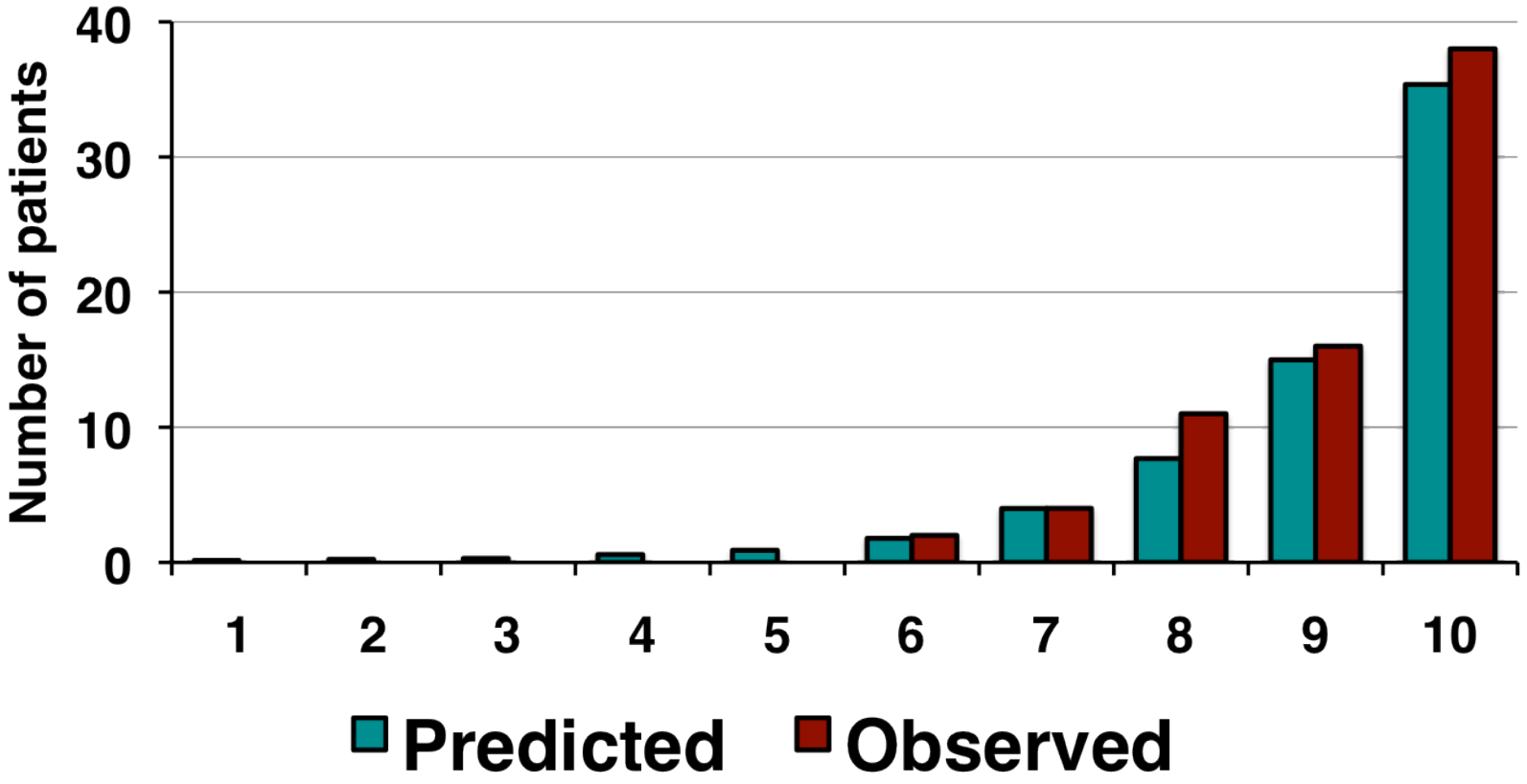
Sensitivity:

90 %

Specificity:

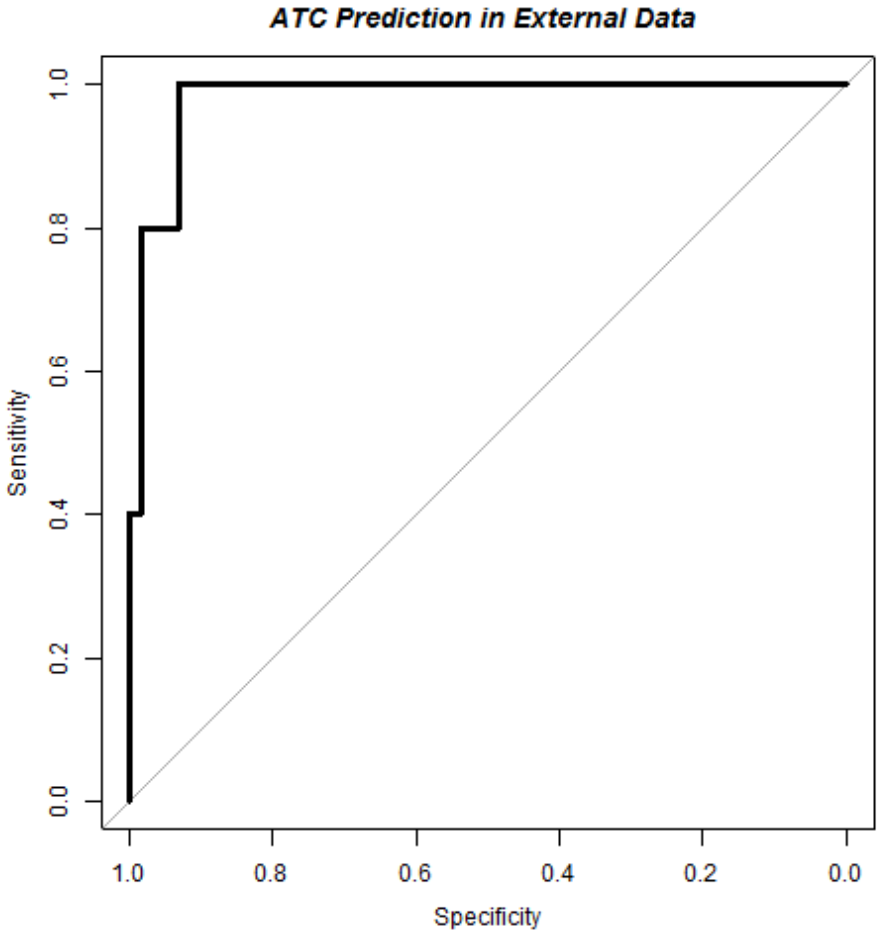
81%

Calibration



HL statistic = 4.4 (p-value = 0.77)

External Validation



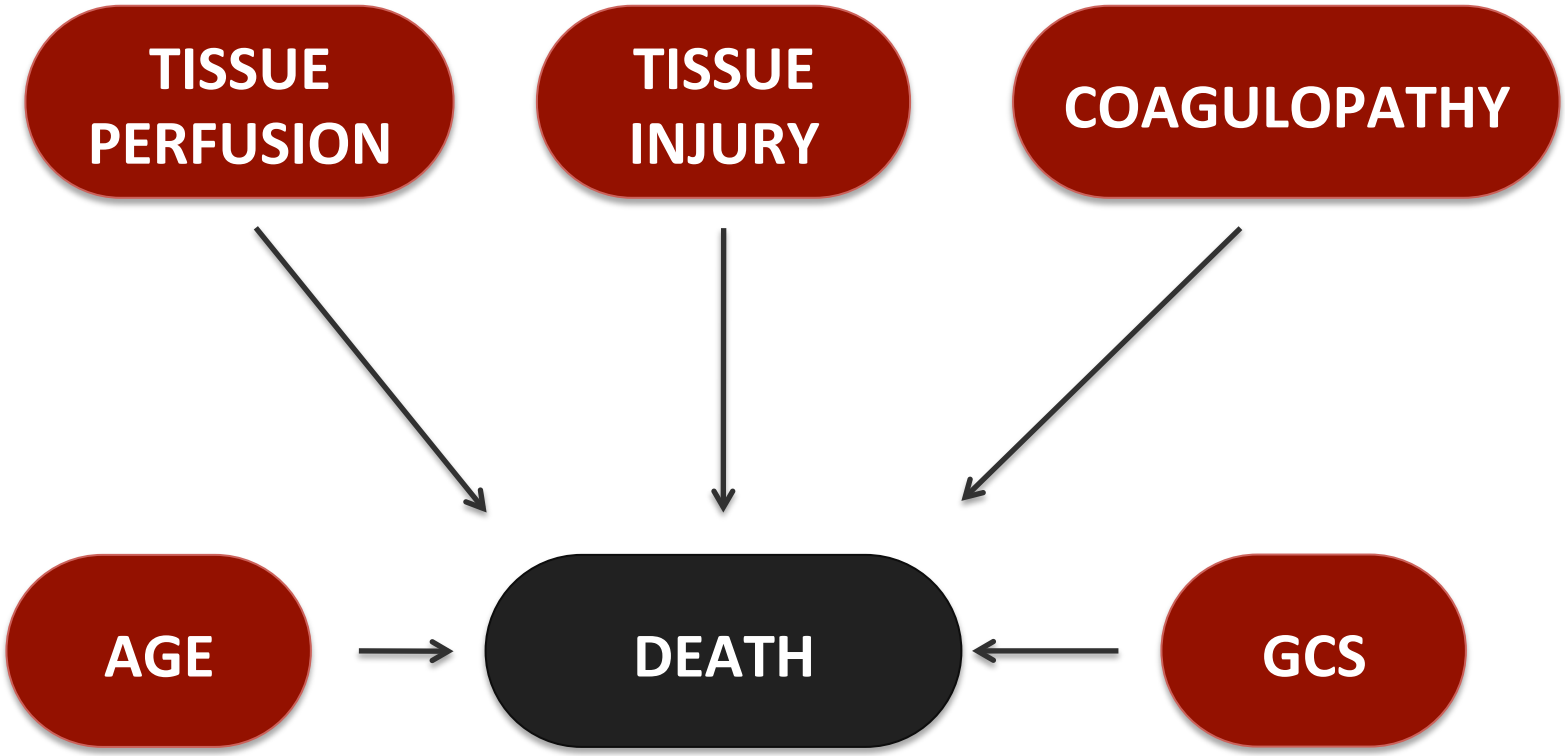
AUROC:
0.979 (0.95 – 1.0)

Sensitivity:
100 %

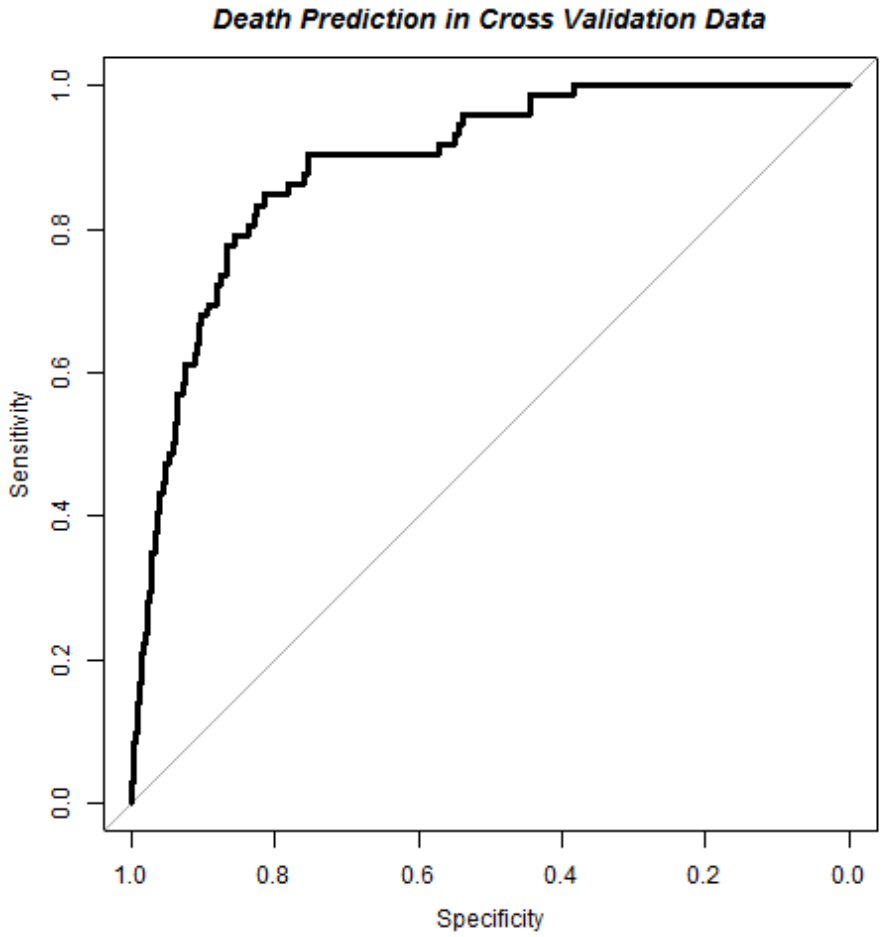
Specificity:
93%

Hosmer-Lemeshow
4.3 (p = 0.68)

Risk of Death



Internal Validation



AUROC:

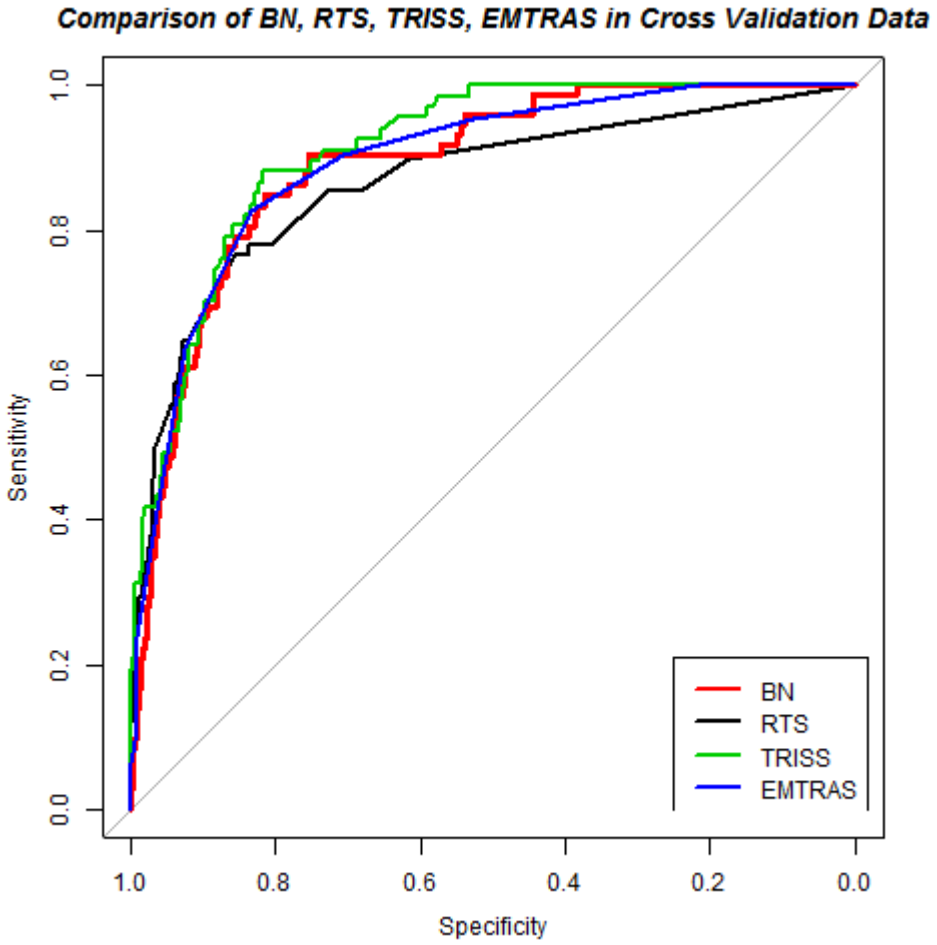
0.89 (95%CI: 0.85 – 0.93)

Sensitivity: 90%

Specificity: 75%

Calibration: p = 0.13

Mortality Prediction

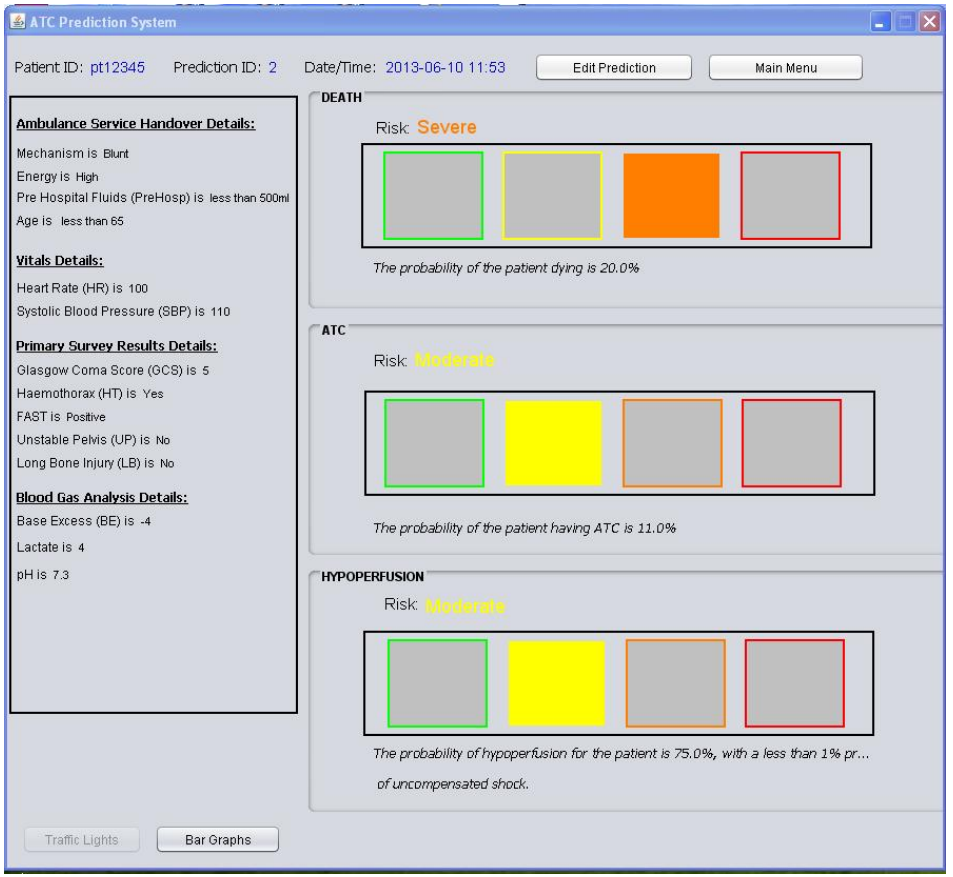


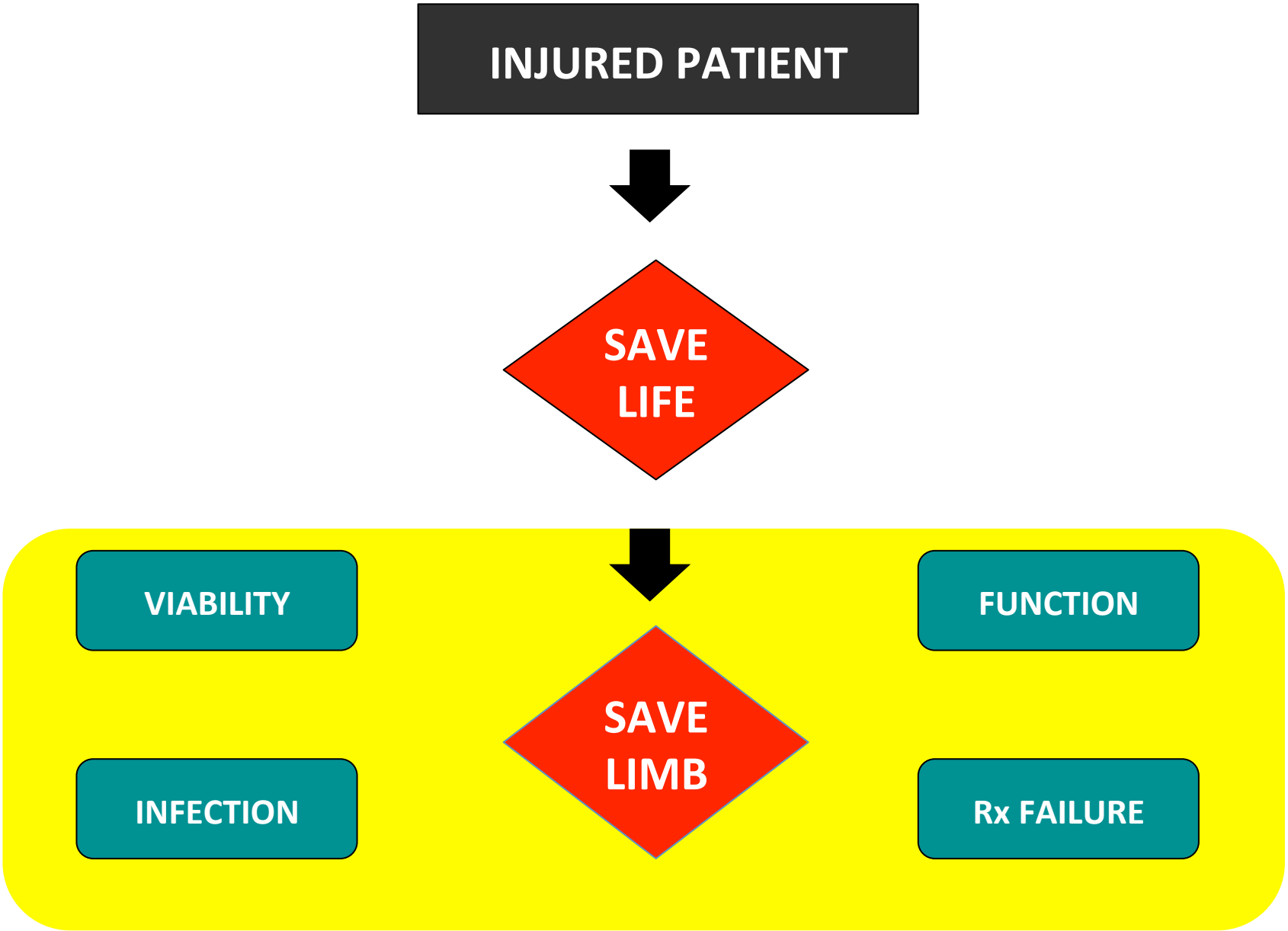
	AUROC	Specificity
BN	0.889	75%
TRISS	0.910	74%
RTS	0.859	61%
EMTRAS	0.895	70%

Prediction → Decision Support

- Risk categories to present model's predictions

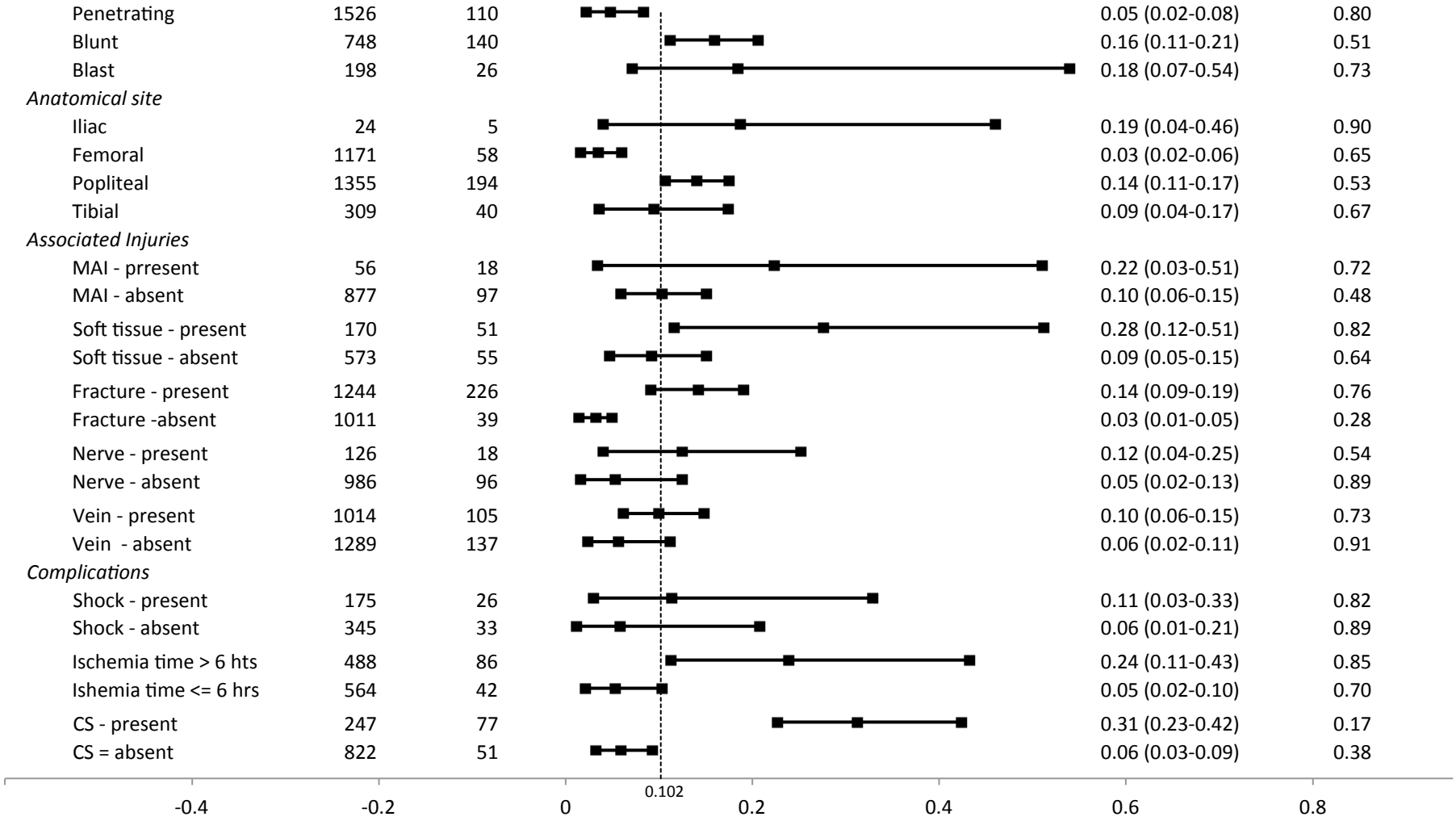
Risk Category	Sensitivity	Specificity	PPV
Yellow	0.90	0.83	0.39
Orange	0.69	0.9	0.49
Purple	0.54	0.97	0.71
Red	0.41	0.99	0.85



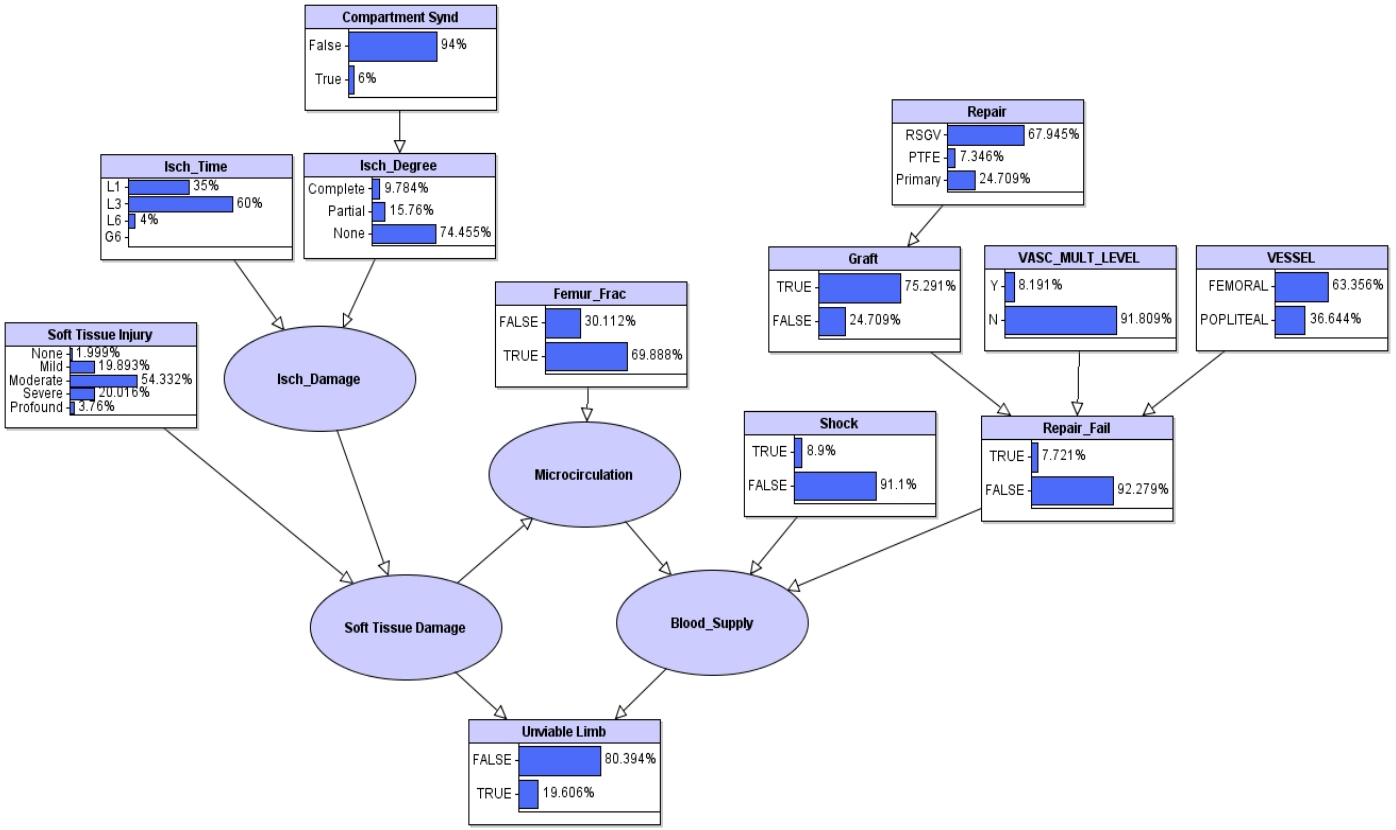

INJURED PATIENT
SAVE LIFE
VIABILITY
FUNCTION
SAVE LIMB
INFECTION
Rx FAILURE

Prognostic Factors for 2nd Amp

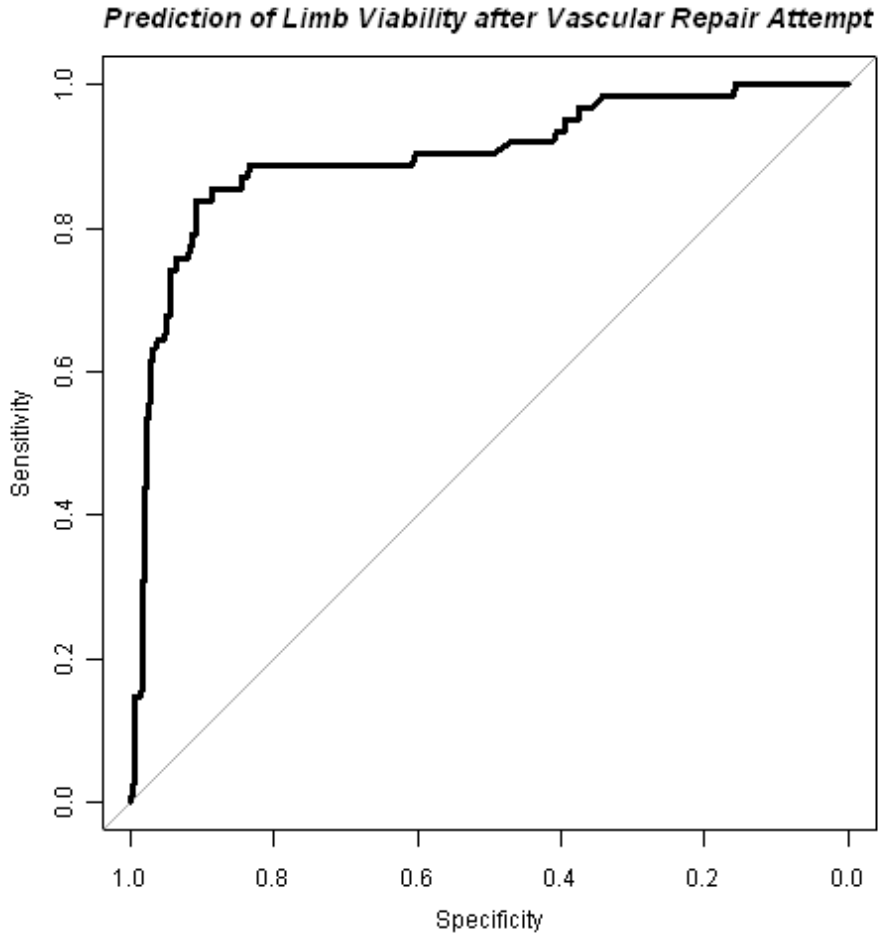
Prognostic Factor	Sample	Events	Pooled Proportion (95% CI)	Heterogeneity
Mechanism of Injury				
Penetrating	1526	110	0.05 (0.02-0.08)	0.80
Blunt	748	140	0.16 (0.11-0.21)	0.51
Blast	198	26	0.18 (0.07-0.54)	0.73
Anatomical site				
Iliac	24	5	0.19 (0.04-0.46)	0.90
Femoral	1171	58	0.03 (0.02-0.06)	0.65
Popliteal	1355	194	0.14 (0.11-0.17)	0.53
Tibial	309	40	0.09 (0.04-0.17)	0.67
Associated Injuries				
MAI - prresent	56	18	0.22 (0.03-0.51)	0.72
MAI - absent	877	97	0.10 (0.06-0.15)	0.48
Soft tissue - present	170	51	0.28 (0.12-0.51)	0.82
Soft tissue - absent	573	55	0.09 (0.05-0.15)	0.64
Fracture - present	1244	226	0.14 (0.09-0.19)	0.76
Fracture -absent	1011	39	0.03 (0.01-0.05)	0.28
Nerve - present	126	18	0.12 (0.04-0.25)	0.54
Nerve - absent	986	96	0.05 (0.02-0.13)	0.89
Vein - present	1014	105	0.10 (0.06-0.15)	0.73
Vein - absent	1289	137	0.06 (0.02-0.11)	0.91
Complications				
Shock - present	175	26	0.11 (0.03-0.33)	0.82
Shock - absent	345	33	0.06 (0.01-0.21)	0.89
Ischemia time > 6 hts	488	86	0.24 (0.11-0.43)	0.85
Ishemia time <= 6 hrs	564	42	0.05 (0.02-0.10)	0.70
CS - present	247	77	0.31 (0.23-0.42)	0.17
CS = absent	822	51	0.06 (0.03-0.09)	0.38



Limb Viability Bayesian Network



Validation – Limb Viability



AUROC:

0.901 (95%CI: 0.85 – 0.95)

Sensitivity: 90%

Specificity: 81%

Calibration: p = 0.01

Conclusion

- Demonstrated viable alternative to scoring systems
  - For complex decision pathways
- Key features
  - Flexible inputs
  - Causal models: historical data and clinical knowledge
  - Include underlying states
  - Measurement data and guided review
  - Adaptable to new evidence
- Promising application to ATC and Vascular Limb Injuries
- Many potential applications of techniques