A Progressive Explanation of Inference in Hybrid Bayesian Networks for Supporting Clinical Decision Making

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Overview

Introduction
Background
Method
Case Study
Conclusion

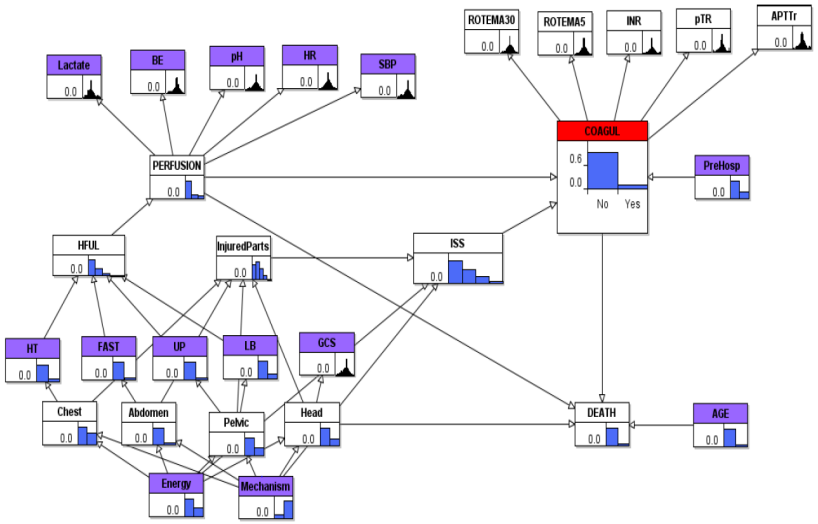
Introduction

Problem:

- Many predictive models have been developed in medicine as decision tools but very few have been trusted and used in practice

Proposed Solution:

- Explain the model's reasoning


ROTEMA30
ROTEMA5
INR
pTR
APTTr
Lactate
BE
pH
HR
SBP
COAGUL
PERFUSION
PreHosp
No
Yes
HFUL
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ISS
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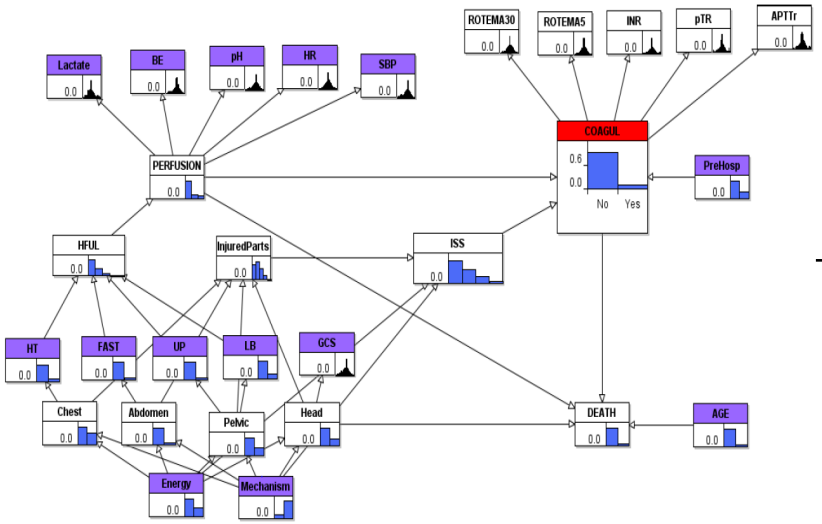
LB
GCS
Chest
Abdomen
Pelvic
Head
DEATH
AGE
Energy
Mechanism



Instantiate the evidence

Background Information

Mechanism of Injury	Energy of Injury	Fluid Volume Transfused	Age
○ Penetrating	◉ High	◉ ≥ 500ml	○ ≥ 65
◉ Blunt	○ Low	○ < 500ml	◉ < 65
○ Unknown	○ Unknown	○ Unknown	○ Unknown

Primary Survey Results

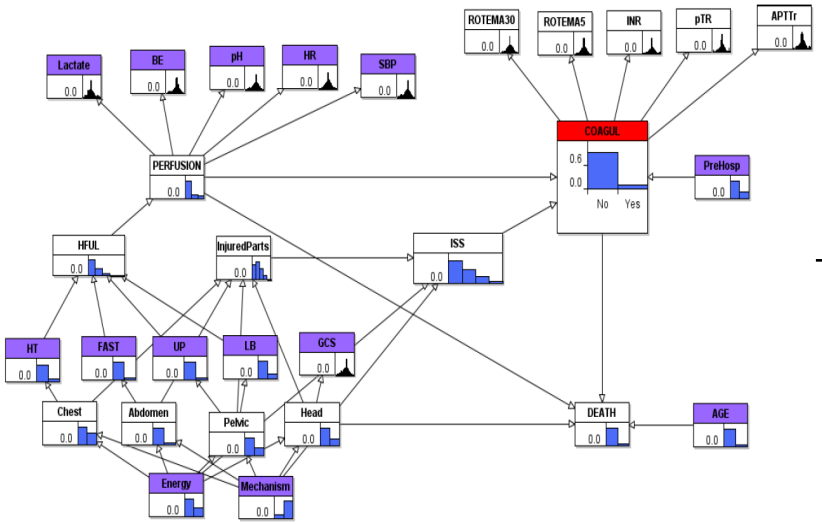
Haemothorax	Long Bone Injury	Unstable Pelvis	FAST Scan
○ Yes	○ Yes	◉ Yes	○ Positive
◉ No	◉ No	○ No	○ Negative
○ Unknown	○ Unknown	○ Unknown	◉ Unknown

Vitals

Heart Rate	Systolic Blood Pressure	Glasgow Coma Score
108	130	8

Arterial Blood Gas

Lactate	Base Excess	pH
4	-4	7.43



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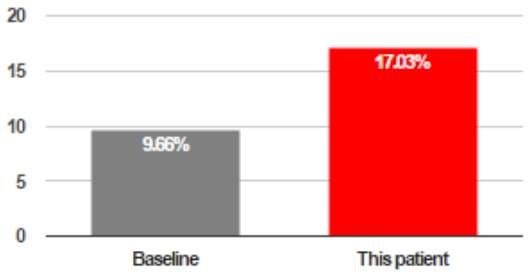
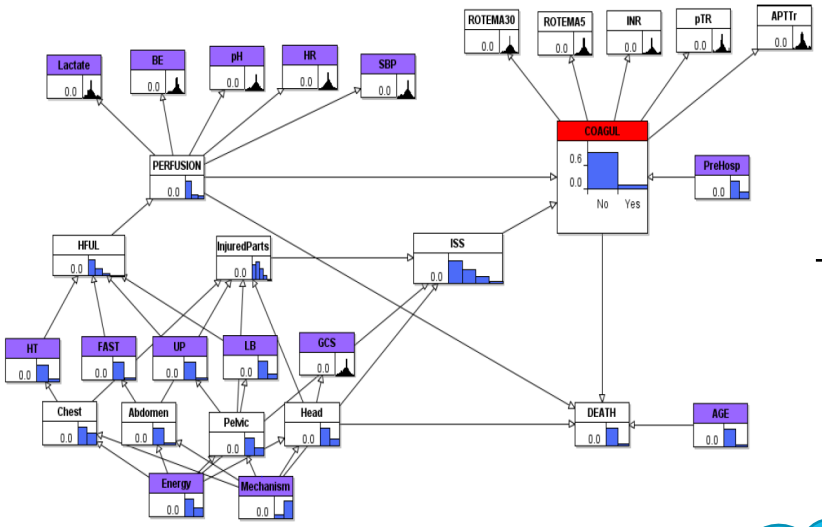
Inferred risk of coagulopathy





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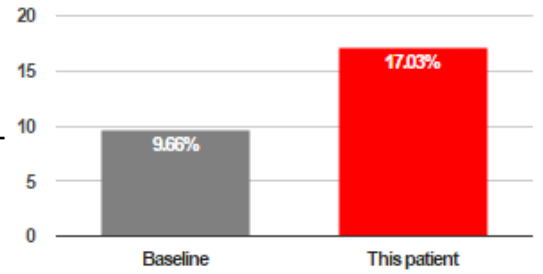
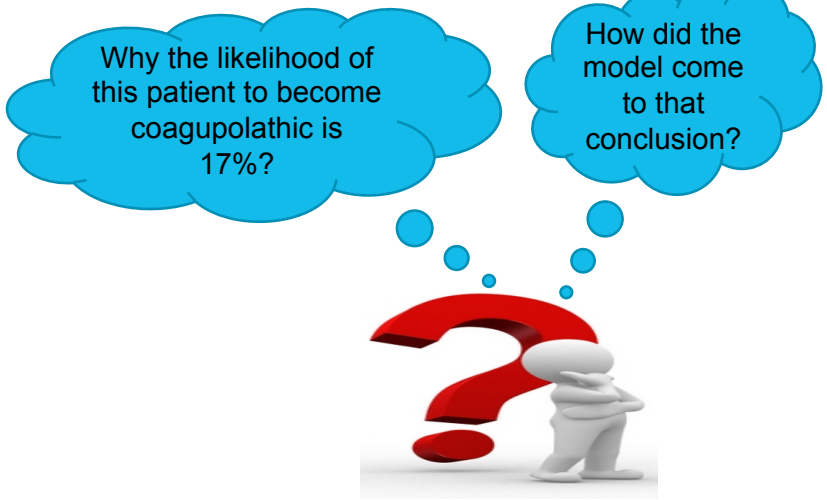


Understanding



What is an explanation?

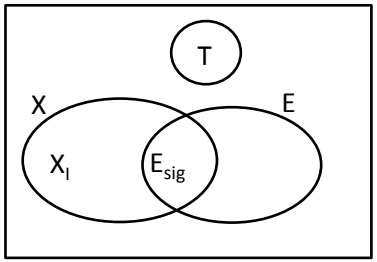
A detailed justification that makes something and its reasons understandable to the receiver of the explanation.

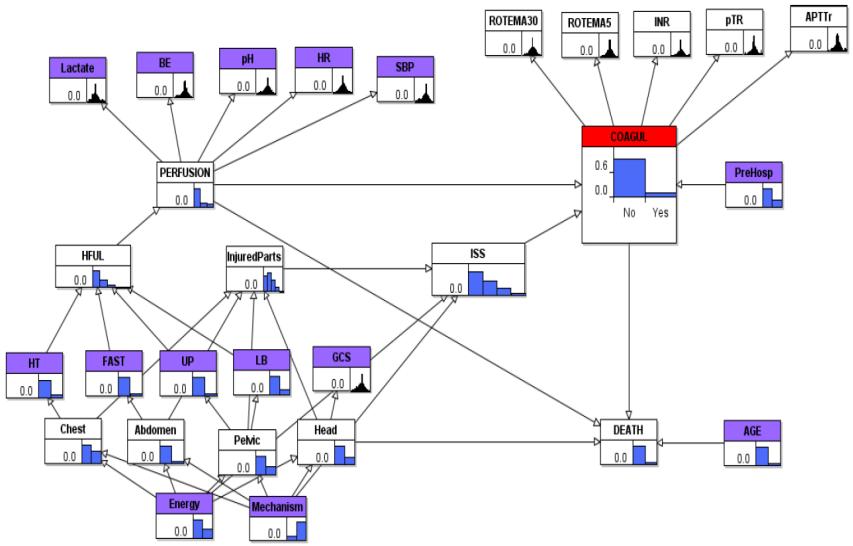
Types of explanation in BNs

- Explanation of the model
- Explanation of the evidence
- Explanation of reasoning

Notation

- T: target variable
- E: set of evidence
- E_{sig}: set of significant evidence
- X_I: set of intermediate variables
- X: set of explanatory variables





Explanation of reasoning

A 3-level explanation of reasoning:

- Level 1: E_{sig} that have a significant effect on T
- Level 2: Flow of information from E_{sig} to T through the unobserved variables X_l
- Level 3: Effect of each E_{sig} on the unobserved variables X_l

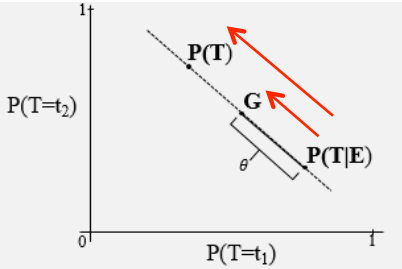
Level 1: Significant evidence variables

Impact:

$Im{\downarrow}E\,(e) \triangleq D{\downarrow}KL\,(P(T|E)\,||\,PTE\backslash e)$

Threshold of significance:

- Threshold ϑ: minimum impact so that $e \in E_{sig}$ iff $\mathrm{Im}_E(e) \geq \vartheta$

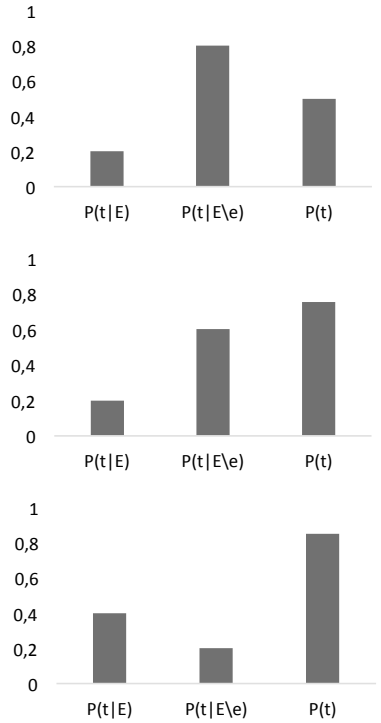


$$G \triangleq PTE - \alpha(PTE - P(T))$$

$$\vartheta \triangleq D{\downarrow}KL\,(P(T|E)\,||\,G)$$

Level 1: Conflict analysis

Conflict Category	Direction	Impact
Dominant	$D_{consitent}$	$Im_E(e) > Im_E(E)$
Consistent	$D_{consitent}$	$Im_E(e) \leq Im_E(E)$
Conflicting	$D_{conflicting}$	n/a
Mixed consistent	D_{mixed}	$Im_E(e)_t \mid t \in d_{cons}(e, t) > Im_E(e)_t \mid t \in d_{conf}(e, t)$
Mixed conflicting	D_{mixed}	$Im_E(e)_t \mid t \in d_{cons}(e, t) \leq Im_E(e)_t \mid t \in d_{conf}(e, t)$



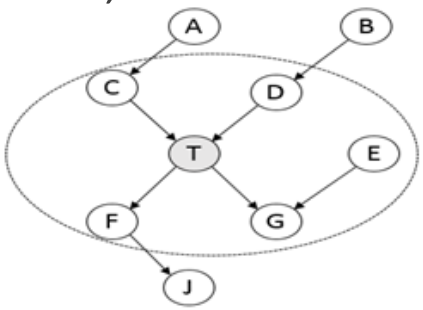
Level 2: Flow of information

Intermediate variables X_I

- Middle step in the reasoning process from E_{sig} to T
- Unobserved variables

Markov Blanket variables

- A variable's parents, children and children's other parents



Level 3: Effect of evidence on the intermediate variables

For each variable in X_I :

- Determine the subset of E_{sig} that are d-connected to X_I
- Carry out a conflict analysis

A complicated real case study

Background Information

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○ Unknown	○ Unknown	○ Unknown	○ Unknown

Primary Survey Results

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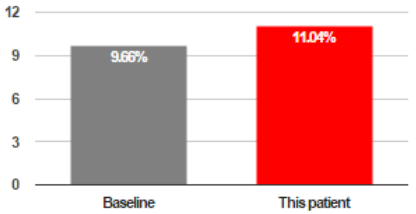
◉ Yes	○ Yes	○ Yes	○ Positive
○ No	◉ No	◉ No	◉ Negative
○ Unknown	○ Unknown	○ Unknown	○ Unknown

Vitals

Heart Rate	Systolic Blood Pressure	Glasgow Coma Score
120	168	5

Arterial Blood Gas

Lactate	Base Excess	pH
0.9	-2.2	7.37



WHY?

Level 1: E_{sig} that have a significant effect on T

- Threshold of significance
- Supporting evidence
- Conflicting evidence

Level 2: Flow of information from E_{sig} to T through the unobserved variables X_l

Level 3: Effect of each E_{sig} on the unobserved variables X_l

- Supporting evidence
- Conflicting evidence

Level 1

The percentage of change in the uncertainty of Coagulopathy between this patient and an average trauma call patient that is considered insignificant is 50%.

What are the factors that support the above prediction of 'Coagulopathy'? Factors that support the above prediction of 'Coagulopathy' (strongest to least):

- *Pre-hospital fluids $\geq$ 500mls (Very important)*
- *GCS = 5 (Very important)*
- *Haemothorax = Yes (Very important)*
- *Energy of injury = High*

What are the factors that do not support the above prediction of 'Coagulopathy'? Factors that do not support the above prediction of 'Coagulopathy' (strongest to least):

- *Systolic Blood Pressure = 168*
- *Long Bone feacture = No*
- *Lactate = 0.9*

Level 2

How does the model utilize the above factors to predict 'Coagulopathy'? As the immediate causes of 'Coagulopathy' the model uses:
(1) 'Tissue Perfusion': 26% increase in risk of having a Normal 'Tissue Perfusion' than an average trauma call patient.
(2) 'Tissue Injury': 230% increase in risk of having a Severe 'Tissue Injury' than an average trauma call patient.

Level 3

(1) Factors that support the prediction of 'Tissue Perfusion':

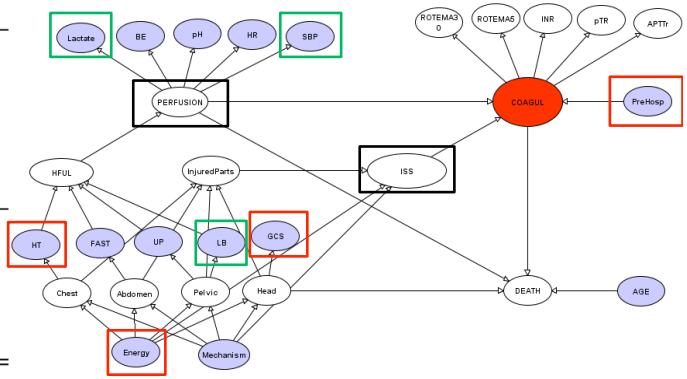
- *Systolic Blood Pressure = 168*
- *Lactate = 0.9*
- *Long Bone fracture = No*

Factors that do not support the prediction of 'Tissue Perfusion':

- *Haemothorax = Yes*

(2) Factors that partially support the prediction of 'Tissue Injury':

- *GCS = 5*
- *Haemothorax = Yes*
- *Energy of injury = High*
- *Long Bone feacture = No*



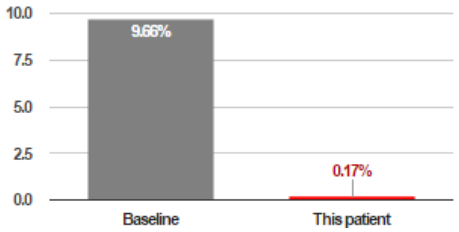
An easy real case study

Background Information			
Mechanism of Injury	Energy of Injury	Fluid Volume Transfused	Age
◉ Penetrating	○ High	○ ≥ 500ml	○ ≥ 65
○ Blunt	◉ Low	◉ < 500ml	◉ < 65
○ Unknown	○ Unknown	○ Unknown	○ Unknown

Primary Survey Results			
Haemothorax	Long Bone Injury	Unstable Pelvis	FAST Scan
○ Yes	○ Yes	○ Yes	○ Positive
◉ No	◉ No	◉ No	◉ Negative
○ Unknown	○ Unknown	○ Unknown	○ Unknown

Vitals		
Heart Rate	Systolic Blood Pressure	Glasgow Coma Score
93	157	15

Arterial Blood Gas		
Lactate	Base Excess	pH
2.8	-0.6	7.41



WHY?

Level 1

The percentage of change in the uncertainty of Coagulopathy between this patient and an average trauma call patient that is considered insignificant is 0.1%.

What are the factors that support the above prediction of 'Coagulopathy'? Factors that support the above prediction of 'Coagulopathy' (strongest to least):

- *Energy of injury = Low*
- *Mechanism of injury = Penetrating*
- *Fast scan = Negative*
- *Haemothorax = No*
- *Long Bone fracture = No*
- *GCS = 15*
- *Pre-hospital fluids < 500mls*
- *Systolic Blood Pressure = 157*
- *Base Excess = -0.6*

Level 2

How does the model utilize the above factors to predict 'Coagulopathy'? As the immediate causes of 'Coagulopathy' the model uses:
(1) 'Tissue Perfusion': 32% increase in risk of having a Normal 'Tissue Perfusion' than an average trauma call patient.
(2) 'Tissue Injury': 78% increase in risk of having a Mild 'Tissue Injury' than an average trauma call patient.

Level 3

(1) Factors that support the prediction of 'Tissue Perfusion':

- *Systolic Blood Pressure = 157*
- *Haemothorax = No*
- *Fast scan = Negative*
- *Long Bone fracture = No*

(2) Factors that support the prediction of 'Tissue Injury':

- *Energy of injury = Low*
- *Mechanism of injury = Penetrating*
- *Fast scan = Negative*
- *Haemothorax = No*
- *Long Bone fracture = No*
- *GCS = 15*

Conclusion

Benefits of an explanation:

- Make the model's prediction more trustworthy
- Potential benefit on the validation of the model's structure

Future Steps

- Enhance the explanation visually
- Evaluate the benefits of the explanation in real time

Thank you for your attention!