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Assessing Mortality of Blunt Trauma with Co-morbidities.

Clive E. Neal-Sturgess

Emeritus Professor of Mechanical Engineering
University of Birmingham
Formerly Jaguar Professor of Auto Engineering
Visiting Professor at:
Coventry University
Birmingham City University

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"..a living organism tends to approach the dangerous state of maximum entropy, which is death." Erwin Schrodinger, What is Life? 1944.

- Supposedly read more times than the Bible
- Inspired Watson & Crick on DNA

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❖What is Entropy?

- ❖ En (Energy) + Tropy (Greek for states)
- ❖ Stastically proportional to the probabilities of microstates in the system
- ❖ Non statistical proportional to the reduction of free energy, i.e. work done
- ❖ From conservation of energy when free energies decrease, something must go up – **Entropy!**

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Entropy - invented many times!

- Joshua Willard Gibbs' - 1863
  - Brilliant American thermodynamicist
  - Published in an obscure American Journal
  - Far from equilibrium & thermodynamic
- Plank-Boltzman – 1872-5
  - Didn't know about Gibbs
  - Assumes equilibrium, so an approximation to Gibbs' - thermodynamic

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Types of Entropy (2)

- von Neumann - 1932
  - one of the great mathematicians of the 21st century
  - generalisation of Gibbs - thermodynamic
- Shannon (Information) - 1948
  - One of the father's of information theory
  - Link to von Neumann, used in ECG and EEG etc.
- Tsallis - 1988
  - Extra disposable constant, so more general
  - Reduces to Gibbs', P-B and VN

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The Injury severity Score (ISS) is the default world standard for assessing the severity of multiple injuries. ISS is a mathematical fit to empirical field data. In 2011 Sturgess demonstrated that ISS is proportional to the Gibbs/Boltzman Entropy

$$ISS = MAIS_1^2 + MAIS_2^2 + MAIS_3^2$$

$$\mathrm{Ln(ISS)} = 2\sum_{i=1}^{i=3} \mathrm{Ln(MAIS_i)}$$

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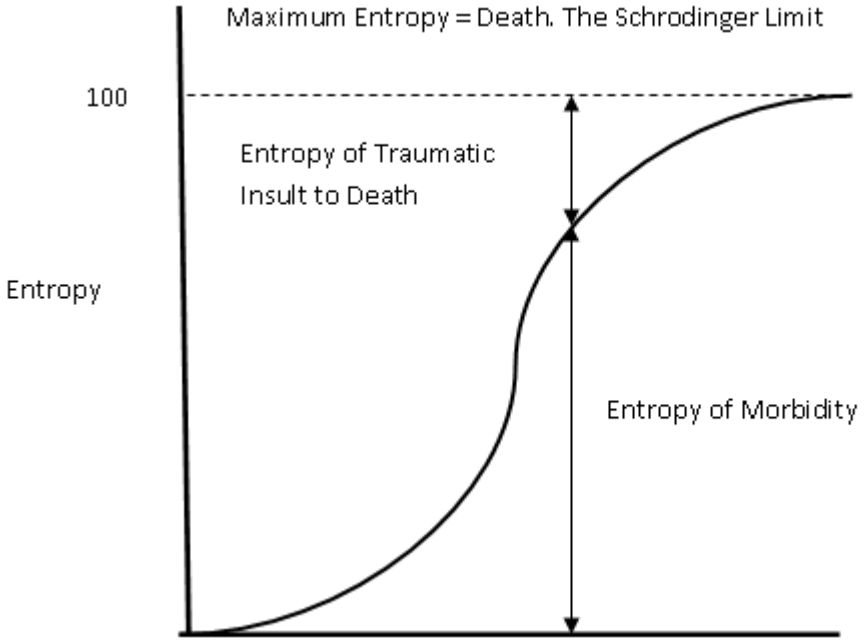

$$S_{Mt} = S_{Mb} + k \sum p_i lg p_i$$

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- Age is universally used as a surrogate for frailty – very coarse grained
  - Can lead to missed diagnoses
- Frailty a complex topic – physiological and psychological reserves
  - 70 metrics!
- Empirical measures ASCOT, TRISS etc
- Statistical, based on means – not specific,
- Need Physics based specific measures

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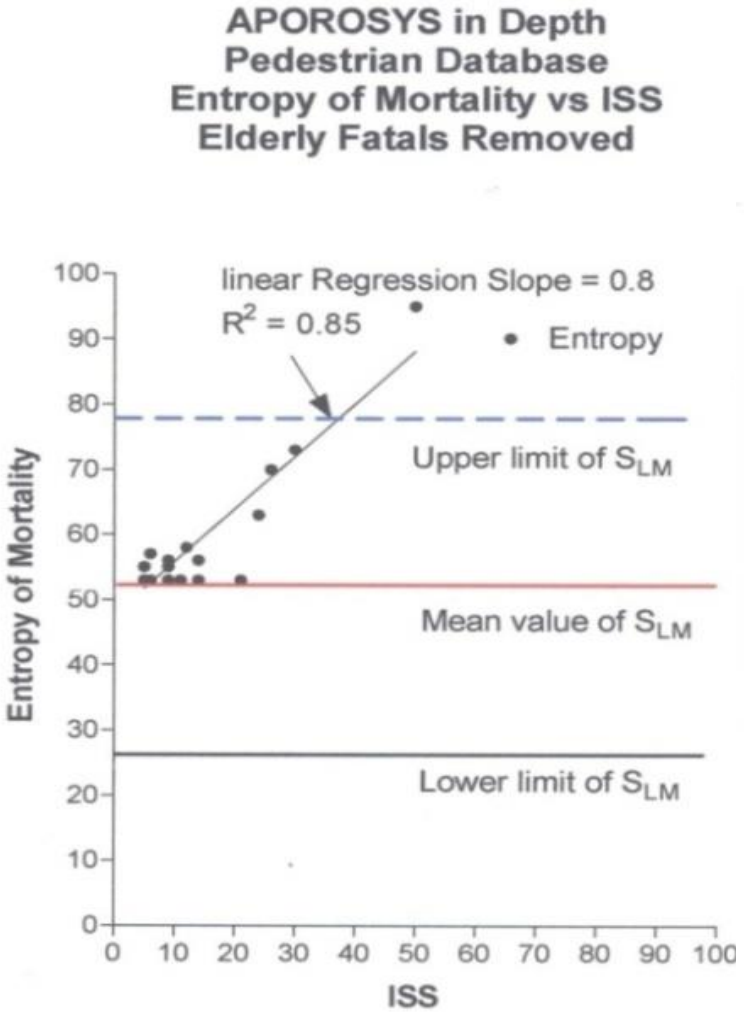

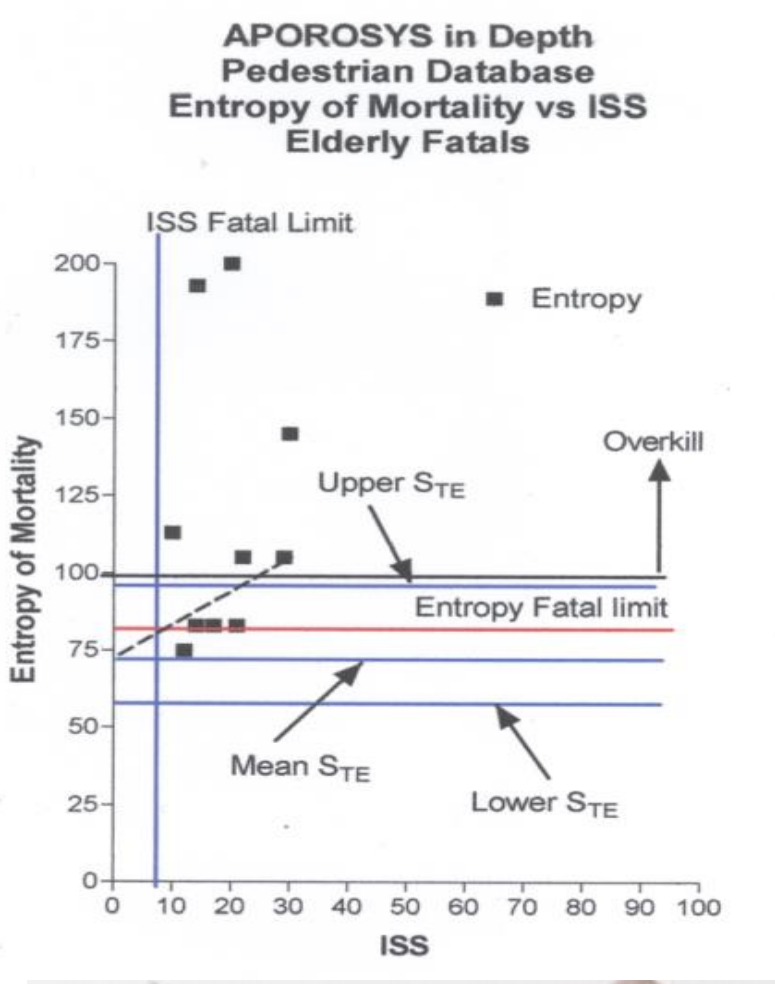

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- The problem is to estimate the **specific** Entropy of Morbidity,
- In an earlier paper (Neal-Sturgess 2011) derived the entropy of mortality in a coarse grained manner, as shown on previous slide.. However, a finer grained specific estimate of the entropy of morbidity is ideally required.

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- Here it is assumed that the principal cause of the increased adverse outcomes, with age from crashes, are **Pre-existing Medical Conditions** (PMC's).
- An Abbreviated Morbidity Score (AMS), analogous to the Abbreviated Injury Score (AIS) is postulated.
- A Combined Mortality Score (CMS) is then postulated based on summing the von Neumann's entropies.

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- If a human body is subject to multiple injuries to a given body region $AIS_{i\text{-}n}$ which are represented as the Eigenvectors (rows) of an Injury Density Matrix IDM, and if the maximum AIS (MAIS) is treated as the Eigenvalue of the injury Eigenvector (diagonalisation), an injury density matrix IDM can be constructed

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$$IDM = \begin{bmatrix} AIS_{11} & AIS_{12} & AIS_{13} \ldots\ldots\ldots \\ AIS_{21} & AIS_{22} & AIS_{23} \ldots\ldots\ldots \\ AIS_{31} & AIS_{32} & AIS_{33} \ldots\ldots\ldots\ldots \end{bmatrix}$$

he 2nd power of the Trace is

$$Tr\,(I)^2 = \mathrm{AIS}_{11}\mathrm{AIS}_{11} + \mathrm{AIS}_{22}\mathrm{AIS}_{22} + \mathrm{AIS}_{33}\mathrm{AIS}_{33} \ldots. = \sum_{i=1}^{n}\sum_{i=1}^{n} a_{ij}a_{ji}$$

Which is the Injury Severity Score, ISS.

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- If the MAIS's are replaced by the respective probabilities of death (p_{ij}) in the form of the Gibbs Entropy i.e. $(\rho log \rho)$ then they can also be regarded as a density matrix, and the relevant value is the von Neumann entropy as:
- $$S(\rho) = -kTr(\rho log \rho)$$
- Which is the true meaning of ISS

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- If the co-morbidities are described as the Abbreviated Morbidity Score {AMS(n)}, it is possible to construct a Morbidity Density Matrix (MDM) as;
- $$MDM = \begin{bmatrix} AMS_{11} & AMS_{12} & AMS_{13} \ldots\ldots\ldots \\ AMS_{21} & AMS_{22} & AMS_{23} \ldots\ldots\ldots \\ AMS_{31} & AMS_{32} & AMS_{33} \ldots\ldots\ldots\ldots \end{bmatrix}$$

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- a vector resultant **R** can be constructed for the co-morbidities, and a vector resultant of **r,** for the trauma as:

$$R^2 = MAMS_1^2 + MAMS_2^2 + MAMS_3^2$$

$$r^2 = MAIS_1^2 + MAIS_2^2 + MAIS_3^2$$

- If the **Combined Mortality Score** (CMS) is, **then**

$$CMS = \lambda R^2 + r^2$$

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The leading causes of Death (2017) are:

Cause of Death	% of Total	Probability of death	TENTATIVE AMS
Heart Disease	23.4	0.234	5
Cancer	22.5	0.225	5
Respiratory Disease	5.6	0.056	4
Stroke	5.1	0.051	4
Diabetes	2.9	0.029	3
Pneumonia	2.1	0.021	3
Kidney Disease	1.8	0.08	3

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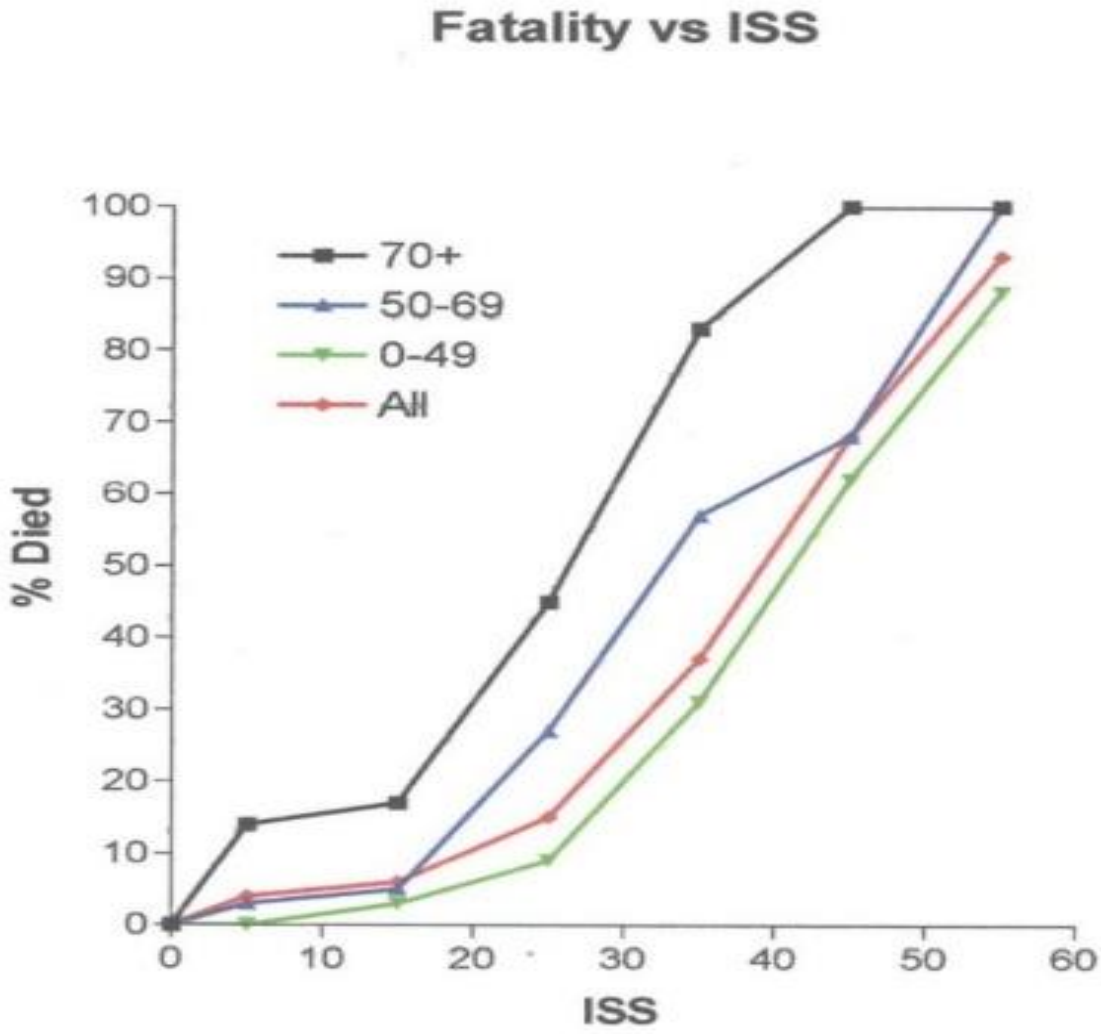

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- It can be seen that for 25 < ISS <45 the curves for the 0-49 age group and the 70+ group are approximately parallel, and separated by around 35 points.
- From the table above, with tentative AMS values, it is considered that the 70+ age group would most likely suffer from heart disease and possibly cancer, plus other conditions,; this would give an ISS uplift of at least $5^2 + 5^2 = 50$. However, in the round, casualties would probably suffer from one condition at score 5, plus others. Therefore, from equation 8, it would appear that a first approximation $\lambda \approx 0.7\text{-}1$.

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Conclusions

- A new Entropy measure of mortality from blunt force trauma additionally including specific co-morbidities of disease is derived based on the von Neumann Entropy – easy to use.
- The trauma measure has been applied to a previously published database, and good first correlation is achieved.

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- Applying Entropy measures to multiple injuries, further highlights the role of co-morbidities, and that the elderly die at much lower levels of injury than the general population.
- These considerations lead to questions regarding current new car assessment protocols, and how well they protect the most vulnerable road users.

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Coventry University

INJURY CAUSATION – PEAK VIRTUAL POWER

Questions ?

c.e.n.sturgess@bham.ac.uk

www.neal-sturgess.com