Perfusion-Diffusion Gas Content Compartmental Models As A Predictor Of Decompression Sickness

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Background

- Probabilistic Models as a predictor of decompression sickness (DCS)
  - Iso-risk
  - Tissue supersaturation ratio or bubble volume
  - Parallel perfusion limited compartments
  - Effective, but predict risk at the wrong time
  - 2 inert gases of concern nitrogen and helium

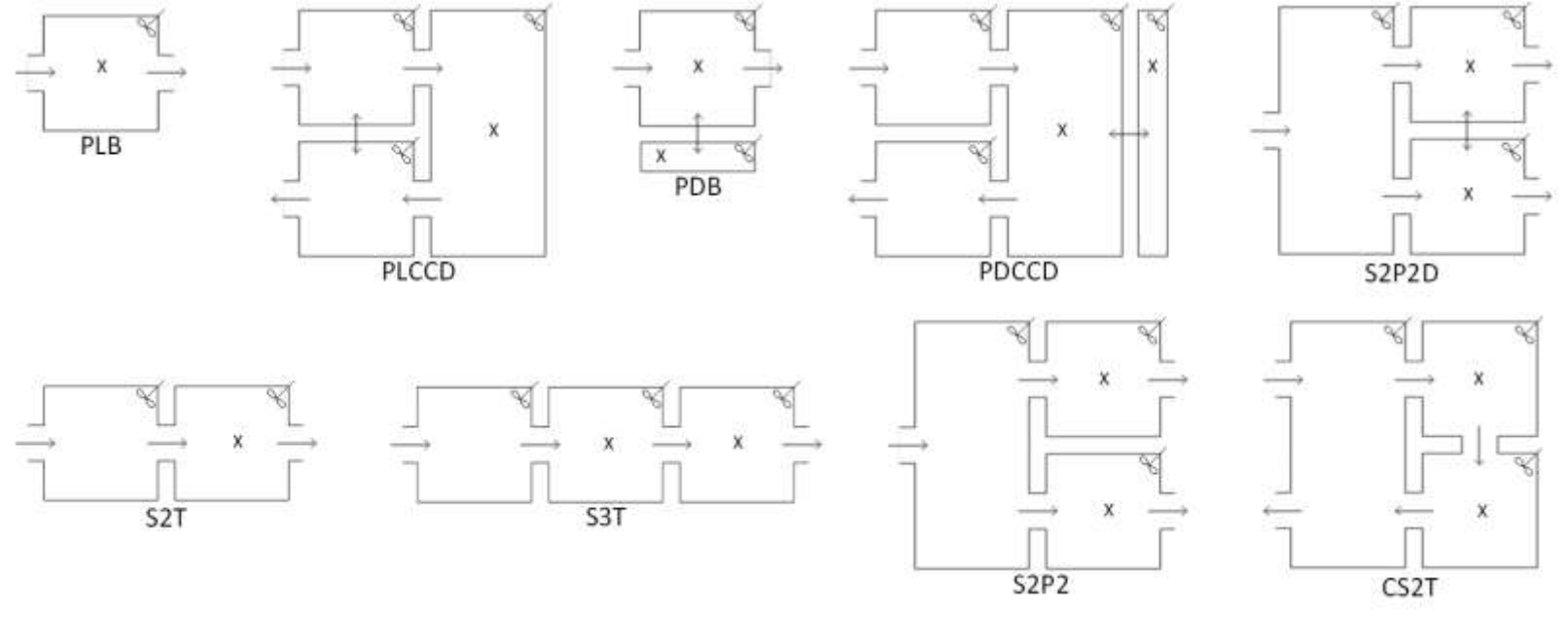
Motivation

- Doolette, Grant, and Upton
  - Skeletal and Cerebral Helium Kinetics
  - 6 model forms
  - Perfusion and/or diffusion limited compartments
- Pharmacokinetic models have existing mechanisms to delay onset
  - Series and/or parallel compartments
  - Serial compartments known to add delay effect
  - Simple code and test

Our Models

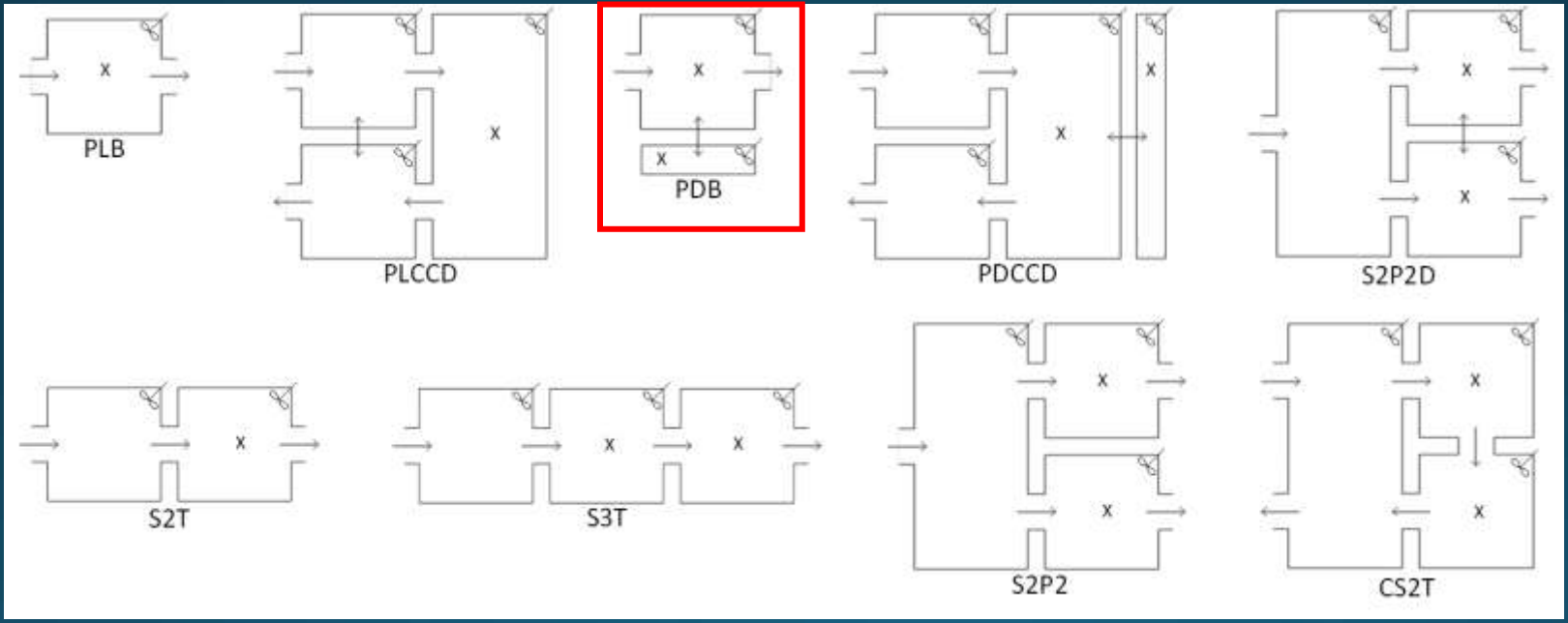
- Assumptions
  - Diffusion is bidirectional and occurs at equal rates
  - Exponential kinetics in every compartment
  - All compartments well mixed
  - System matrices derived from mass balance
- 4 Models from Doolette, Grant, and Upton plus 5 others
  - Models from Doolette et al
    - Perfusion Limited Base (PLB)
    - Perfusion-Limited Countercurrent Diffusion (PLCCD)
    - Perfusion-Diffusion Base (PDB)
    - Perfusion-Diffusion Countercurrent Diffusion (PDCCD)
  - Models derived to add delay
    - Serial Two Tissue (S2T)
    - Serial Three Tissue (S3T)
    - Serial Two Parallel Two (S2P2)
    - Serial Two Parallel Two Diffusion (S2P2D)
    - Central Serial Two Tissue (CS2T)

Model Forms



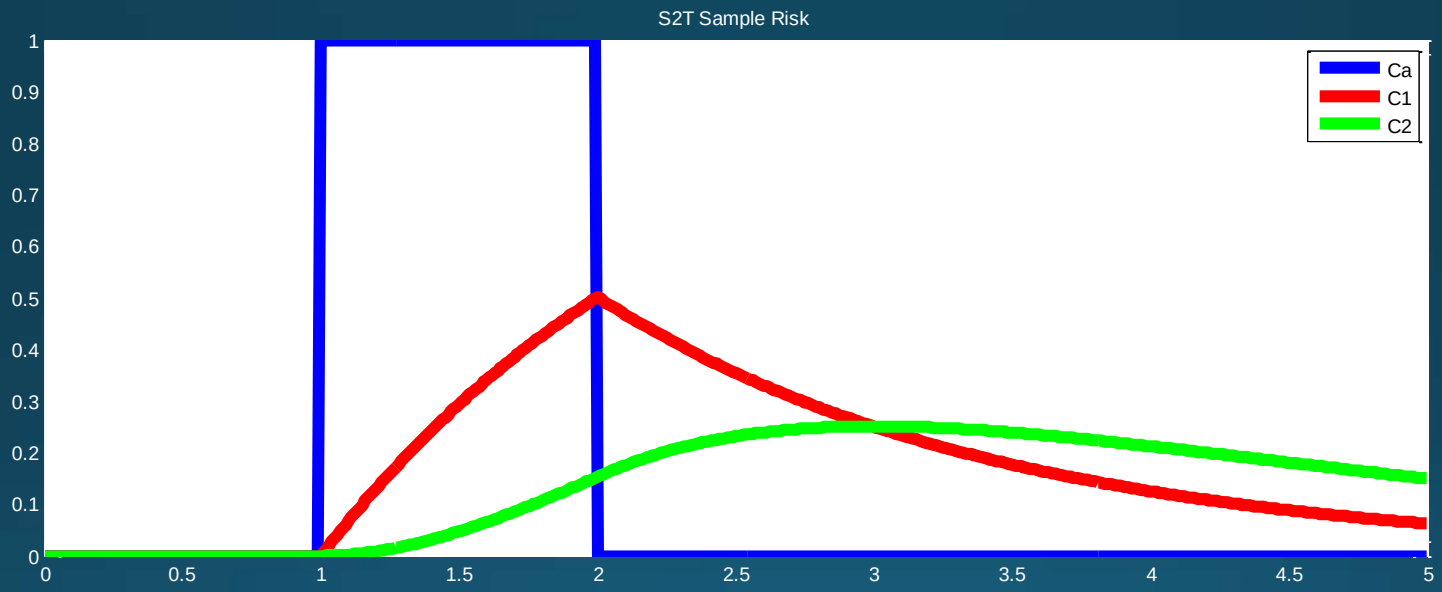
Risk bearing compartments marked with an X

Model Forms



Risk bearing compartments marked with an X

S2T Risk Delay



Methods

- Models implemented in C++ and C#
- Data set described by Parker et al (NMRI98)
  - 1,349 dive profiles
  - 223 cases of DCS
  - Marginal DCS ignored
- Model fitting performed with Nelder-Mead and Levenberg-Marquardt algorithms
- Local resources and Blue Gene/Q at Argonne National Laboratory Leadership Computing Facility
- Goal of 256 solutions to consider fitting complete
- Akaike Information Criterion (AIC) used to compare models

Methods – Sub Groups

- One model type may fit a specific type of diving (bounce, submarine escape, sat, etc…) better than others
- Data broken into 7 sub groups
  - Single bounce dives
  - Single bounce dives excluding submarine escape
  - Repetitive dives
  - Single bounce and repetitive dives
  - Oxygen decompression dives
  - Saturation dives
  - Submarine escape and aggressive bounce dives
    - Not described as a sub group by Parker et al

Results Full Data Set

Model	Solutions	Best Log Likelihood	AIC
CS2T	32	-1366.75	0.999828
PDB	3	-1395.35	1.04E-12
PDCCD	0	N/A	0
PLB	256	-1387.17	7.47E-08
PLCCD	240	-1379.98	1.34E-05
S2LPD	1	-1482.98	1.22E-51
S2LP	3	-1376.50	0.000159
S2T	256	-1388.39	8.1E-09
S3T	2	-1400.15	8.52E-15

Results Sub Groups

Sub Group	Best Model	AIC
Bounce No Repet	PDB	1
Bounce No Repet No SubX	PDB	0.9251954463683 06
Bounce Repet Only	PDB	0.5285372629630 23
Bounce With Repet	PDB	1
O2 Decompression	PLB	0.5777794353405 92
Saturation	CS2T	0.6866754259631 61
SubX Enhanced	PDB	1

Future Work

- Parallel Functional Groups
  - Are the data combinable?
  - How many groups are statistically justifiable?
  - Do parameters hold steady or change when refit?
- Add a bubble

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