NEW CLASSES OF INTERCONNECTED COMPARTMENTAL DCS MODELS

Howle LE[1,2], DiMuro, G[2], Doolette, DJ[3], Vann RD[4,5]
[1]BelleQuant Engineering, PLLC, Mebane, NC
[2]Mechanical Engineering, Duke University, Durham, NC
[3]Navy Experimental Diving Unit, Panama City, FL
[4] Anesthesiology Department, Duke Medical Center, Durham, NC
[5]Divers Alert Network, Durham, NC

INTRODUCTION

- Parallel, well-perfused compartmental decompression models generate gas kinetics that are *mono-exponential* in each compartment.
- *Multi-exponential* DCS models can arise from interconnected tissue compartments [1].
- Multi-exponential models have been shown to model gas washout dynamics better than mono-exponential models [2-9].
- Multi-exponential dynamics can be fitted by considering either macro [2-8] or micro [1,8] constants.
- Multi-exponential gas dynamics models have been shown to extrapolate better than mono-exponential gas dynamics models [4,9].

METHODS

- We derived exact solutions for general interconnected models with any number of compartments and for any interconnection.
- Four 3-compartment models were considered based on the structure of the tissue coupling eigenvalue matrix: upper triangular (UT), symmetric (SY), skew symmetric (SK), general (GN).
- Each of the three compartments was potentially risk-bearing.
- Models were fitted to the Navy BIG292 data set [10] using maximum log likelihood with parallel processing [11].
- Fractional (0.1) marginal DCS events [12] were used for consistency with earlier works.
- Failure times [13] were not used in calibration.
- New models were compared with the EE1 three parallel compartment model [14] as null.
- Model extrapolation was tested on 5164 exposures with 214 full and 329 marginal DCS cases.
- Extrapolation quality was quantified using Pearson's group χ^2 test.

RESULTS

Fitting	2 LL diff.	Added DOF	95% Limit	95% Test
UT/EE1	16.98	3	7.81	Pass
SK/EE1	9.33	3	7.81	Pass
SY/EE1	27.41	3	7.81	Pass
GN/EE1	27.65	6	12.59	Pass
GN/UT	10.67	3	7.81	Pass
GN/SK	18.32	3	7.81	Pass
GN/SY	0.24	3	7.81	Fail

Table 1. Model fitting comparisons for the BIG292 calibration data set. All models were a significant ($p < 0.05$) improvement over the EE1 null model.

Extrapol.	Obs.	EE	UT	SK	SY	GN
Total DCS	246.9	306.3	235.4	284.6	280.0	285.9
Pears. X^2		76.90	40.20	99.21	65.52	68.10

Table 2. Extrapolation dive prediction study. The UT model outperformed all other models.

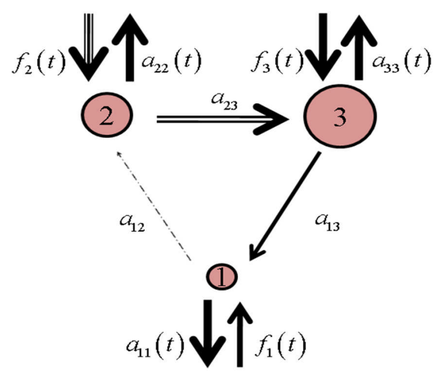

Figure 1. Upper triangular (UT) interconnected model structure. Arrow thickness represents the strength of the gas transfer with direction shown for a *positive* coefficient. f_i, a_{ii} , and a_{ij} respectively represent gas uptake from arterial blood, elimination to venous blood, and inter-compartmental transfer.

- Interconnected models with a single risk-bearing compartment failed to fit BIG292.
- All four new interconnected multi-exponential models with risk in each compartment were significant ($p<0.05$) improvements over the EE1 null model for the calibration data (Table 1).
- The SK model generalized more poorly to extrapolation data than the EE1 null model (Table 2).
- The UT, SY, and GM models generalized to the extrapolation data better than the null model (Table 2).
- The UT model was superior to all other models on the extrapolation data (Table 2).
- The UT model performed especially well on surface O_2 decompression dives.
- The UT model structure used 3 risk-bearing compartments that couple from slower to faster compartment (Figure 1).

REFERENCES

1. Jacquez. Univ. Michigan Press. 1985.
2. Weathersby *et al.* J. Appl. Phys. 1979.
3. Weathersby *et al*. J. Appl. Phys. 1981.
4. Tikuisis *et al.* Und. Biomed. Res. 1988.
5. Novatny *et al.* J. Appl. Phys. 1990.
6. Doolette *et al.* J. Pharm. Bioph. 1998.
7. Doolette *et al*. Acta Phys. Scand. 2001.
8. Doolette *et al.* Acta Phys. Scand. 2005.
9. Goldman J. Appl. Phys. 2007
10. Survanshi *et al.* NMRI 97-36. 1997.
11. Howle *et al.* Comp. Bio. Math. 2009.
12. Howle *et al.* J. Appl. Phys. 2009.
13. Weathersby *et al.* J. Appl. Phys. 1992.
14. Thalmann *et al*. Und. Hyp. Med.1997.

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