DELAY DIFFERENTIAL EQUATIONS AS AN EXPLICIT METHOD OF ALIGINING DCS MODEL PREDITION WITH DIVE DRIAL OUTCOME

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INTRODUCTION

Delayed onset of decompression sickness (DCS) with respect to the time of surfacing is common for most dive types, with the exception of saturation dives [1]. Some DCS predictive models, such as LE, have attempted to delay risk accumulation by use of modified gas kinetics [2]. Bubbles models also show delayed risk accumulation [3]. These models improve log likelihood values by better aligning risk accumulation with the observed DCS event windows. Explicit techniques exist which allow for temporal shifting of model predicted risk through the use of a time lag [4]. These techniques are applied to our previously studies pharmacokinetic DCS models [5].

METHODS

17 delay differential equation (DDE) models were derived based on our previously explored pharmacokinetic models [5]. Each model accumulated risk in 1-3 compartments, although some models contained up to four compartments in total. Delay was applied to the input in the first model compartment using an optimized delay parameter, (τ). Equation 1 shows the functional form of the compartment differential equation for PLB and DDEPLB to highlight the functional differences. Models were optimized using the Nelder-Mead algorithm on the Parker NMRI98 data set, which consists of 1349 dive profiles with 223 reported cases of DCS [6]. Model gains were calculated explicitly using our previously published technique [8]. Marginal DCS cases were not included as DCS events as they have been shown to decrease model performance [7].

TABLES, FIGURES, AND EQUATIONS

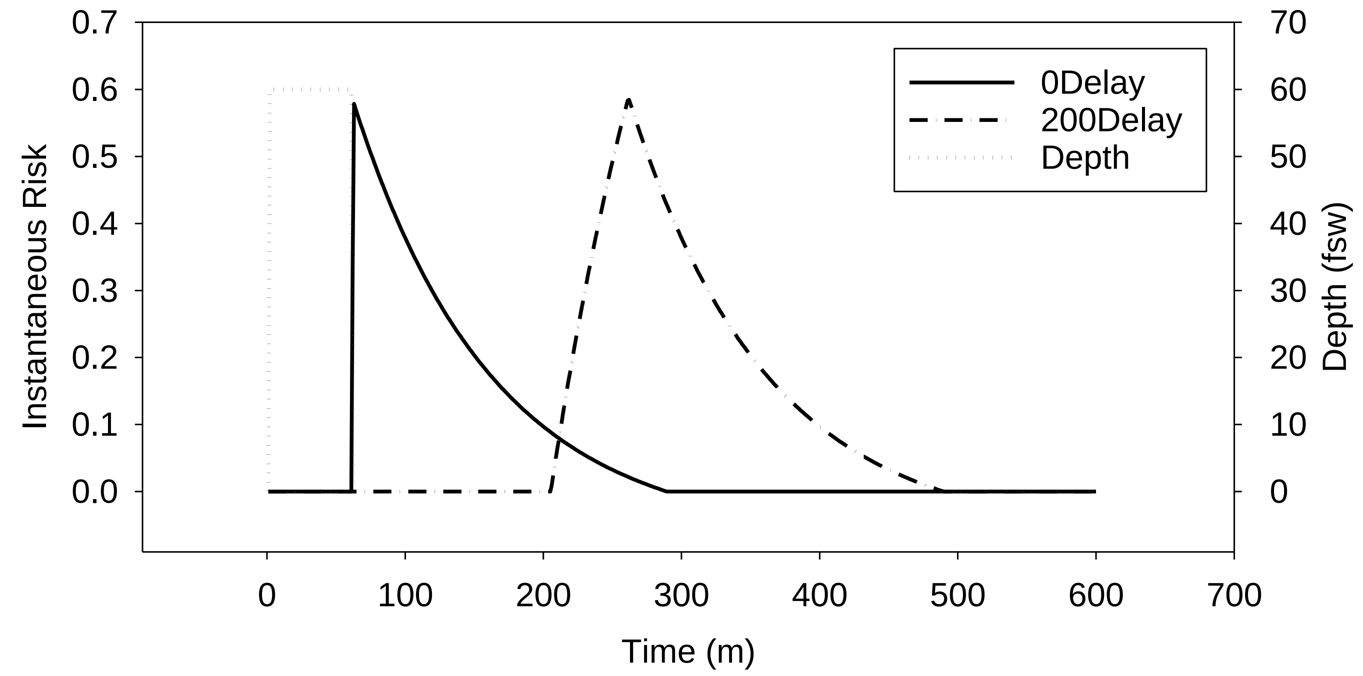
(a)

$$\text{PLB}: \frac{dp}{dt} = k_1\left(p_{art} - p\right)$$

$$\text{DDEPLB}: \frac{dp}{dt} = k_1\left(p_{art}(t-\tau) - p\right)$$

k : Tissue Rate t : Time
p : Tissue Pressure τ : Time Delay

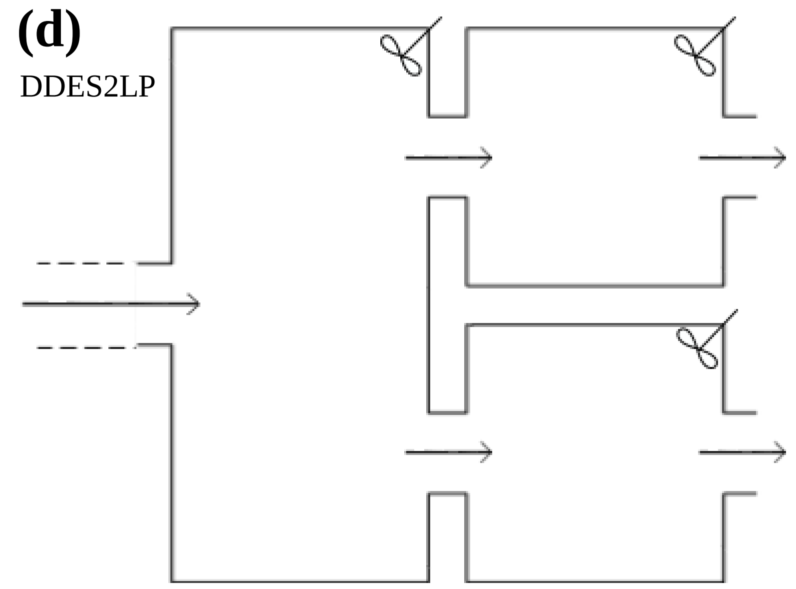
(b)



(c)

Model	L.L.	AIC
DDECS2T	-1203.3	0
DDECS2T3	-1174.06	0
DDEPDB	-1172.82	0.07
DDEPDCCD	-1247.58	0
DDEPLB	-1271.48	0
DDEPLCCD	-1271.48	0
DDES2LP	-1170.21	0.93
DDES2LPD	-1271.65	0
DDES2T	-1277.08	0
DDES3T	-1170.13	0

(d)



(a) PLB (not delayed) and DDEPLB (delayed) models.
(b) Comparison of PLB tissue tension with DDEPLB on a typical 60 FSW 60 minute dive profile using a delay parameter τ of 200 minutes.
(c) Summary of model fitting results. The DDSS2LP model contained 92% of evidence weight.
(d) Graphic model design of the DDES2LP.

DISCUSSION

Optimization of the various DDE models resulted in up to 32 solutions per model. The best LL solutions were used for AICc comparison. DDES2LP dominated the AICc weighting comparison with 92% of the overall evidence weight. The best fitting parameter set produced similar LL values to those observed in previous PK findings. Delay parameter values ranged between 1 and 120 minutes.

Based on the initial findings, delay applied to the input may allow improved predictive quality for some types diving operations. Continued research efforts will include investigations into DDE PK model performance on similar diving subsets previously explored [5].

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