Modeling Oxygen Prebreathe Protocols for Exploration Extravehicular Activities Using Variable Pressure Suits

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INTRODUCTION: Exploration missions are expected to use variable pressure extravehicular activity (EVA) spacesuits as well as a spacecraft "exploration atmosphere" of 56.5 kPa (8.2 psia), 34% O2, both of which provide the possibility of reducing the oxygen prebreathe times necessary to reduce decompression sickness (DCS) risk. Previous modeling work predicted 8.4% DCS risk for an EVA beginning at the exploration atmosphere, followed by 15 minutes of in-suit O_2 prebreathe, and 6 hours of EVA at 29.6 kPa (4.3 psia). In this study we model notional prebreathe protocols for a variable pressure suit where the exploration atmosphere is unavailable.

METHODS: A probabilistic model of DCS risk based on a biophysical model of decompression stress was used to evaluate EVA scenarios, beginning from saturation at 101.3 kPa (14.7 psia), 21% O_2, followed by 95% O_2 breathing at suit pressures ranging from 56.5 to 29.6 kPa (8.2 to 4.3 psia) for up to 6 hours. Previous validation of the model was based on significant prediction ($p<0.0001$) and goodness-of-fit with 84 cases of DCS in 668 human altitude exposures including a variety of pressure profiles.

RESULTS: Model predictions suggest that 4 hours at 56.5 kPa (8.2 psi) followed by 2 hours at 29.6 kPa (4.3 psi) would require a 2 hour prebreathe to limit DCS risk to 8.5%. The same 2 hour prebreathe would alternatively allow for 3 hours at 56.5 kPa (8.2 psia), 2 hours at 41.4 kPa (6.0 psia), and 1 hour at 29.6 kPa (4.3 psia) with 8.4% predicted DCS risk. The predicted DCS risk for the latter scenario reduces to 7.9% (0.5% reduction) when two 15-minute recompressions to 56.5 kPa (8.2 psia) are added during the 2 hours at 41.4 kPa (6.0 psia).

DISCUSSION: Prebreathe benefits of variable pressure suits are limited if crewmembers are initially saturated at 101.3 kPa (14.7 psia), 21% O_2 and may be outweighed by increased fatigue and injury risk associated with working in high pressure suits. Previous modeling work and empirical human and animal data indicate that intermittent recompressions (IR) can reduce decompression stress; however, minimal benefit of IR is predicted for these scenarios because significant gas phase growth has already occurred before IR is available.