Do lipids or proteins in plasma reduce bubble surface tension? The interrelationships between plasma lipid and proteins, surface tension and post-dive venous gas embolism

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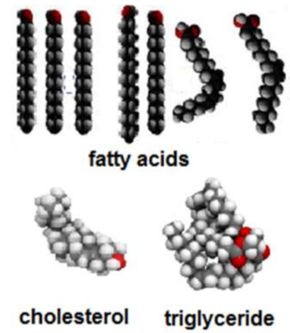
Theory & modeling

Triglycerides (TriG) and **cholesterol** (Ch) are insoluble and have inappropriate 3-D structures for formation of bubble surfactant layer. Phospholipids cannot form spontaneously micelles.

Molecular dissolved **free fatty acids** (dFFA; long chain; only nM range!, calculated with reaction equation at the right) can just cover all bubbles (irrespective BG grade), but

1. this takes many hours and
2. the long-chain-FFA critical micelle concentration is in the mM range!

Albumin (Alb) can cover all bubbles $\mathbf{10^7}$ times.



$P_{bubble} = P_{ambient} + P_\gamma = P_{ambient} + 2\gamma/r$ *

P_γ is Laplace pressure, γ **surface tension,** r bubble radius.

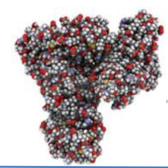
Surfactant lowers P_γ: new $P_\gamma = 2(\gamma - \Gamma)/r$.

Γ is action of surfactant. $\gamma_{water} = 72$ mN/m

(Lung surfactant $\Gamma > 40$ mN/m.)

$K_d = [\text{free albumin}]\cdot[\text{dFFA}]\cdot[\text{FFA-albumin}]^{-1}$

* Simplified



Albumin is FFA transporter, ca. 15 nm Φ

More info:

Schellart, ASEM 2014;85:1086-91

Schellart, Rozložník and Balestra, UHM 2015;42:133-41.

Hypothesis

None of the blood lipids act as surfactant.

Methods

Correlate post exposure albumin, total protein, Alb, triglycerides TriG, total Ch, dFFAs and total FFA (mM range), with **venous gas bubbles** (KISS at 40, 80, 120, 160 min post-dive, precordial) and with γ (measured with dynamic bubble method).

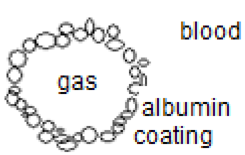
52 male divers, 40-50 years, lean, very fit. Half obtained fat rich and half fat poor meals to enlarge FFA and TriG range in plasma. 63 simulated dives (dry air-dive, profile 21msw/40min). 11 subjects with both diets (paired testing).

Main Findings

- Pre- and post exposure, no significant and consistent effects of lipids and proteins on surface tension γ.
- Lipids and proteins measured post-exposure do not affect KISS.
- **KISS does not correlate with γ.**
- γ is ca. 57 mN/m (corrected).
- No KISS differences found with within-subject fat-rich versus fat-poor meals (paired t-tests, no significant correlations).
- All analyses with subjects with KISS>0: same results.

Discussion

The 15 mN/m decrease of γ (rel water) can hardly stabilize bubbles. Albumin is a promising candidate (see e.g. milk chemistry) to coat bubbles and such reducing γ.



Conclusions

1. Most likely, dive bubbles have NO lipid surfactant.

2. Probably, bubbles have an albumin coating –> small decrease of γ –> hardly stabilizing.