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Can measurements of exhaled nitric oxide (NO) provide a noninvasive measure of decompression stress in humans?

NAVAL SUBMARINE MEDICAL
RESEARCH LABORATORY
Submarine Base New London,
Groton CT 06349

D.M. Fothergill, J. Gertner, D. Schwaller, M. Keller
and J. McCluskey



Background

Current non-invasive methods for estimating decompression stress

Venous Gas Emboli (VGE) detection and quantification using Doppler or Ultrasound Techniques.

Disadvantages:

1. Technique dependent (need skilled technicians)
2. Subjective
3. Very coarse classification of decompression stress (grades 0 - 4 for Spencer Scale)
4. Non-linear scoring scale relative to bubble count/volume
5. Bubbles scores provide no indication of the physiological insult resulting from the decompression stress.



Background

Is there a non-invasive biological marker that can be used to measure the level of decompression stress induced by a hyperbaric exposure?

Mixed expired NO increased following intravenous infusion of air into rabbits in amounts comparable with that liberated in decompression sickness (Agvald et al., 2006).

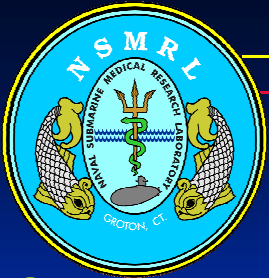
Possible mechanisms for \uparrow NOexp by VGE

- Reduction of NO scavenging from blood due to altered blood flow in the pulmonary circulation.
- Release of inflammatory mediators that upregulate iNOS in the lungs.



Objective

- To determine if exhaled nitric oxide (NO_{exp}) measurements provide a reliable and sensitive noninvasive marker of decompression stress in humans.



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Methods (Hyperbaric Exposures)

Subjects: 12 U.S. Navy trained divers (repeated measures design)

Hyperbaric Exposure:

Dry hyperbaric chamber dive to 47 fsw with mild cycle exercise while breathing normoxic nitrox bottom mix. (Equivalent air depth = 60 fsw)

Independent variable: bottom time, 60, 70, & 80 min with order randomized and successive dives presented at 1 week intervals.

Air Decompression profile for all dives:

Ascend @ 30 fsw/min from 47 fsw to 10 fsw,
hold for 7min at 10 fsw,
then decompress to the surface at 30 fsw/min.

Surface control trials (n=8): 80 min mild exercise breathing air from regulator in chamber at surface pressure



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Methods (Expired NO measurement)

Dependent variables: Expired NO analysis (NO_{exp})

Data collected pre-dive (baseline)

Post-dive every 30 - 40 min for 2.5 hrs starting 10 min after reaching surface

24 hrs post dive

Sievers® NOA 280i chemiluminescence NO gas analyzer

50, 150, 250 ml/s expired flow rates and end tidal NO.





Methods (VGE grading)

Dependent variables: Bubble score

Pre-dive (baseline), Post-dive every 30 - 40 min for 2 hrs starting 10 min after reaching surface, 24 hrs post dive

VGE score graded according to Brubakk and Eftedal (2001) scale
precordial trans-thoracic echocardiographic examination using Sono-Heart
Elite, Sonosite Inc. Converted scores to bubble counts/cm² for statistical
analysis.

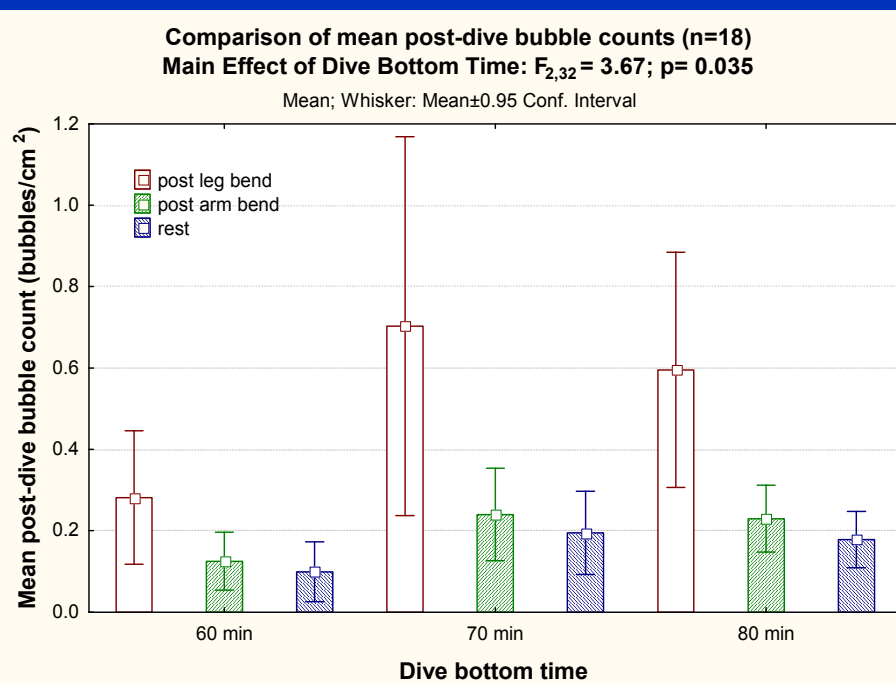
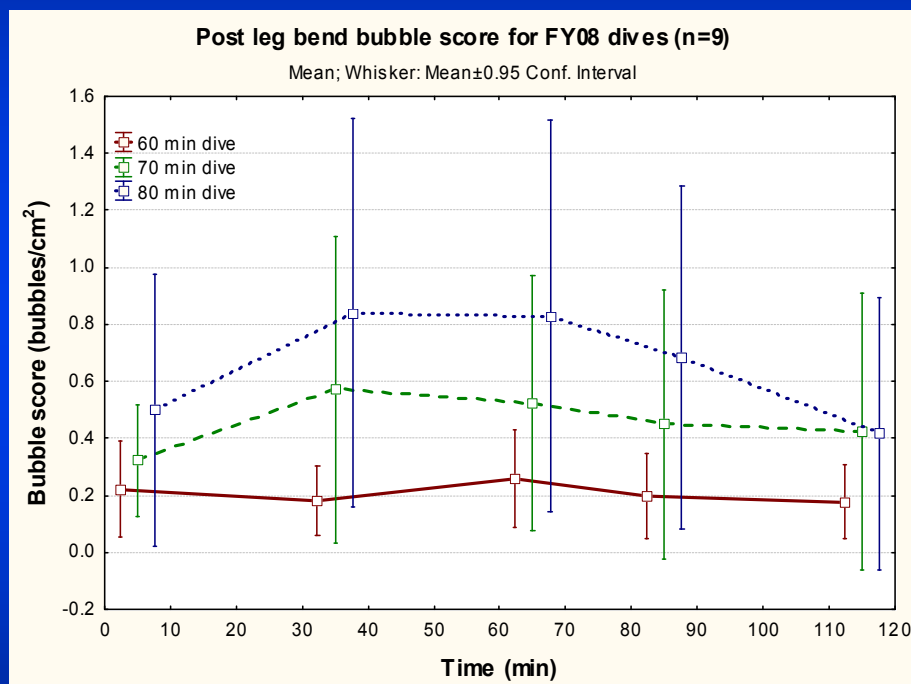
	EB Grade	Bubble count (bbls/cm ²)
	0	0
0 No bubbles	1-	0.01
1 Occasional bubbles	1	0.05
2 At least one bubble/4th cardiac cycle	1+	0.1
3 At least one bubble every cardiac cycle	2-	0.15
4 Continuous bubbling (at least one bubble/cm ²)	2	0.2
5 “White-out”, (individual bubbles cannot be seen)	2+	0.3
	3	0.5
	3+	1.0
	4	2.0
	4+	5.0
	5	10.0

From Nishi et al., (2003)



Results

Bubble Score Analysis

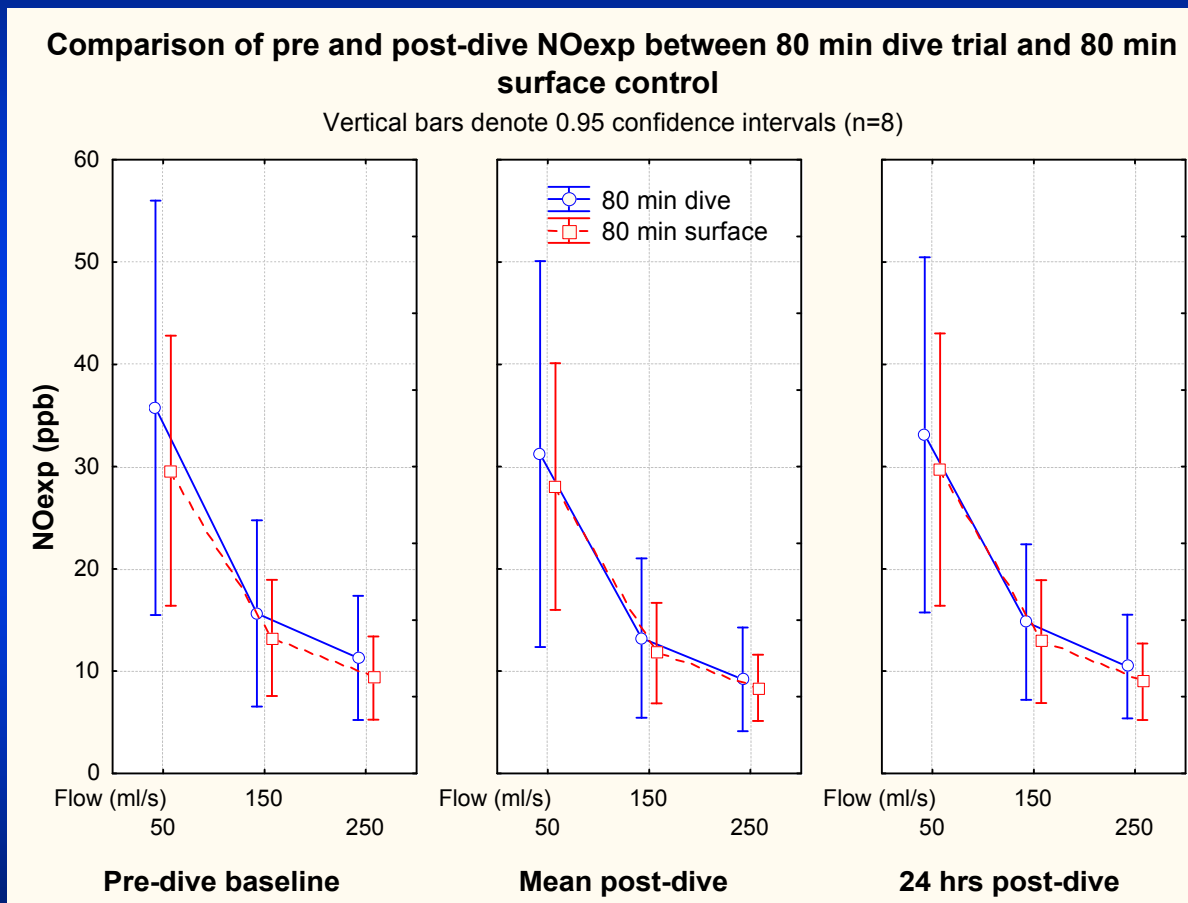


Tukey's HSD Post Hoc analysis showed significant difference in mean post-dive bubble score between 60 min and 70 min BT (0.16 vs .38 bubbles/cm²; $p=0.039$)



Results

NOexp Analysis: 80 min dive vs 80 min control surface trial (n=8)



No difference in NOexp between control and 80 min dive ($p=0.283$)

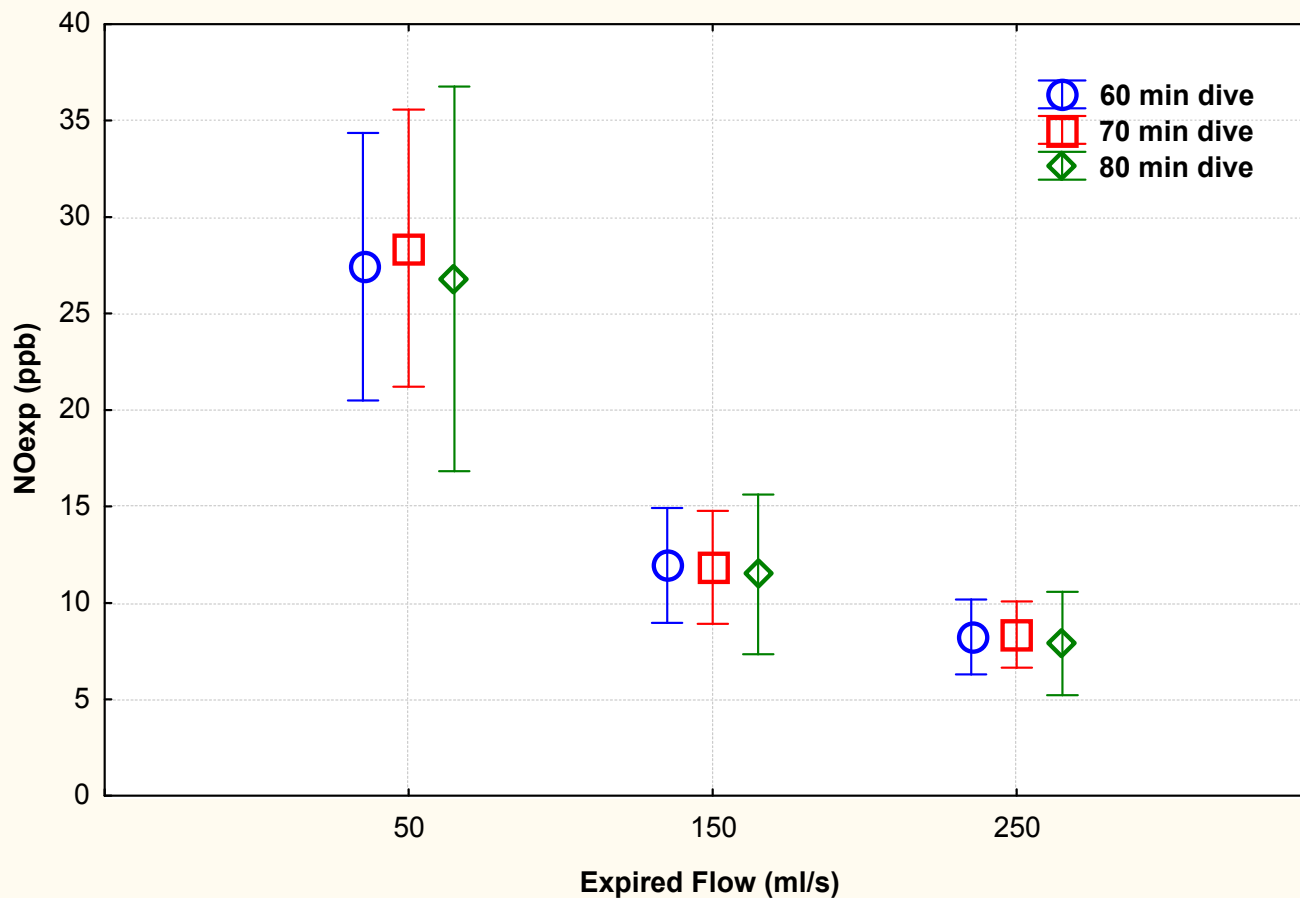
Mean post-dive NOexp 11% lower than pre-dive baseline NOexp ($p=0.035$)



Results

NOexp Analysis

Fig 4. Comparison of the mean post dive expired NO between the different dive profiles
Vales are means (n=12). Error bars show 95% confidence limits



No difference between dives (60, 70 and 80 min) on NOexp ($p=0.824$)



Conclusions

- The current dive profiles:
 - ◆ 1. Generated significant VGE
 - ◆ 2. Elicited different levels of decompression stress
 - ◆ 3. Did not affect post-dive measurements of NOexp.
- **Expired levels of NO do not provide a useful measure of decompression stress when dives are performed within decompression table limits.**



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