# How to avoid a

# Isobaric Counter Diffusion hit

*or...a simple visualization for determining the tolerable increase in inspired nitrogen percentage during the decompression phase of Trimix dives.*

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Background

**Type III DCS caused ICD is predominantly a problem when carrying out Trimix dives that are deep enough and long enough to generate formal decompression stops that require the use of a hypoxic Trimix deeper than 40meters/130ft. An analysis program embodying these concepts to identify known unsafe ICD gas switching practices and unsafe decompression is made available here**

Assumption

***Formal decompression can only be carried out safely when the TOTAL quantity of dissolved gas from all partial pressures of inert gases in a tissue is less than the tissues overall M-value.*** It is very important to view decompression of the Trimix diver in this manner to get an understanding of what's going on with ICD.

Since, the quantity of a dissolved gas for a saturated medium is equal to:-

***Current saturation pressure x solubility factor in the medium***

For lipid tissues, the solubility factors of Nitrogen and Helium are as follows

Solubility of Helium=0.015

Solubility of Nitrogen=0.067 (approx 4.5 times more soluble)

(Ref:- Solubility factors from 'Scuba Diving in Safety & Health by Chris Duer, MD) ISBN 0-9614638-0-5)

***Note that the solubility of Nitrogen in lipid tissues is more than 4 times that of Helium***

But, the diffusability (the speed the gas goes into and out of solution) will also come into the dynamics of the overall model. The speed of diffusivity of Helium is 2.65 times faster than Nitrogen.

So lets look at the aiming conditions by examining a gas switch 'at the ascent ceiling' from Trimix 20/25 to Nitrox32 at 40 meters deep

These are the partial pressure 'aiming points' for the tissues in (bars)

| **Depth** | **Ambient pressure** | **Trimix 20/25** | | **Nitrox32** | |
|---|---|---|---|---|---|
| | | **pp-n2** | **pp-He** | **pp-N2** | **pp-He** |
| 40m/130ft | 5 bars | 2.75 | 1.25 | 3.4 | 0 |

Although the sudden jump in ppN2 appears small, one must remember that the 'aiming point' for the TOTAL amount of dissolved gas in the tissue is actual as follows

Before switch

(2.75x0.067) + (1.25x0.015) =0.18425+0.01875 =0.203 eq(1)

Immediately after the switch

(3.4x0.067) + ( 0) =0.2278+0 =0.2278 higher than eq(1) !

***Hence the effect of switching to Nitrox from Trimix has the effect of INCREASING the overall gas loading within the tissue since the loss of 25%helium is more than taken up by the increase in Nitrogen from 55 to 68%(13%). This is not a good thing if you happen to be sitting on the ascent ceiling at this time. This will cause an immediate fast tissue DCS Hit.***

Conclusions

1. Switching from Trimix20/25 to Nitrox32 at 40meters aims to increase gas overall tissue gas loading
2. Since the solubility of Nitrogen is 4.5 times more soluble than Helium, Nitrogen should never increase more than (say) 1/5 the reduction of Helium content to keep the aiming point for the dissolved gases the same

## This suggests a simple rule

## The ICD-avoidance gas switching rule of 1/5ths '

### Necessary if carrying out formal deco on intermediate Trimix

| % Helium Gas reduction | Permissible %Nitrogen Increase |
|---|---|
| 10 | 2 |
| 20 | 4 |
| 30 | 6 |
| 40 | 8 |
| 50 | 10 |
| 60 | 12 |
| 70 | 14 |
| 80 | 16 |
| 90 | 18 |

This would suggest that if you were carrying out formal decompression stops on intermediate Trimix at the time:-

**A Switch fromTrimix20/25 to Nitrox 32 is NOT OK** since Nitrogen jumps from 55 to 68% (a 13% jump), where the rule of 5$^{th}$ suggests a maximum allowable increase in %Nitrogen for a 25% drop in Helium of only 5%.

**However, A switch from Trimix 20/25/55 to Trimix 32/8/60 would likely be tolerated.**

**Key XX/XX/XX is Oxygen%/Helium%/Nitrogen%**

I have no idea if this gas switching ICD avoidance algorithm is a true and thorough explanation for the effects that take place in ultra deep Trimix dives, but it's predictions successfully avoid all the historical ICD cases that I had data for, It took into account the differing solubility's of helium and Nitrogen, and successfully predicted Mark Ellyatt's Gas choices and Helitrox decompression schedule for his 313meter Open circuit Trimix plunge a couple of years a go.

***This dive represented the first successful use of ICD avoidance in an Open Circuit scuba dive to these depths by calculating the gas percentage change tolerable. Also, it was the first time that the diver carrying out a Trimix plunge to these depths didn't spend his last 6 hours of deco puking on***

***every breath. A desirable result...***

Mark complained about the helium bill, but the savings it avoided in missed 'USN-table 6 chamber rides' more than compensated for this, and he was back teaching 'Discover Scuba Diving' instead of his usual Discover Scary Drowning courses just a few days later.

The only other successful ICD avoidance technique I am aware of was used by late Sheck Exley' by using 'phased in switching of Trimix to Nitrox'. The technique is explained thoroughly in is book 'Cavern Measureless to Man' ISBN 0-939748-33-9 published by Cave Books 1994. I'll give you Sheck's ICD avoidance technique here for reference. Sadly, although Sheck is no longer with us, he plainly had an unusually good instinctive feel for what was going on in his body with regards to mixed gas effects ad how to avoid them. Sheck realized that ICD was predominantly fast tissue event'

**<EXTRACT 'CAVERNS MEASURELESS TO MAN'**
**Author:- SHECK EXLEY page 259**

*"At 260 feet and 250 feet...*

*I counted sixty-second stops with my fingers, then addressed a new source of concern: Jochen and Gene's mysterious vestibular hit. At 240 feet I had to switch from breathing 50 percent helium and 40 percent nitrogen to air, which contains 79 percent nitrogen. According to their information, the abrupt increase in nitrogen could result in instant death. And all authorities predicted a sudden onset of severe narcosis.*

*To make the switch as gradual as possible, I took only a single breath of air from the tank we had earlier left at 240 feet, then switched back to the helium mix for two breaths. Then came two air breaths, then back to the deep mix for one inhalation. Finally I switched over to air completely, bracing myself for the severe narcosis and dreaded vestibular hit, all the while doing my best to count off the seconds required for the stop. Nothing happened, no narcosis, no sudden lapse into unconsciousness. The only thing I felt was warmer, thanks to not having to breathe helium any more. Apparently my strategy of keeping a maximum amount of nitrogen in the deep mix worked."*

<EXTRACT ENDS>

Sheck's dive plan for his 1989 dive to 881ft at Nacimiento del Rio Mante in Mexico, also follows and uncanny resemblance to what we now know to be a correct decompression profile for a Trimix dive to these depths. The only thing missing in his plan was a Helitrox decompression schedule.

I've put a copy of Sheck's successful 1981 dive plan up on the web at for analysis purposes at http://www.scubaengineer.com/sheck_exley_mexico_dive.htm

As to the time scales and diffusion dynamics, or what percentage change of gas can be tolerated over time (on a second by second basis) and at what depth? I'll need a few weeks of uninterrupted thought to visualize it before I can hatch the math for the time dependent exponential math matrix that's generating these effects. All I have at the moment is a feel for what's going on. But it's a start.

My feeling is that taking into account ICD effects during gas switches and the compensation of HPNS with huge END's represent the two least researched problems that can afflict ultra deep Trimix divers.

Any comments on this work in progress would be highly appreciated.

Regards,

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