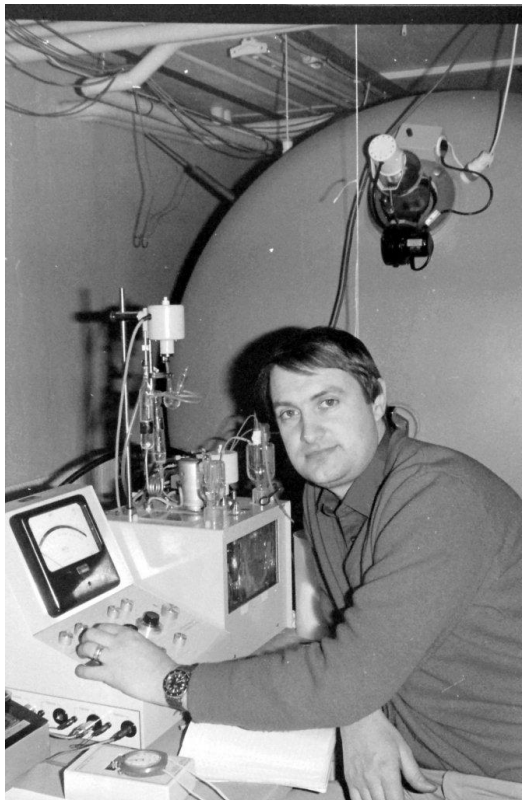
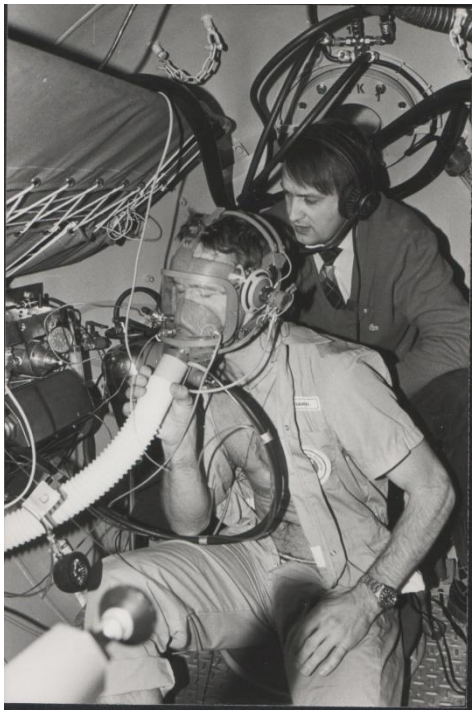
What have we learned in 80 years of diving medicine research? 1944 to 2024

Hans Örnhagen



Lund University 1960-tal



Pre tests hydrox 1984, MDC

Apo island 2016

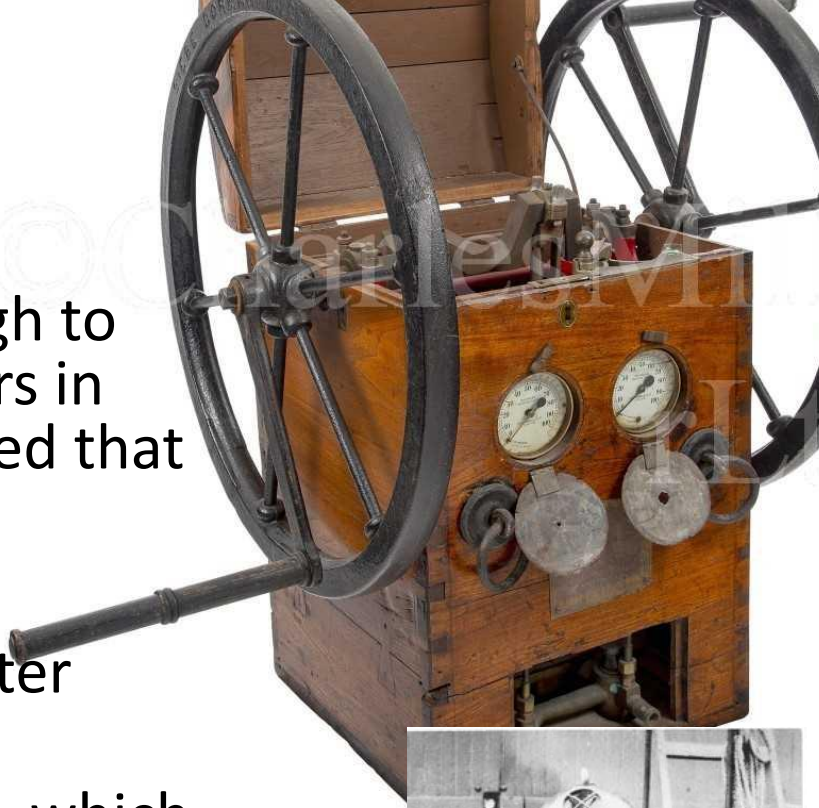
A summary:

- Depth narcosis can be avoided using heliox
- Rebreathers save gas and makes divers ”unvisible”
- It is possible to dive with diabetes
- It is possible to dive with asthma
- You can dive deep on one breath
- Bubbles in your blood is not decompression illness
- Oxygen, 100%, is the best remedy against bubbles
- Immersion pumonary edema IPE, can be the explanation behind unexpected dive fatalities
- It is not neccesary to do a lot of medical examinations and pulmonary X-rays, but you must be healthy and be physically fit if you shall dive.

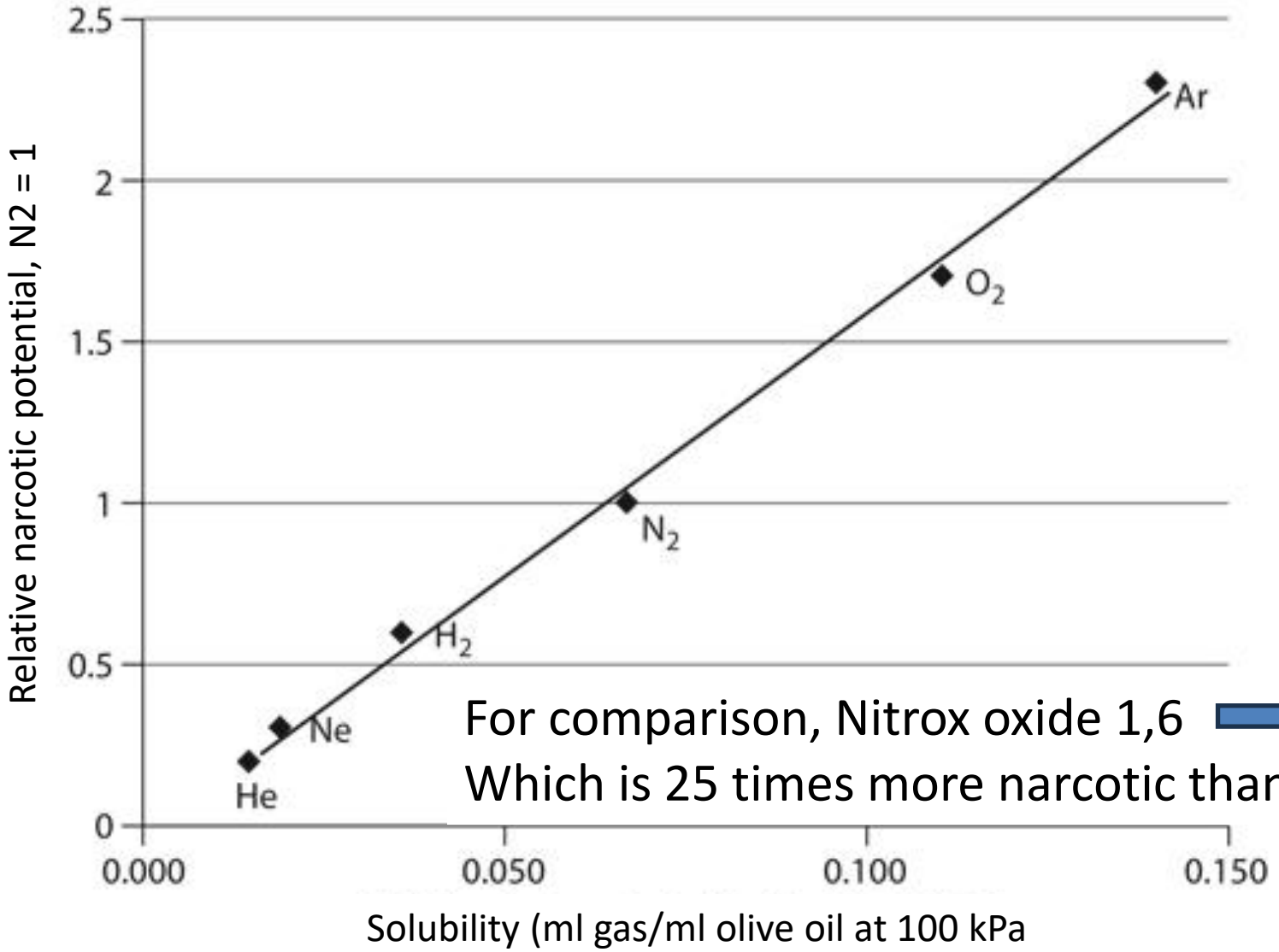
But how did we come to these conclussions?

Depth narcosis

- When air pumps became good enough to dive to depths of more than 50 meters in the late 19th century, it was discovered that divers were mentally affected.
- The divers behaved as if intoxicated
- The intoxication was stronger at greater depths.
- Parallels were drawn to nitrous oxide, which had begun to be used for anesthesia in the mid-19th century
- Prof Overton, in 1901, at Lund University, claimed that the “narcotic effect” could be related to fat solubility.

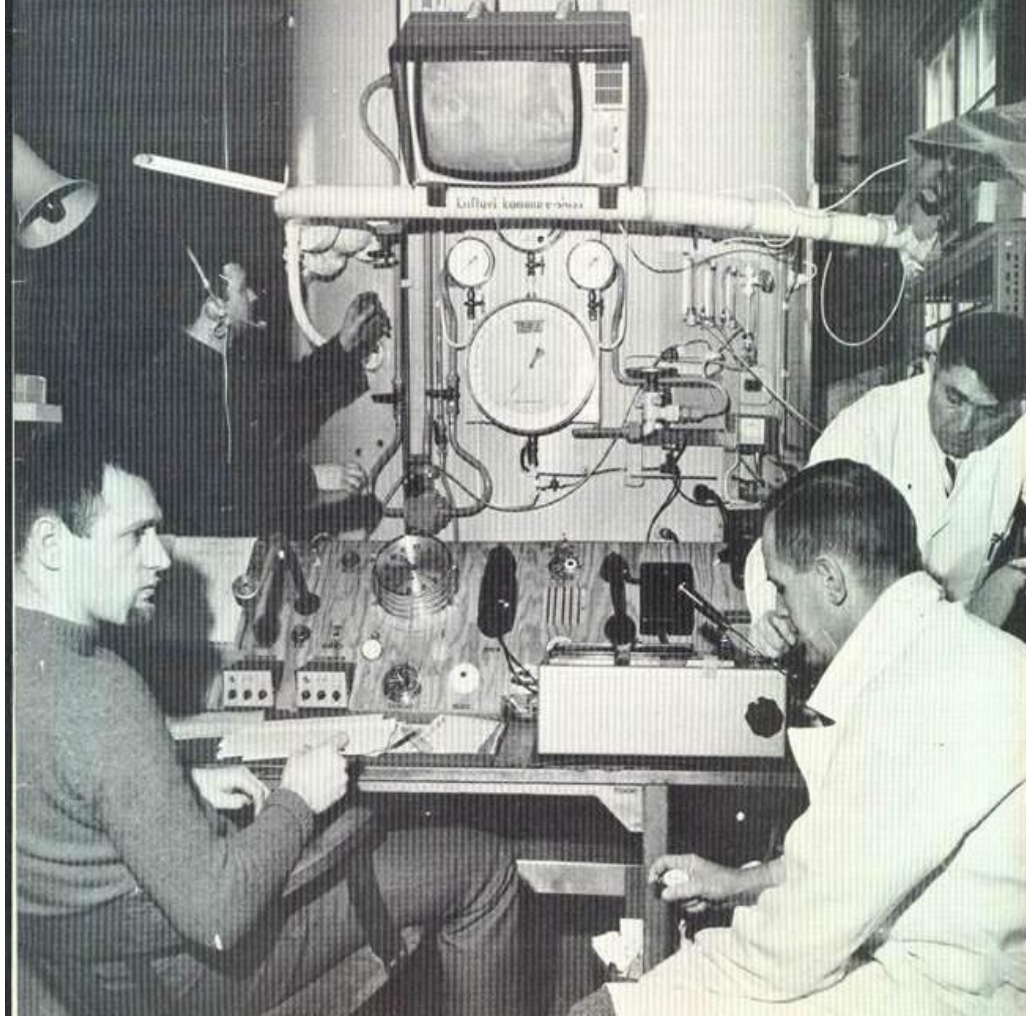


Narcotic potential and solubility in fat for some gases



For comparison, Nitrox oxide 1,6
Which is 25 times more narcotic than N2

Helium diving in pressure chambers in the 1930s did not cause any depth narcosis, and during Zetterström's dive to 165 m with hydrox in open sea in 1945, no narcosis was noted.



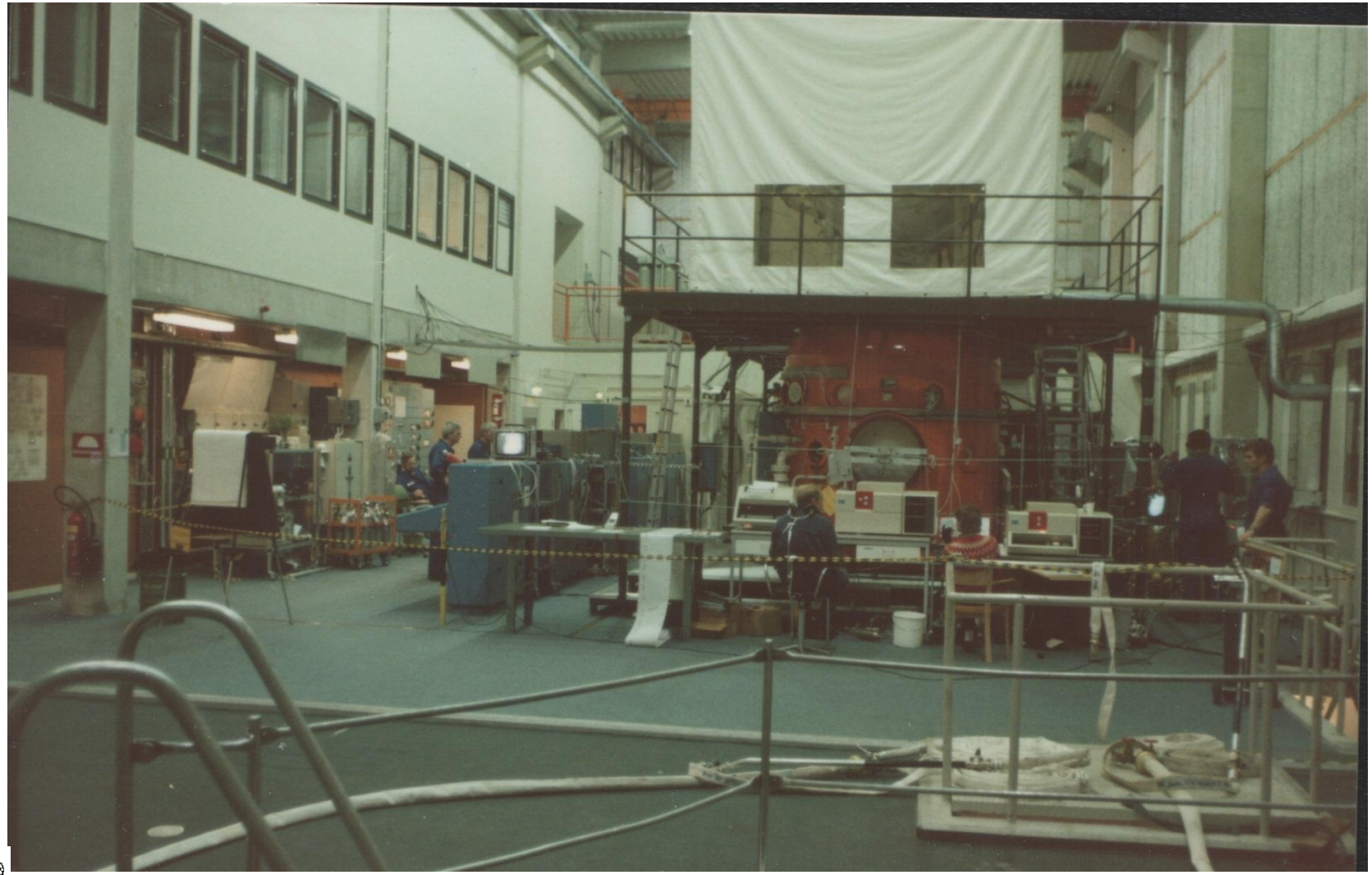
Here is a photo from the Dyktankhuset in Stockholm where depth narcosis during deep diving with air was studied in the 1960s.

High pressure neurological syndrome, HPNS

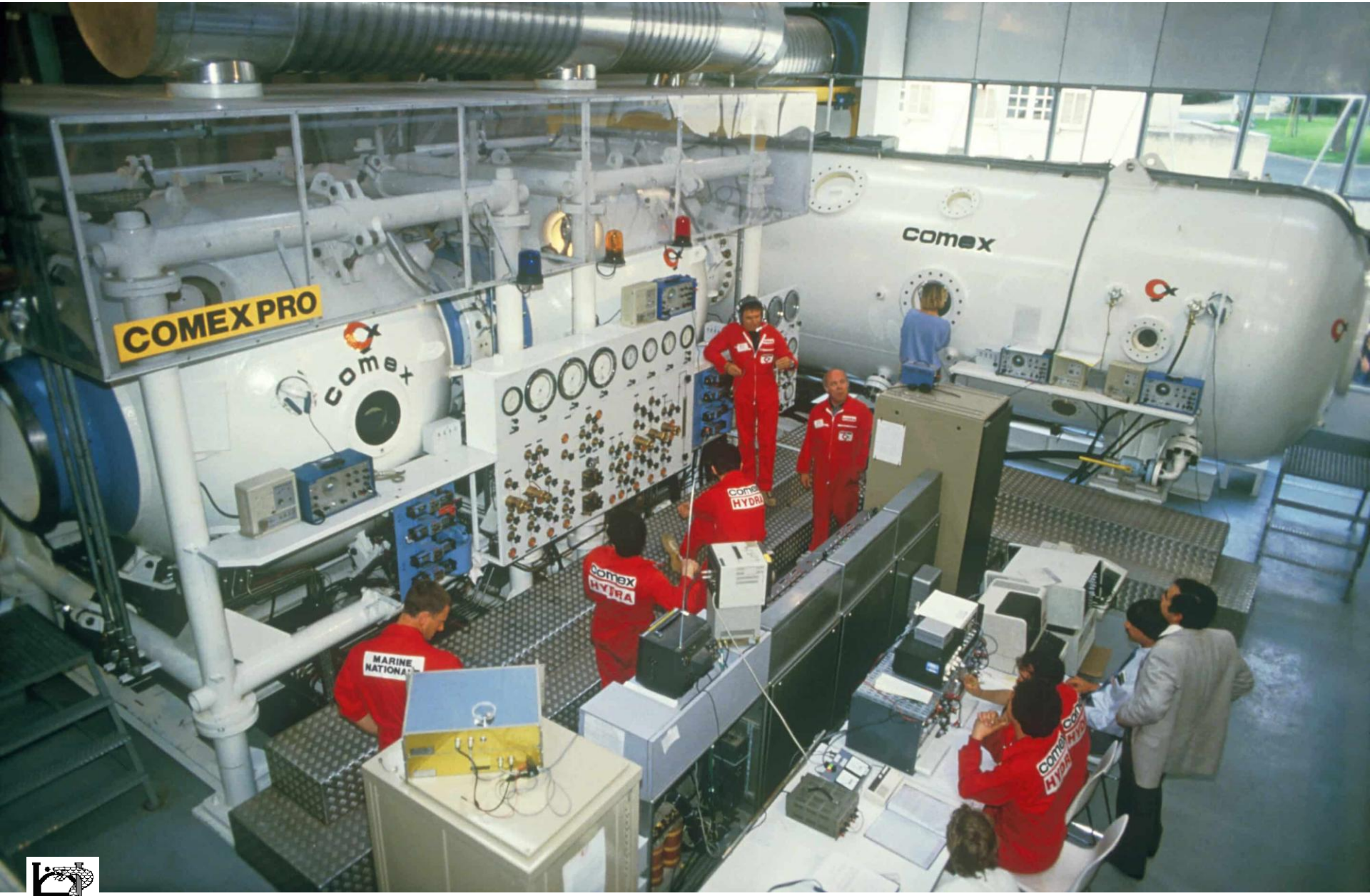
- When diving with heliox to greater depths > 150 m, nausea and shaking hands (tremor) occurred.
- It was believed in the 1970s that this was helium narcosis.
- Experiments with liquid-breathing animals in the 1970s, which were not exposed to gases at high pressure, showed the same symptoms as divers in heliox at great depths and the term HPNS was coined.
- In 1945, Zetterström had dived to 165 m with hydrox without noticing depth intoxication or HPNS.
- It was thought that anesthesia could counteract HPNS and dives with a small addition of N2 in heliox were made in the 1980s.

- In France and Sweden, both animal and human experiments were conducted with hydrox in the 1980s to investigate depth intoxication and HPNS during deep diving.
- It was found that hydrox became too intoxicating at depths greater than about 200 m However, in France they continued with trimix with helium, hydrogen and oxygen mixes (Hydreliox)

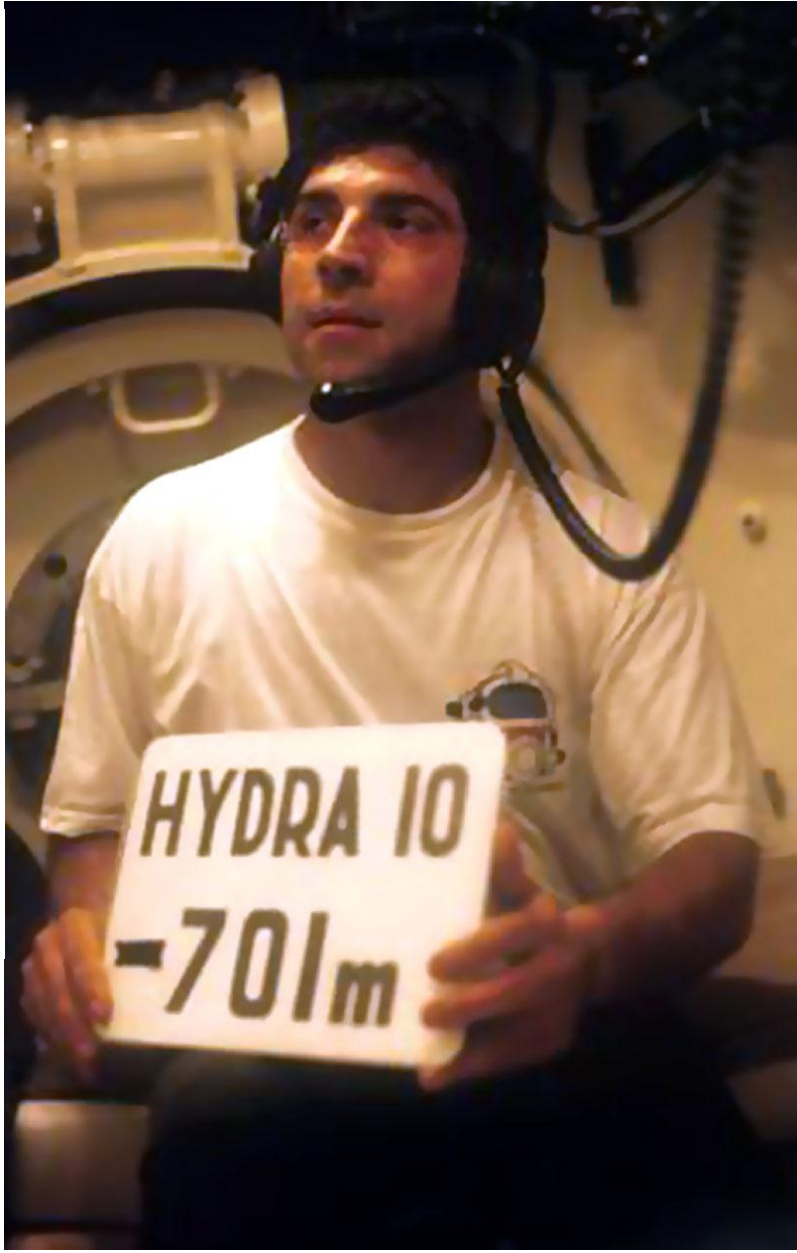
Experiments using hydrogen-oxygen (hydrox) at the Swedish Navy diving center, Berga, 1984



The experimental chamber system at COMEX, Marseille, France



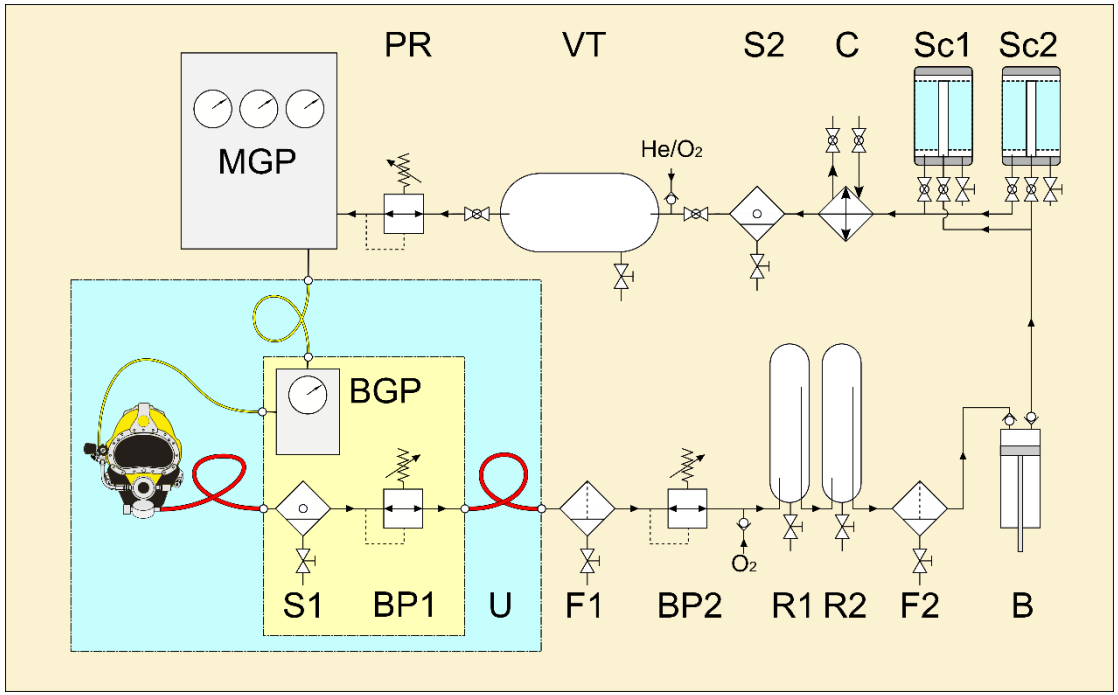
Comex in France made several chamber dives with hydreliox (H2HeO2) in the 1980s. The highest pressure ever experienced by a human was at Hydra X, in 1989 when Theo Mavrostomos reached 701m before the 43-day decompression started.



Conclusions regarding professional diving

- Air is the best/cheapest gas for shallow diving
- Nitrox can increase efficiency
- Heliox should be used deeper than 50 m
- To avoid HPNS, compress slowly
- There is no advantage to mixing narcotic gases
- There is no evidence that diving itself would cause injuries if one has had a career without diving-related injuries such as DS

Diving to great depths requires a lot of gas and rebreathing systems begin to be used. Gas recovery system for diving bell 1980.



Rebreather systems can also be used to avoid leaving bubbles behind during clandestine operations. Here, a Russian oxygen diver from WW2.

- In the 1940s, it was shown that oxygen was toxic at excessively high partial pressures.
- With pure oxygen, we can dive to 8 m without the risk of oxygen cramp.
- Forty years later, in the 1980s, when longer nitrox dives and saturation diving became common, it was discovered that even lower partial pressures can cause lung damage if the exposure is several hours long.
- Today, there are effective diving procedures to avoid oxygen damage in both the CNS and lungs.

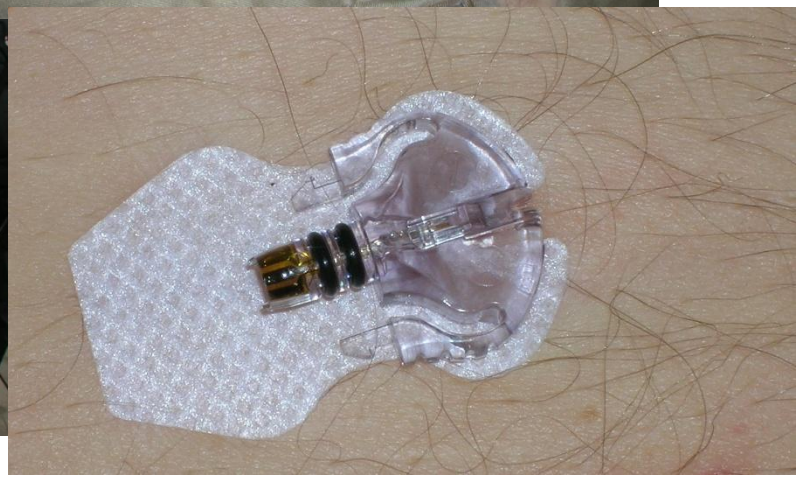
On diabetes and diving

- In the “beginning”, when sportsdiving started in the 1950s, people were not allowed to dive with insulin-treated diabetes due to the risk of unconsciousness.
- Just before the turn of the century, in 2000, it became common to have your own battery-powered glucose meters and better insulin was presented.
- In 2005, Chris Edge, UK, presented a report showing that people with diabetes were not involved in more accidents than people without diabetes.
- Swedish guidelines for diving with diabetes were presented after the SANMA meeting in 2010.

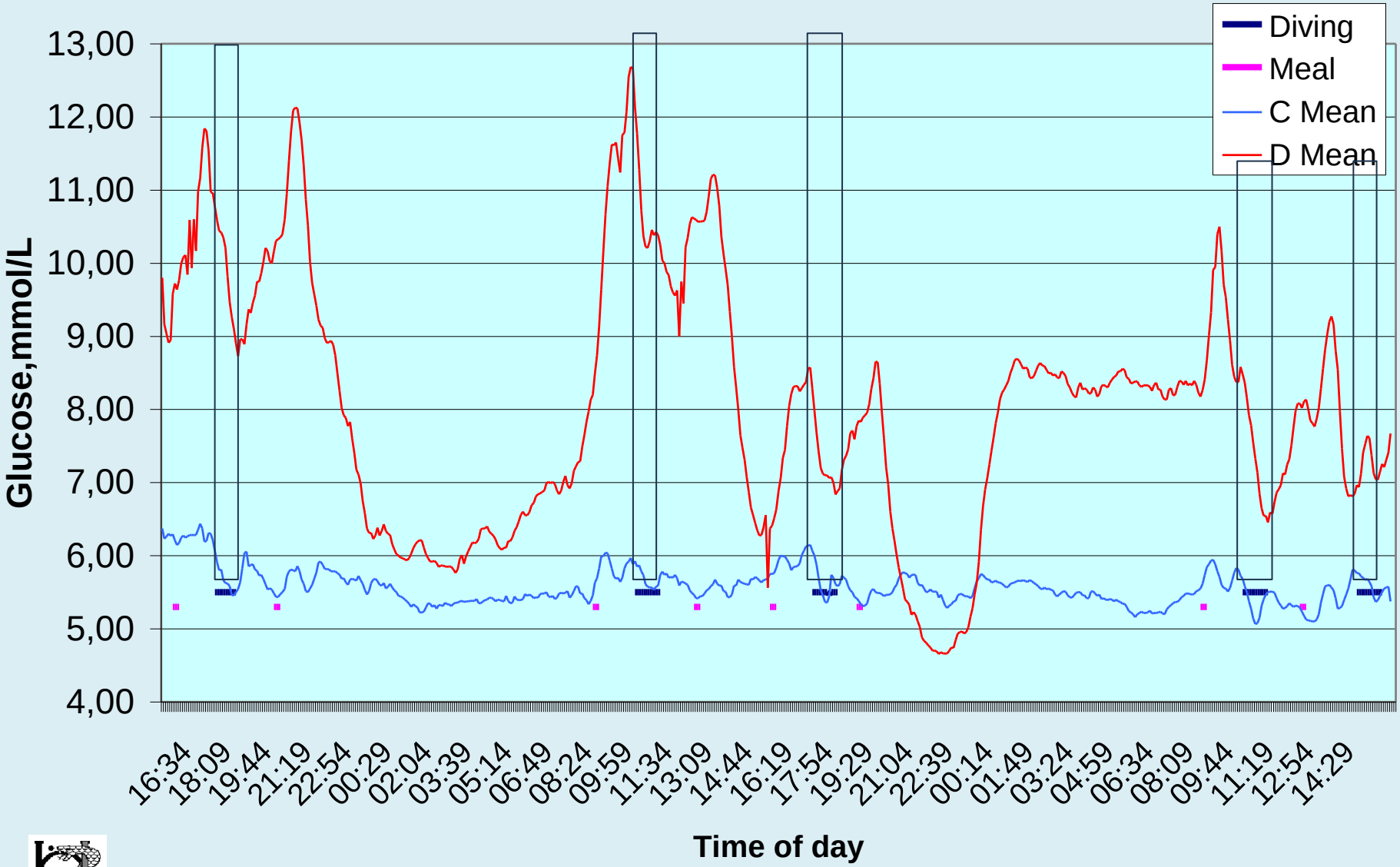
Swedish research in the 2000s has contributed to knowledge about diabetes and diving.

Diabetes and recreational diving

Peter Adolfsson[1], Hans Örnhagen[2], and Johan Jendle[3]



Glucose diabetics and controls

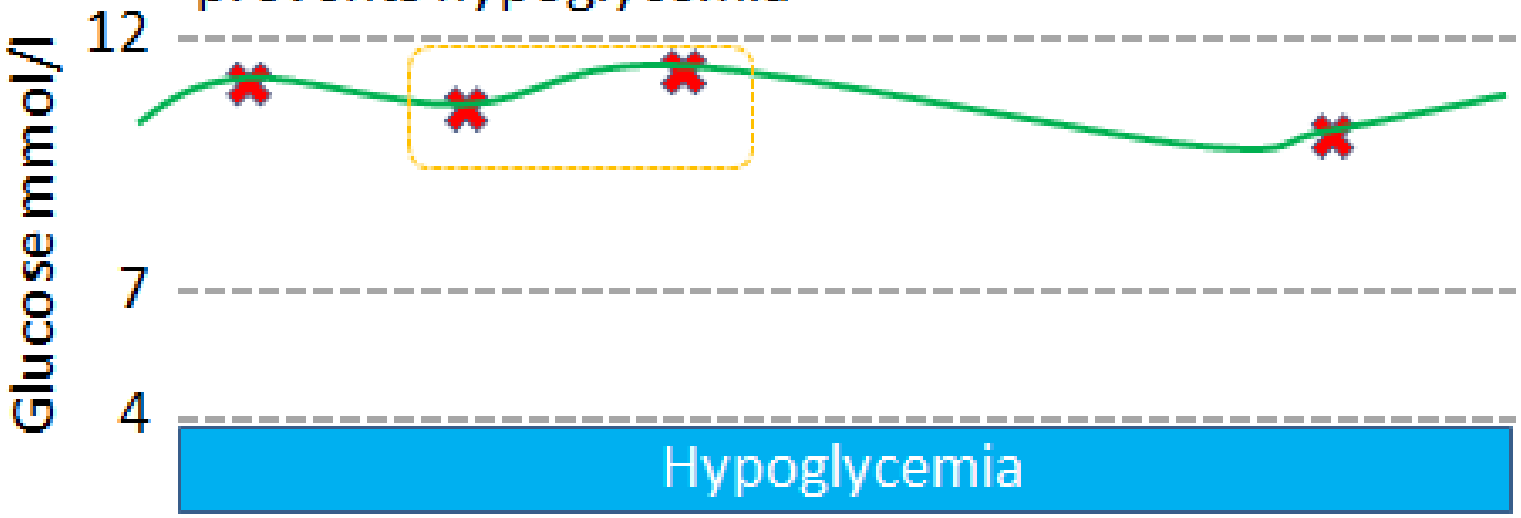


Monitoring schedule

Time: 60 30 10

Post dive

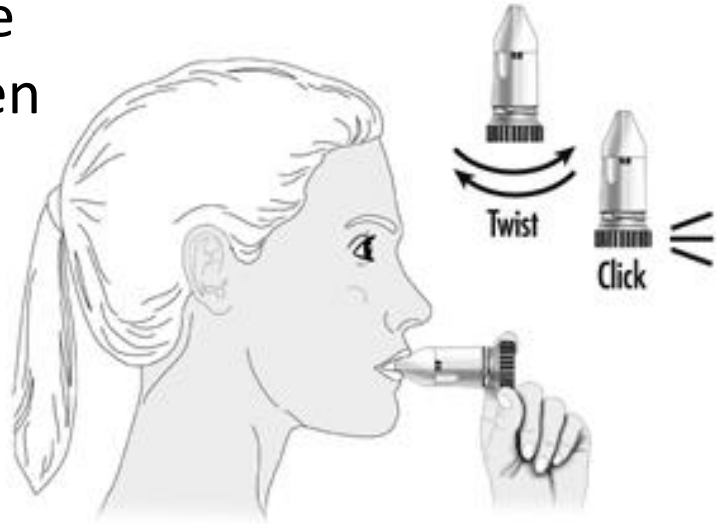
Added carbohydrates 10 min pre dive together with a stable or rising glucose value 30-10 min pre dive prevents hypoglycemia



Persons approved for recreational diving should be notified to jjendle@hotmail.com
Prof Johan Jendle, University Hospital, Örebro, is an endocrinologist and EDTC-trained diving doctor with a special interest in diving with diabetes. By reporting to Dr Jendle, divers will have access to updated information about diving with diabetes.

On asthma and diving

- In the “beginning” of sportdiving in the mid-1950s, it was believed that diving with asthma was dangerous because you could risk a “lung burst” if you had to do a direct ascent in an “our of air” event.
- Great emphasis was placed on spirometry to check that those who were going to dive had a sufficient expiratory capacity, FEV1.0 and FEV%
- A calculation example shows that an FEV% of 30% is sufficient % to empty the lungs sufficiently during a direct ascent in water. The current minimum requirement in many places is FEV% >75.
- The problem with asthma is that minute ventilation can become insufficient when hard work is required in an emergency situation With the help of steroid treatment, it is possible to reduce the irritability of the airways and then it becomes possible to dive.



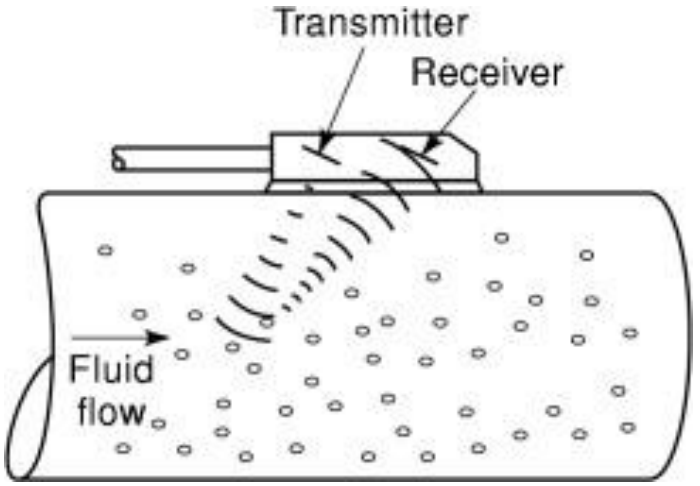
Breath hold diving

- In the “beginning”, the 1940s, it was believed that the lungs would be damaged if you dived deeper than the depth where the lung volume was reduced to the residual volume. The record at the time was 40m
- In 1977, data was published that demonstrated “blood-shift”, i.e. the transfer of blood to the lung capillaries.
- The film “The Big Blue” was presented in 1988 and freediving became popular. The record at the time was 110 m.
- Various competition disciplines emerged and in a 2007 competition with a sled on a wire (free class), Herbert Nitsch reached 214 m. Still the world record.

Freediving competition is often called Apnea. Safety divers meet to deal with unconsciousness due to lack of oxygen, “Shallow water black-out”.

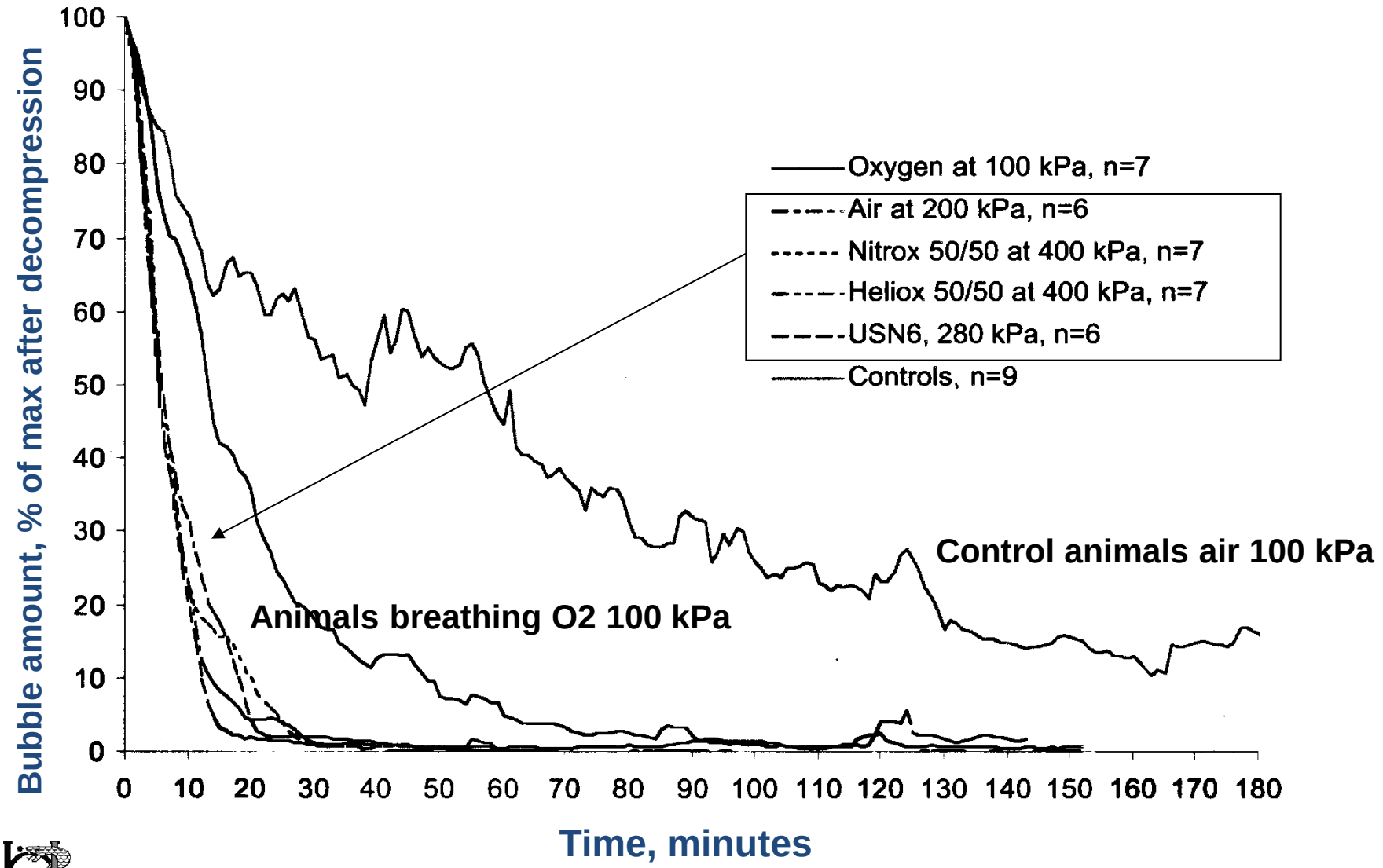
Bubbles in the body after diving

- In the “beginning”, it was believed that “joint bends” were bubbles in joint capsules and periosteum.
- Bubbles in flowing blood were first detected with ultrasound in the 1970s.
- The first bubbles in the arterial system were shown in connection with saturation decompression in Norway in the 1980s.
- Today we know that you can have large amounts of bubbles in the venous system without developing decompression sickness.
- Most, if not all, venous bubbles get trapped in the lungs and the gas is exhaled.
- PFO means that bubbles can cross over to the arterial side, but a PFO only increases the risk of DS from 1 in 10,000 to 2.2 in 10,000 dives. Bubbles affect white blood cells, blood chemistry, and the lining of blood vessels.



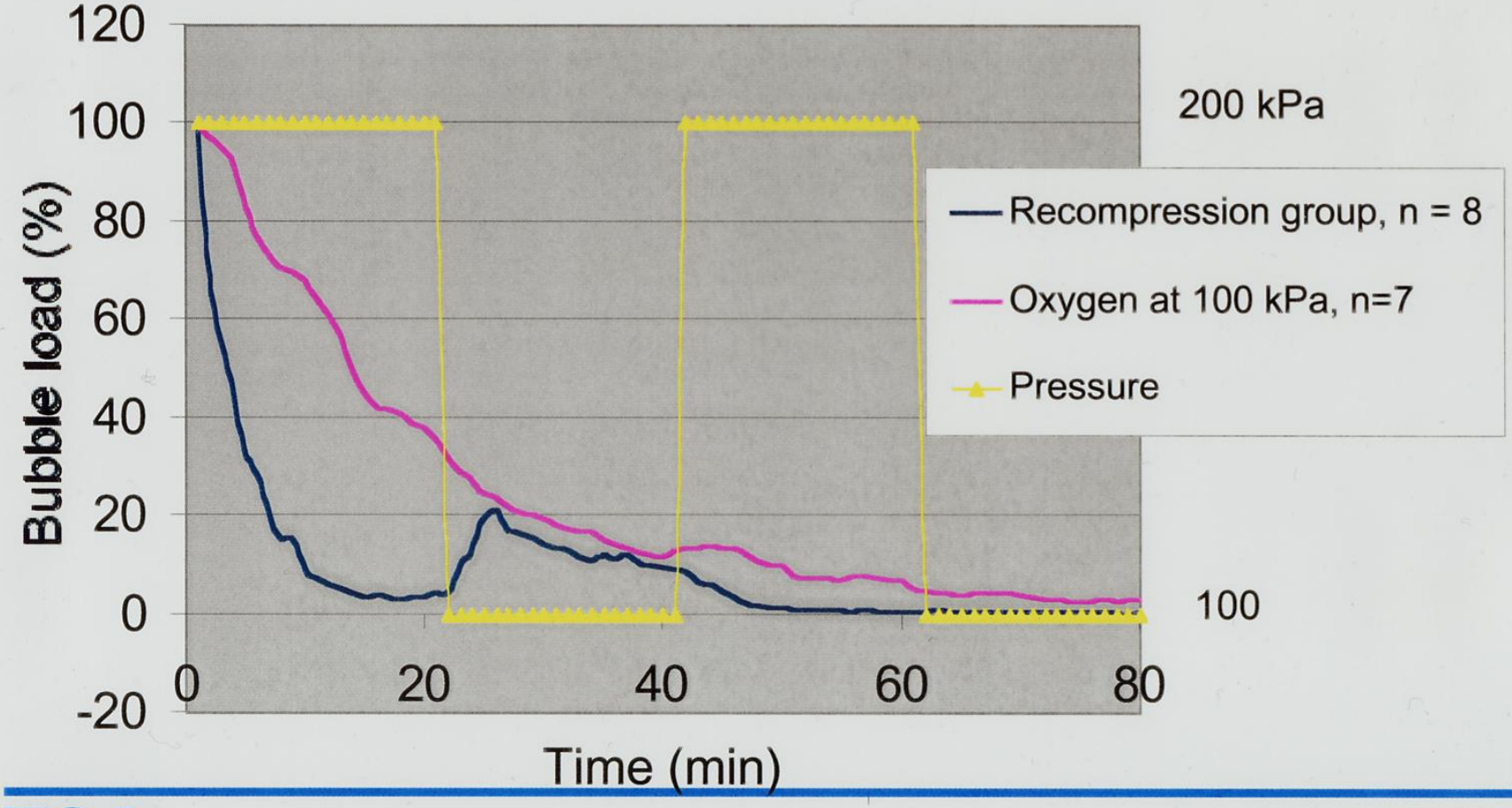
Time course for bubble disappearance after air dives 40 min at 40 m.

Ultrasound imaging, in anesthetized minipigs.



Koteng, Örnhagen and Brubakk. EUBS 1998

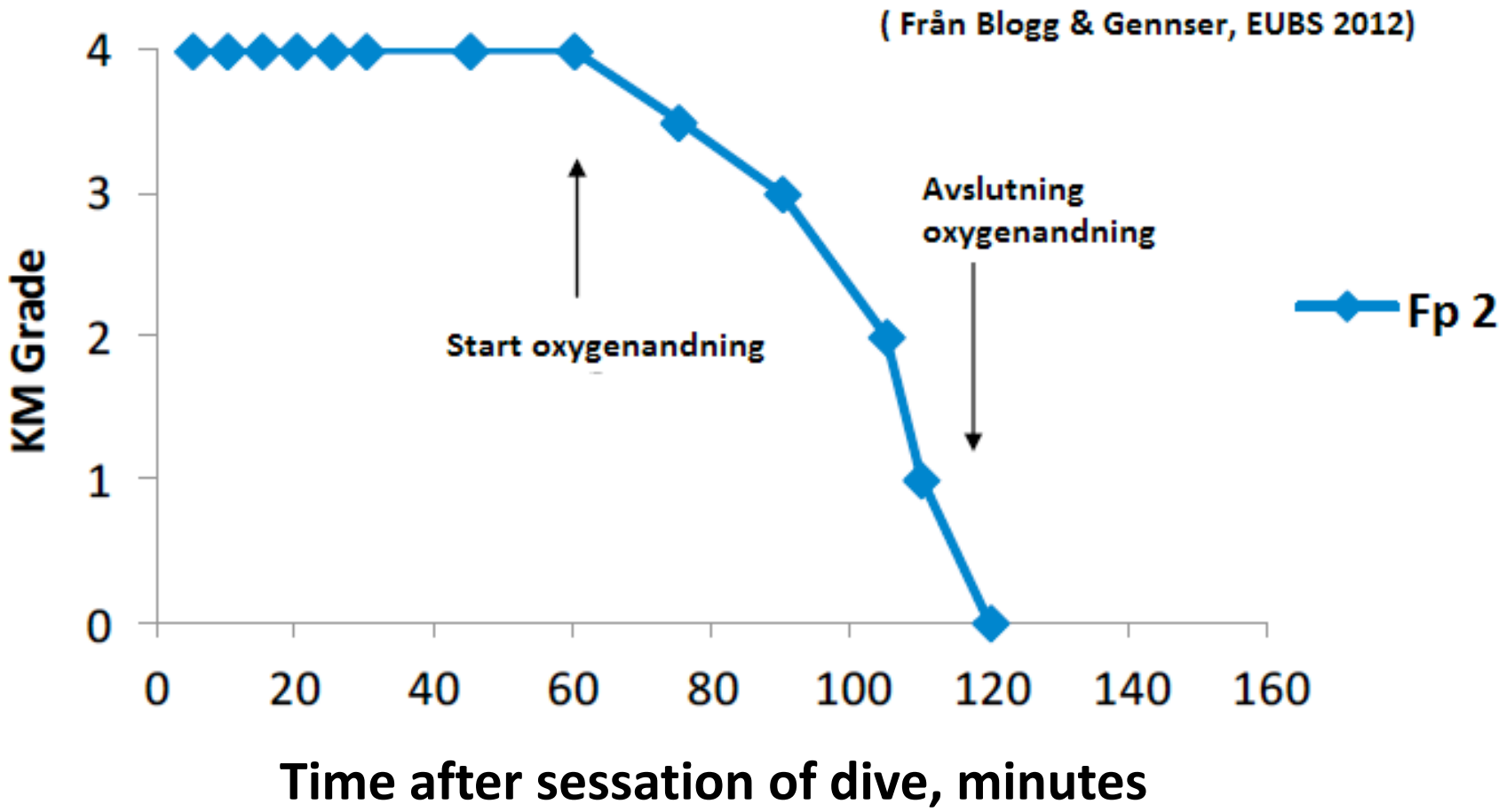
Bubble elimination in pigs after 40 m air dives



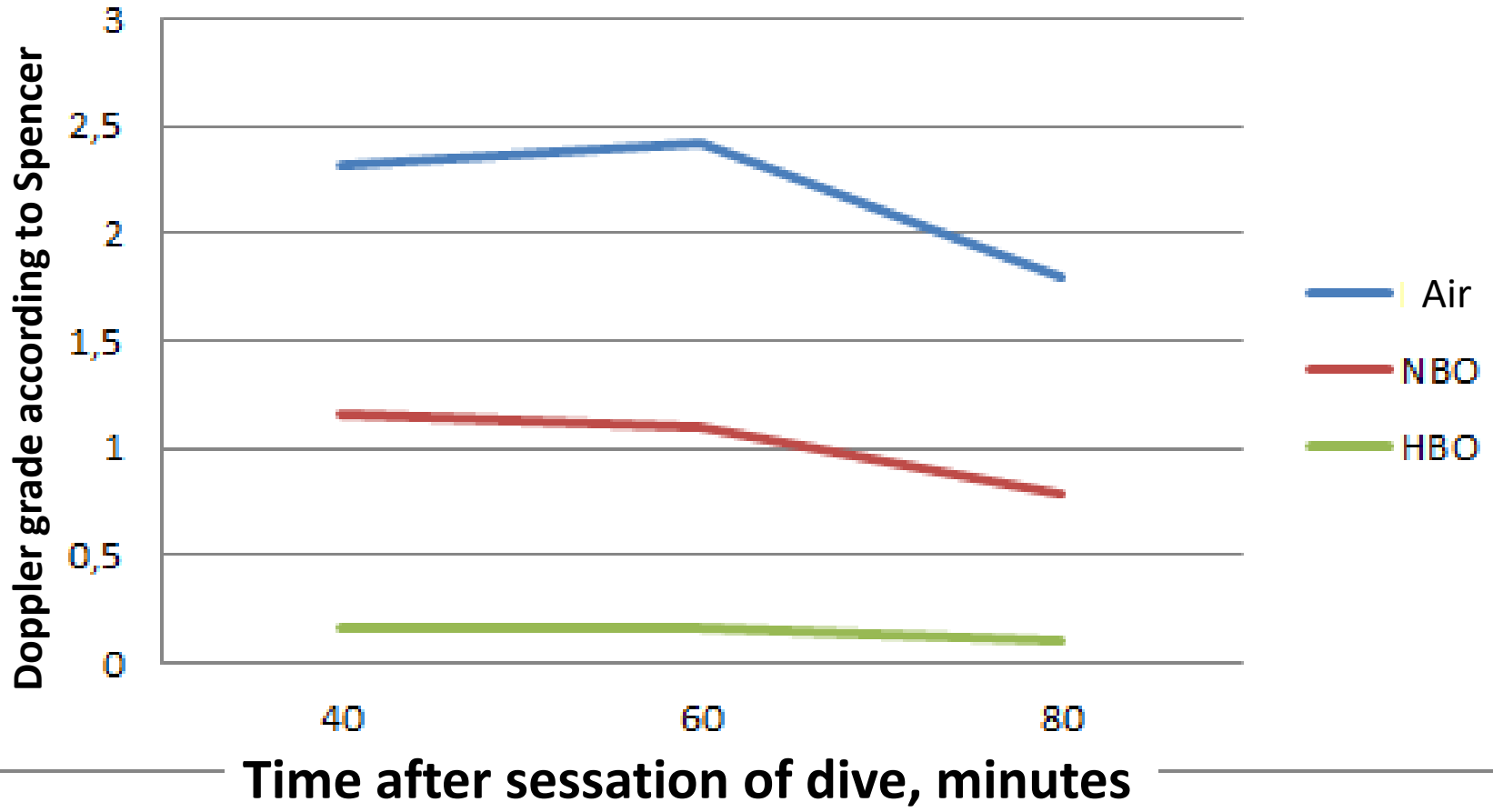
FOA Naval Medicine Division

UHMS 2000, The effect of pressure on bubble.....
Örnhagen, Koteng & Brubakk

Effect of oxygen breathing on the bubble content in the venous blood of a male diver after diving



Bubble grade after diving using different post dive routines. Blatteau & JM Pointer, 2009



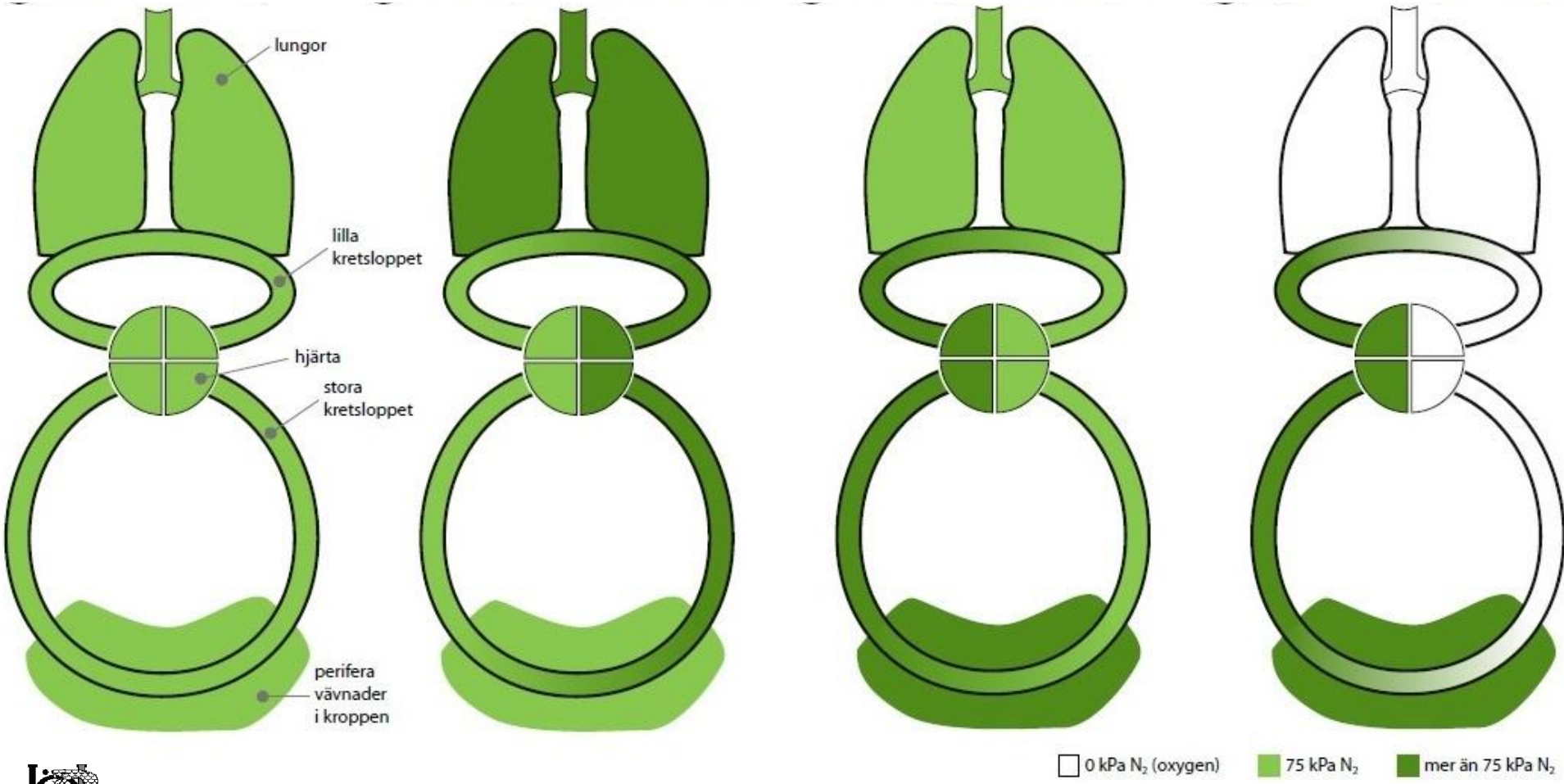
Breathing pure oxygen (100 %) is the best way to quickly get rid of bubbles and excess nitrogen in the blood.

Air breathing before Dive

Air breathing at bottom

Air breathing at surface after dive

Oxygen breathing at surface after dive



IPE, immersion pulmonary edema, is maybe the explanation for some unclear diving accidents

- In the “early days”, up until the 1990s, unexplained deaths in recreational diving were often classified as lung rupture or drowning.
- In 1988, Wilmshurst presented data suggesting that recreational divers could suffer from pulmonary edema due to sudden blood overflow in the lungs
- Today we believe that this mechanism, the parts of which we do not know in detail, maybe is behind unexplained deaths during diving.
- If you experience shortness of breath and coughing during a dive, stop immediately and get to the surface and out of the water. Breathing oxygen while sitting provides relief.

Fitness to dive, FTD and medical examination

- In the “beginning” of recreational diving in the 1950s, there were no requirements for documented health for recreational diving.
- In the 1960s, the first medical certificate and requirements for a medical examination were introduced.
- A study in Scotland in 2000 showed that annual medical examinations only found occasional pathological changes that health declarations had not already revealed.
- In 2003, CEN developed minimum health requirements for recreational diving. In 2013, most scuba schools adopted CEN’s proposal with a health declaration and medical examination only in special cases.

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- It is possible to dive with diabetes
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- It is not neccesary to do a lot of medical examinations and pulmonary X-rays, but you must be healthy and be physically fit if you shall dive.

Thank you for inviting me and thank you for listening.