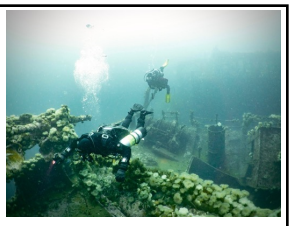
Level 1 – Dive Medicine Pulmonary Issues and Diving



- May 11 , 2026
- Chair Discipline of Anesthesia
- Associate Professor of Anesthesiology
- Hyperbaric Medical Staff Newfoundland and Labrador Health Services
- Contract Physician Atlantic Offshore Medical Services
- **E-mail: gzbitnew@mun.ca**

AOMS ATLANTIC OFFSHORE MEDICAL SERVICES

CUHMA ACMHS

MEMORIAL UNIVERSITY

1

Disclosures:

- I have no financial relationships with any manufacturers
  - Past-President of CUHMA, Past Vice-Chair AFC Committee Diving and Hyperbaric Medicine
- Opinions expressed are my own

2

Objectives:

- Review of Respiratory physiology
- Barotrauma
- Obstructive disease – asthma/COPD
- Pneumothorax – Spontaneous/Traumatic
- Immersion Pulmonary Edema
- OSA/COVID
- Need good function to be able to complete high levels physical exertion, and avoid risk of pulmonary barotrauma from gas trapping

3

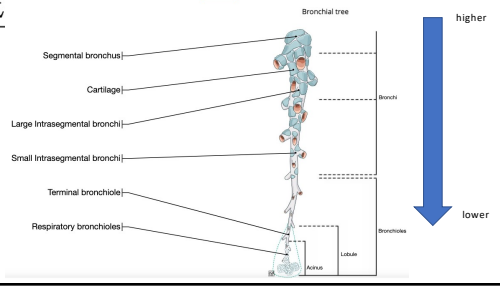
Respiratory Physiology

- Respiration: O^2 in CO^2 out
- Starting with nose and mouth air is humidified and warmed
- Conductive airways (trachea to terminal bronchioles) allow gas transport and no gas exchange, transitional airways allow for transport with limited gas exchange (respiratory bronchioles to alveolar ducts), respiratory airways for gas exchange (alveoli and alveolar sacs)
- Large airways > 2 mm create 90% of total airway resistance
- Bronchi divide into 10 bronchopulmonary branches which make up 5 lobes of lung (3 right and 2 left)

4

Divisions of the bronchial tree

$$Re = \frac{\rho u L}{\mu}$$



5

Basics

- Nasal airway should be free of obstructions
- No evidence of chronic sinus disease
- Want to rule out:
  - Prior Pneumothorax or pneumomediastinum
  - Prior chest surgery
  - Asthma
  - COPD
  - Sarcoidosis
  - Cystic Fibrosis
  - Tuberculosis
  - Pulmonary fibrosis
  - Acute pulmonary infection
  - Any lung disease (Birt-Hogg-Dube Syndrome, lung cancer)

Family history of atopy, asthma, eczema, lung diseases

Occupational exposure: farmer's lung, crab asthma, soft wood dust

Social History: smoking (cigarettes and cannabis, vaping), alcohol, drug use

6

Ask about occupational history….

- Occupational asthma – exposure to chemicals or materials in workplace
- Asbestosis
- Silicosis
- Coal Worker's Pneumoconiosis
- Byssinosis
- Hypersensitivity Pneumonitis – moldy crops, dust, pesticides

7

USC Catalina Hyperbaric Chamber to 165 fsw
https://www.youtube.com/watch?v=f6DDBFovht0

8

Changes in Diving

Depth	Pressure	Air Volume	Air Density
0m/ 0ft	1 atm	1	X1
10m/ 33ft	2 atm	1/2	X2
20m/ 66ft	3 atm	1/3	X3
30m/ 99ft	4 atm	1/4	X4
40m/ 132ft	5 atm	1/5	X5

- Density of Gas increases with pressure, restricting breathing
- There is thoracic displacement of blood from periphery, reducing lung volume
- Work of breathing increases (↑density, ↑hydrostatic pressure, and altered respiratory mechanics)
- Resistance and Dead space ventilation increases from adding underwater breathing apparatus
- CO2 retention can result from this

$$\mathrm{Re} = \frac{uL}{\nu} = \frac{\rho u L}{\mu}$$

Osborne Reynolds

9

Risks of Diving

- Hypothermia, Panic, Drowning, Physical trauma
- Technical problems: hypoxia, hyperoxia, poisoning by inappropriate gas mixture, aspiration from regulator malfunction
- Decompression Illness: Henry's Law – solubility of a gas in a liquid is proportional to the partial pressure of the gas over the liquid
- Loss of buoyancy control – may lead to barotrauma from Boyle's law (volume of a gas at constant temperature varies inversely with pressure exerted on it)
- Barotrauma – may occur on descent is spaces not equalized leading to alveolar exudation and hemorrhage

10

Ontario Code for Medical Examination of Divers

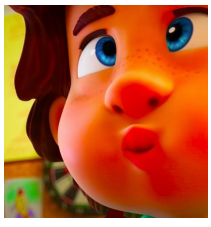
regulation 629/94 (Diving Operations) OHSA

- Spirometry on initial examination and periodically if indicated
- CXR (PA and lateral) initially and periodically if indicated
- Must include FVC, FEV1, FEV1/FVC ratio and FEF 25-75%
- If < 75% predicted should have detailed pulmonary function tests and respirology consultation (consider methacholine challenge)
- Must enquire specifically regarding asthma
- Contraindications to diving include active sarcoidosis, cystic fibrosis with pulmonary involvement and fibrotic lung disease

11

Breath Holding

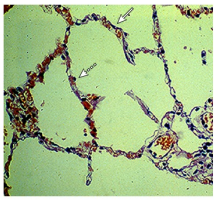
- Most adults can hold breath for about 1 minute breathing room air without hyperventilation – PaO_2 decreases to 65-70 mmHg and $PaCO_2$ increases by about 12 mmHg
- The breakpoint at which normal people are compelled to breath is $PaCO_2$ of 50 mmHg
- Pre-breathing oxygen can hold 2-3 minutes or until $PaCO_2$ is 60 mmHg
- Hyperventilating $PaCO_2$ down to 20 mmHg increase breathholding to 3-4 minutes
- Hyperventilating with 100% oxygen prior to breath-holding extends apneic period to 6-10 minutes



12

Normal lung

Alveolar wall =surfactant lining layer, thin capillary epithelial cell, basement membrane, pulmonary capillary endothelial cell

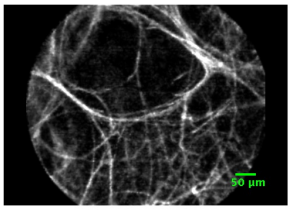


High-power photomicrograph shows alveoli containing capillaries within a narrow interstitium. The alveoli are lined with thin, elongated type I pneumocytes (arrow) and smaller numbers of cuboidal type II pneumocytes (dashed arrow).

Courtesy of Steven E Weinberger, MD.

UpToDate

Normal alveolus on confocal laser endomicroscopy



Reproduced with permission. Copyright © 2015 Dr. David Wilson and Dr. Adam Wellikoff, Louisiana State University Health - Shreveport, LA. All rights reserved.

Descent time 3 min UpToDate

300 million alveoli in each lung

13

Scanning Electron Micrograph of a Human Lung

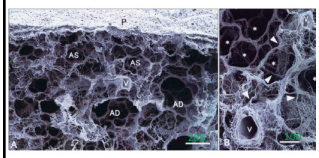


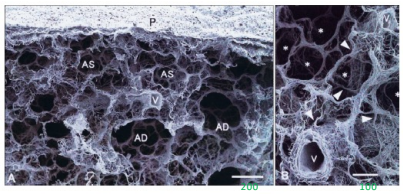
Table 1.1 Dimensions of key structures

Structure	Size
Red blood cells (RBC)	6–8 µm/2–2.5 µm
Neutrophils (one type of WBC [white blood cell])	9–15 µm
Arterioles	100–300 µm
Capillaries	5–10 µm
Endothelial cells	1–2 µm thick and 10–20 µm diameter
Platelets	2–3 µm
Venules	7–50 µm
Microbubbles (MBs)	≤1 µm
Microparticles (MPs)	≤1 µm

Compr Physiol. ; 2: 675–709. doi:10.1002/cphy.c100081.

14

Scanning Electron Micrograph of a Human Lung



Maximal tissue sustained Elastic pressure is 0.13 – 0.2 ATM over ambient which starts at 4 fsw

Human RBC 6-8 μm by 2-2.5 μm

Compr Physiol. ; 2: 675–709. doi:10.1002/cphy.c100081.

15

CHEST

Volume 81, Issue 5, May 1982, Pages 648-650

Can Pulmonary Barotrauma Cause Cerebral Air Embolism in a Non-Diver?

C. Gresham Bayne CDR, MC, USN *, Terrie Wurzbacher LCDR, MC, USN *

- 21 year old male trying to swim underwater across 25 yard pool at 6 feet of depth, upon failing second time stood up and complained of headache, dizziness and "tingling" all over
- 5 minutes later vomiting and 5-minute grand-mal seizure which ended spontaneously at which point CPR was begun
- Initial rhythm for paramedics was VT, in ER VF, called after 41 minutes

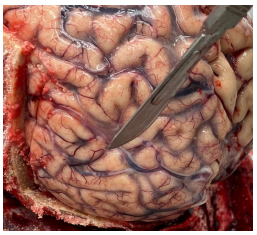
16

Arterial Gas Embolism

85% symptoms at 5 min
100% symptoms at 10 min

Clinical findings in air embolism

Symptoms	Physical findings
Dyspnea (100 percent incidence)	Tachypnea
"Gasp reflex"[4]	Wheeze
"Sucking sound"[4]	Rales
	Respiratory failure
Cardiac	
Substernal chest pain	Hypotension
	Tachycardia
	Mill wheel murmur[5]
	Signs of right heart failure (eg, elevated JVD)
	Shock
Neurologic	
Sense of doom	Change in mental status
Dizziness/lightheadedness	Focal neurological deficits
Skin	
	Crepitus over superficial vessels (seen rarely in setting of massive air embolus)
	Livedo reticularis
Ocular	
	Bubbles within the retinal arteries



UpToDate

17

Human Physiology in an Aquatic Environment

October 2015 · Comprehensive Physiology 5(4):1705-1750 · Follow jou

Pulmonary Barotrauma

- Can even be seen without compressed gas
- Breath holding on ascent – Diver panic
- After normal ascent or at depth if:
  - Airway obstruction (asthma/inflammation/mucous plugs)
  - Blebs/Bullae
  - Occult lesions (tumour/cyst)

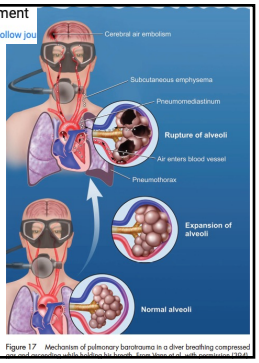


Figure 17 Mechanism of pulmonary barotrauma in a diver breathing compressed

18

292 Diving and Hyperbaric Medicine Volume 50 No. 3 September 2020

Case reports

Arterial gas embolism breathing compressed air in 1.2 metres of water

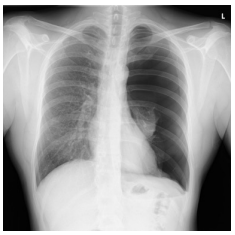
Neil B Hampson[1], Richard E Moon[2]

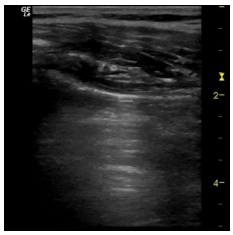
- 25-year-old fit military aviator
- Left temporal headache and then rapidly bitemporal 5-10 min after exiting pool, unsteady Rhomberg falling to right and mild difficulty with finger to nose pointing
- Only need a trans-pulmonic (intratracheal-intrapleural) pressure of 60-70 mmHg to tear pulmonary parenchyma
- If intra-alveolar pressure was 0 mmHg and respiratory compliance was 0 ml/mmHg at TLC, this could be achieved by adding 1/10 of an ATA or 76 mmHg to system (1 meter underwater)

19

Goal to avoid this

Case courtesy of Dr Andrew Dixon, Radiopaedia.org, rID: 45149





Case courtesy of Dr Ian Bickle, Radiopaedia.org, rID: 86926

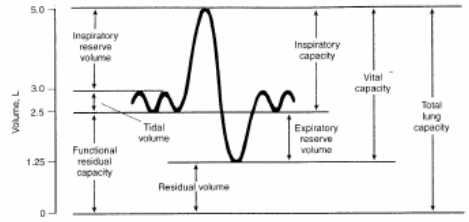
20

How do we assess the Diver for Respiratory fitness?

- HISTORY:
  - Prior lung disease, Respiratory symptoms current and past (childhood events), prior chest trauma, episodes of pneumothorax, occupational exposures*
- Exam
- Spirometry (PEF >80%)
- CXR – PA and Lateral
- Consider –HRCT chest, Methacholine challenge, Body Plethysmography, exercise testing
- **CSA Z275.2 "Pay particular attention to indices of flow at low-mid volumes (FEF25, FEF 25-75, FEF 50), < 75% values not necessarily disqualifying but trigger detailed lung function tests and Respirology consult"**

21

Common Lung Volumes



22

Respiratory Rate

- With reduced lung compliance, larger changes in pleural pressure are needed to create the same tidal volume.
- Patients with low lung compliance breath with lower tidal volumes and more rapid rate
- **Spontaneous respiratory rate is most sensitive clinical index of poor lung compliance**

23

UNDERSEA & HYPERBARIC MEDICINE

Respiratory fitness for occupational diving, what is new?

Pieter-Jan van Ooij, MD, PhD[1]; Robert A van Hulst, MD, PhD[2]

[1] Diving Medical Center Royal Netherlands Navy, Den Helder, The Netherlands
[2] Department of Anesthesiology and Hyperbaric Medicine, Amsterdam UMC, Location AMC, Amsterdam, The Netherlands

CORRESPONDING AUTHOR: Pieter-Jan van Ooij – pjam.v.ooij.01@mindef.nl

THE LUNG AND DIVING – UHM 2025 VOL 52 NO 1

- In healthy selective population may use a Z-score of +/- 1.96
- Look at trend based on previous records
- High Resolution CT-chest is gold standard for identifying bullae or blebs (use in clinical history subjects) – Bullae and Blebs contraindication of fitness to dive
- Move away from initial CXR – still required by Z275.2
- Large lungs FVC > Z 1.96 (FEV1 may not increase to same degree)*

24

UHM 2018,VOL. 45, NO. 2 – DIVING AFTER PSP

Review Article

Can my patient dive after a first episode of primary spontaneous pneumothorax? A systematic review of the literature

M. Alvarez Villela, MD [1,2], S. Dunworth, MD [1,4], N.P. Harlan, MD [1,5], RE Moon, MD [1,3]

- Primary spontaneous pneumothorax – occurs in patients who have no apparent lung disease
- Peak is ages 15-34
- Age related and declines with time
- Looked at 491 studies 40 met criteria
- Mean probability of PSP recurrence was 0-67%, average of 22±15.5%
- Follow up ranged 1-120 months, mean of 36
- 63±39% recurrences occurred during the first year
- Time to recurrence 2.8 -107 months with a mean of 20 months

25

UHM 2018,VOL. 45, NO. 2 – DIVING AFTER PSP

Review Article

Can my patient dive after a first episode of primary spontaneous pneumothorax? A systematic review of the literature

M. Alvarez Villela, MD [1,2], S. Dunworth, MD [1,4], N.P. Harlan, MD [1,5], RE Moon, MD [1,3]

- Presence of surgically detected blebs or bullae ranged 77-90%
- High-resolution CT had sensitivity of 84-88% and specificity of 100% for detecting emphysema like changes
- **Lower resolution CT scans** can have sensitivity of **36%**
- Conventional Chest radiography 15% vs HRCT and 60% vs axial CT
- Role of Emphysema like changes (blebs and bullae) seem to be more prevalent in patients with PSP
- More common on those with recurrence 59-89% vs 0-15%
- CXR with combination of pleural thickening, lung blebs, pleural irregularities and pleural adhesions has higher recurrence with 3 abnormalities 67% vs 12% with none at 2 years

26

Risk factors for recurrence of PSP

- ***Height/weight ratio*** *>3.2 (cm/kg add 0.22 for men)*
- *Pulmonary fibrosis*
- *Age 60 or older*
- *Never-smoker status*
- Recurrence free survival (RFS)
- Single risk factor 98±2% at 1, 5, and 10 years
- Four risk factors 47±19% at 1 and 5 years, 31±18% at 10 years

- All risk groups
- RFS 85% at 1 year, 82% at 2 years, 82% at 3 years
- No recurrences in any groups after 8 years

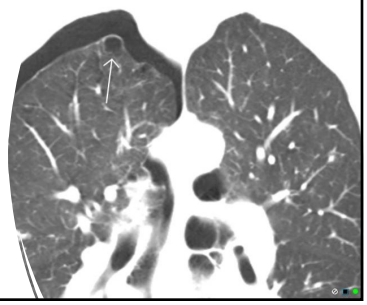
- Mean recurrence lower in surgically treated population 4.0±4% vs 22±15.5% general population

27

Blebs

- Small subpleural thin-walled(<1mm) air containing spaces, not > than 1-2 cm in diameter
- More common in young, thin, smokers

- Case courtesy of Chris O'Donnell, Radiopaedia.org, rID: 19792



28

Pneumothorax and Diving

- Rare
- Caused by pulmonary barotrauma due to entrapped air leading to alveolar rupture and potential AGE/Pneumomediastinum/Pneumothorax
- Breath-holding on ascent is a risk
- Many cases have occurred at depth form ?obstructive airway disease and regional differences in lung tissue compliance
- Big risk of expansion and tension pneumothorax on ascent

Change In Volume With Pressure

Depth (msw)	Absolute Pressure (bar)	Volume (l)	Fraction	% Change
0	1	2000	1	0
10	2	1000	1/2	50
20	3	666	1/3	33
30	4	500	1/4	25
40	5	400	1/5	20

29

Depth	Pressure	Air Volume	Air Density
0m/ 0ft	1 ATA	1	X1
10m/ 33ft	2 ATA	1/2	X2
20m/ 66ft	3 ATA	1/3	X3
30m/ 99ft	4 ATA	1/4	X4
40m/ 132ft	5 ATA	1/5	X5

- Rupture of pulmonary structures us by overstretching of parenchyma
- In normal breathing, ventilation relatively homogenous (uniform time constants exhalation)
- In lung disease different regions have different constants, strain between regions could lead to rupture

- Inter-regional inhomogeneity is worse in diving due to gas density and increased resistance
- This could account for pulmonary barotrauma seen without change in ambient pressure

Only need Transpulmonic Pressure Gradient 60-70 mmHg = ~ 1 meter

30

Review | Rare Genetic Interstitial Lung Diseases Open access

Birt–Hogg–Dubé syndrome

Cécile Daccord | Jean-Marc Good | Marie-Anne Morren Show More

European Respiratory Review 2020 29(157): 200042; DOI: https://doi.org/10.1183/16000617.0042-2020

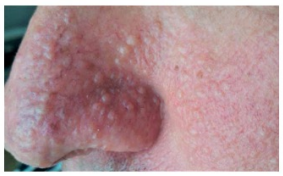


FIGURE 2 Fibrofolliculomas in Birt–Hogg–Dubé syndrome. Multiple skin-coloured tiny papules of the paranasal area can be seen.

- Rare autosomal dominant disorder
- Multiple pulmonary cysts with recurrent pneumothoraces, cutaneous fibrofolliculomas, various renal tumours

31

IPE - 1.1% Divers surveyed

- Risks: Age > 50 years, female, heart disease, excess pre-exercise fluid, tight wet suits, cold exposure
  - DUKE REVIEW
- Overweight/obesity
- Hypertension
- Cardiac Abnormalities:
  - Dysrhythmias (paroxysmal A fib, symptomatic sinus bradycardia, irregular heartbeat with syncope, LBBB, mitral valve prolapse/leaky valve, depressed cardiac function (depressed LV, nonischemic cardiomyopathy), **pulmonary hypertension**, repaired PFO/ASD/ligated PDA, **pulmonary disease** (asthma, reactive airways, obstructive lung disease), **hypothyroidism**, **diabetes mellitus**, **PCOS**, **sleep apnea**

32

Immersion Pulmonary Edema and Comorbidities: Case Series and Updated Review

Medicine & Science in Sports & Exercise, 47 (6), 1128-1134.

DIONNE F. PEACHER[1], STEFANIE D. MARTINA[1], CLAIRE E. OTTENI[1], TRACY E. WESTER[1], JENNIFER F. POTTER[1], and RICHARD EDWARD MOON[1,2]

[1]*Department of Anesthesiology, Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC;* [2]*Department of Medicine, Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC*

TABLE 1. Preexisting risk factors at the time of immersion pulmonary edema incident from literature review.

Asthma (9,57)	4
Cardiomegaly (34)	2
Chronic atrial fibrillation (21,57)	2
Coronary artery disease (14, 23, 27)	3
Diabetes (6,27)	4
Exercise-induced cough (30)	1
Hyperlipidemia (17,27,34,61)	22
Hypertension (14,15,27,32,34,57,61,67)	25
Left ventricular hypertrophy (6,29,34)	9
Peripheral vascular disease (14)	1
Sleep apnea (27,34,61)	6

33

Acute Medicine & Surgery 2021;8:e703

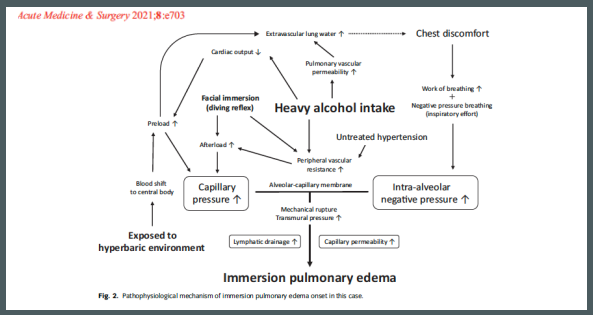
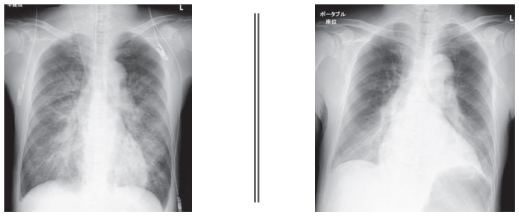


Fig. 2. Pathophysiological mechanism of immersion pulmonary edema onset in this case.

34

Initial CXR After 72 hours



35

What happens in IPE?

- IPE stress failure of pulmonary capillaries from increased hydrostatic pressure
- ↑ intrathoracic blood volume (immersion)
- ↑ cardiac output
- Exaggerated pulmonary vasoconstriction (arterial/venous)
- ? Smaller-than-normal pulmonary lymphatic network (reduced absorptive capacity for lung water)

Photo: Jill Heinerth

36

Asthma

Spectrum of Disease:
Childhood only (no puffers after 12 years)
Family history (Atopy triad: Eczema, Allergies, Asa sensitivity)
Puffer use with URTI
Emergency visits
Steroid use (intravenous, po verses inhaled)
Hospitalization
Intubation/ECMO

Emotional, Cold or Exercise Triggers – NO DIVING
Frequent Rescue Medications – need specialist review
Hospitalizations/Intubation – unlikely to be fit

IF post-bronchodilator increase > 10% confirms reactive airways
If suspicious of asthma – GET METHACHOLINE CHALLENGE

37

Thorax. 2003 Jan;58(1):3-13

Asthma

May be permitted to dive with/without inhaled anti-inflammatory agents if:

- Free from symptoms
- Normal spirometry (FEV1 > 80%, FEV1/FVC > 70%)
- Negative exercise test (<15% fall in FEV1 after)

Monitor with twice daily PEF and refrain if:

- Active asthma (bronchodilator in last 48 hours)
- Reduced PEF >10% from baseline
- Or increased variability (>20% diurnal)

- Exercise induced bronchoconstriction
- 5-20% of general population
- 90% of symptomatic asthmatics
- Correlates with airway inflammation and airway hyperresponsiveness
- **Mild episodic asthma patients do not experience clinically significant bronchoconstriction even with strenuous exercise – these are the ones we will clear**
- Usually 6-10 minutes on ergometer or treadmill, raise heart rate to 80-90% predicted maximum. FEV1 decreases by 10% or more

38

Clinic Rev Allerg Immunol (2016) 50:18–22
DOI 10.1007/s12016-015-8474-y

SCUBA Diving and Asthma: Clinical Recommendations and Safety

Christopher A. Coop · Karla E. Adams · Charles N. Webb

- Bronchospasm may develop in distal airways causing airway obstruction
- Uncontrolled expansion of distal airway on ascent (Boyles's law) may cause pulmonary barotrauma (AGE, pneumothorax)

- Pollen contamination of air tank may exacerbate atopic asthma
- Aspiration of seawater may induce bronchospasm
- In general need thorough history, spirometry, allergy testing, and bronchial challenges (methacholine)
- **Exercise, emotion, cold induced should not dive**
- No dive if rescue medication within 48 hours

39

Risks of Asthma

- Pollen contamination in sensitive diver causing exacerbation under water (*Parietaria* pollen)
- Significant reductions in FEV1. FEV1/FVC ratio, FEF in asthma group after dive to 5 m for 10 min – may impair function of small airways

40

ORIGINAL ARTICLE

Lung function over six years among professional divers

M Skogstad, E Thorsen, T Haldorsen, H Kjuus

Occup Environ Med 2002;**59**:629–633

Occup Environ Med 2002;**59**:629–633

- Divers exposed to increase pO2, venous gas microembolism from decompression stress – may induce inflammatory reactions and gas exchange abnormalities
- Increased WOB from increased gas density may result in respiratory muscle training and increased vital capacity

- Prior studies show divers tend to have reduced maximal expiratory flow rates at low lung volumes
- This small airway dysfunction is related to cumulative diving exposure
- DLCO is known to be reduced immediately after deep saturation dives

41

ORIGINAL ARTICLE

Lung function over six years among professional divers

M Skogstad, E Thorsen, T Haldorsen, H Kjuus

Occup Environ Med 2002;**59**:629–633

- All students were males at Norwegian commercial diving school in Oslo
- 93 students approached and 87 agreed to participate, 83 completed 1 year follow-up, 81 for 3 year, and 77 for 6 year
- Of 77 completers 26 were smokers at baseline, 5 of these had quit by year 6 but 7 had begun during follow up

- Initially 5 asthma in past
- Average age 24.9 years, mean physical training 4 hours/week and 3.3 hours/week 6 years later
- Weight from 80.2 kg to 84.7 kg
- Reference group male students from 5 classes at Norwegian Police Academy – average age 22.4 years mean weight 79.8 kg to 85.3 kg

42

Diving Related Diseases

- First 3 years of follow up – 10 episodes of DCS, 4 middle ear barotrauma
- Second 3 years of follow up – 1 joint DCS and 1 neurological, 3 middle ear barotrauma
- 4 Divers quit from diving related disease, sequelae of neurologic DCS and hand eczema
- See greater annual reduction in FVC, FEV1, and MEF rates in divers vs policemen in those who continue to dive
- Some have seen increased FVC

43

British Journal of Industrial Medicine 1985;**42**:59–62

Effect of commercial diving on ventilatory function

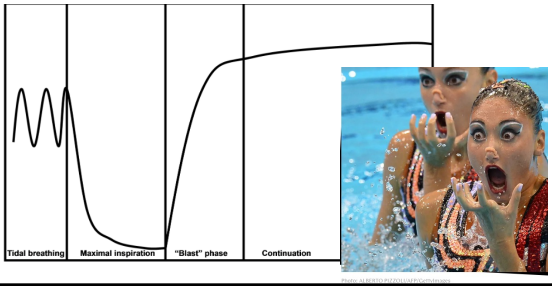
S J WATT

From the Institute of Environmental and Offshore Medicine, University of Aberdeen, and Offshore Medical Support, Aberdeen, UK

ABSTRACT A retrospective analysis of spirometric data from divers attending for annual medical examination at intervals from three to nine years was carried out to examine the long term effect of diving on lung volumes. Those divers with records over a three or four year interval (group 1, n = 224) showed a mean reduction of forced vital capacity (FVC) of 240 ml; those with records over a five or more years interval (group 2, n = 123) showed a reduction of FVC of 400 ml. These reductions remined significant when expressed as a percentage of predicted normal values. The reduction of FVC between records did not correlate with the diver's age, maximum operating depth, duration of diving career, or weight change but was positively correlated with the initial FVC. The reductions in FVC were similar in smokers and non-smokers. The change in forced expiratory volume in one second (FEV_1) followed a similar pattern but was less pronounced than the effect on FVC. The decline in FVC associated with diving occurs from values of FVC that are above the predicted normal; few values below predicted normal were observed. The effect may represent either a gradual return towards the predicted normal or a pathological reduction in lung volume.

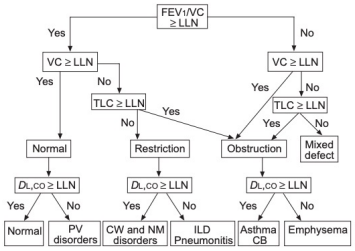
44

Spirometry



45

Interpretation of PFTs



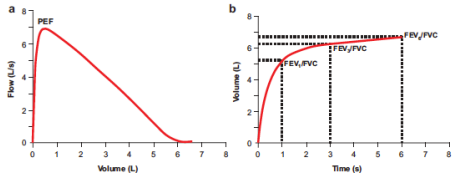
46

EXPERT REVIEW OF RESPIRATORY MEDICINE
2019, VOL. 13, NO. 6, 559–569
https://doi.org/10.1080/17476348.2019.1607301

REVIEW

Advances in spirometry testing for lung function analysis

Agnaldo José Lopes [a,b]



FEV3/FVC may be more accurate than FEF_{25-75} in diagnosing small airway disorder

FEV6 is convenient alternative to FVC (FEV1/FEV6 ratio <0.72 for diagnosing COPD)

47

Simple Way to look at it

1. Look at FEV1/FVC ratio (<70% obstructive)
2. FVC reduced and FEV1/FVC normal (restrictive), if FVC normal early/mild disease
3. FEV1 severity of obstruction (80%=mild, 50-79% moderate, 30-49% severe, <30% very severe)
4. TLC < 80% predicted confirms restrictive, if normal could be poor effort
5. Check RV or RV/TLC suggest air trapping, ↑TLC hyperinflation (emphysema/COPD)
6. Check DLCO - ↓ impaired gas exchange (emphysema, pulmonary fibrosis, pulmonary hypertension), normal in asthma, ↑ pulmonary hemorrhage, polycythema, asthma

48

Severity of Abnormality based on FEV1% Predicted

TABLE 6 Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV_1)

Degree of severity	FEV_1 % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

% pred: % predicted.

A three-level system to assess the severity of lung function impairment using z-score values should be used;
normal z-scores >−1.645
mild z-scores between −1.65 and −2.5
Moderate z-scores between −2.51 and −4
Severe z-scores < 4.1

Eur Respir J 2005; 26: 948–968
DOI: 10.1183/09031936.05.00035205

49

Summary Table

Pattern	FEV1/FVC	TLC	DLCO	Common Causes
Obstructive	↓	Normal/↑	↓ (COPD) / Normal (Asthma)	Asthma, COPD, bronchiectasis
Restrictive	Normal/↑	↓	↓ (fibrosis) / Normal (neuromuscular, obesity)	ILD, obesity, neuromuscular
Mixed	↓	↓	↓	Advanced COPD with fibrosis, sarcoidosis

50

Eur Respir J 2005; 26: 948–968
DOI: 10.1183/09031936.05.00035205

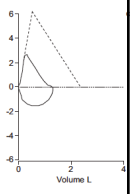
SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING"
Edited by V. Brusasco, R. Crapo and G. Viegi
Number 5 in this Series

Interpretative strategies for lung function tests

- Obstructive defect is disproportionate reduction of maximal airflow in relation to maximal volume that can be displaced
- Implies airway narrowing during exhalation and is defined by FEV1/FVC ratio below 5th percentile
- Concern when FEV1 and FVC are concomitantly decreased and FEV1/FVC ratio is normal – may occur when flow is so slow they can not exhale long enough to empty to RV[#]

- Earliest change in airflow obstruction in small airways is slowing of terminal spirogram (greater reduction in flow measured after 75% FVC exhaled or mean expiratory flow between 25 and 75% of FVC than in FEV1)
- As more advanced disease or central airways become involved FEV1 will be reduced out of proportion to FVC

Concave



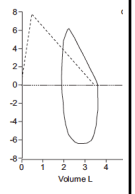
51

Restrictive abnormalities

- Reduction of TLC below 5th percentile and normal FEV1/FVC ratio
- Suspect when VC is reduced, FEV1/FVC increased (>85-90%)
- Pattern of reduced VC with normal or increased FEV1/VC is often caused by submaximal inspiratory or expiratory efforts and/or patchy peripheral airflow obstruction
- Reduced VC alone is associated with low TLC only half of the time

- Pneumothorax and noncommunicating bullae can have normal FEV1/VC and TLC measured in body plesmography, but low FEV1 and VC values. Gas dilution TLC will be low
- Low TLC from single-breath test VA should not be interpreted as restriction, systematically underestimates TLC

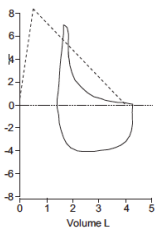
Convex



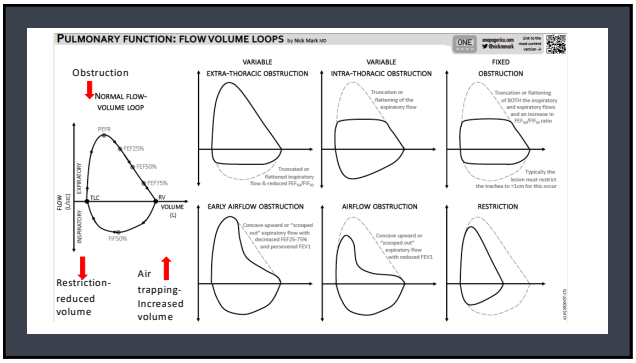
52

Mixed abnormalities

- Co-existence of obstruction and Restriction
- Physiologically FEV1/FVC and TLC below 5th percentiles for relevant predicted values
- If FEV1/VC is low, and VC is normal superimposed restriction is ruled out
- If FEV1/VC is low and largest measured VC is below normal and there is no measure of TLC by body plesmography one can only state VC is also reduced maybe due to hyperinflation but superimposed restriction can not be ruled out



53



54

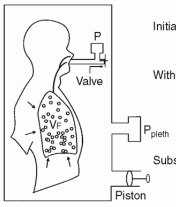
Body Plethysmography – Non-mobilizable volumes

- Placed in volume-constant clear glass box about the size of a phone booth, has an airtight seal and controlled leak to stabilize the pressure within
- Volume and pressure changes are measured as you breath in and out
- Allows measurements of FRC, RV, **TLC**, airway resistance

55

Hyatt's Interpretation of Pulmonary Function Tests: A Practical Guide 5th edition Figure 3-6

Plethysmography uses Boyle's Law



Boyle's law: $PV = P^1V^1$ (Eq. 1)

Initially: $P = P_B$ barometric pressure (cm H_2O)
$V = V_F$ unknown volume of this lung (FRC)

With compression: $P^1 = P_B + \Delta P$ where ΔP is the increase in alveolar pressure measured at the mouth
$V^1 = V_F - \Delta V$ where ΔV is the decrease in volume due to compression

Substituting in Eq. 1 gives: $P_B V_F = (P_B + \Delta P)(V_F - \Delta V)$

and: $V_F = \frac{\Delta V}{\Delta P}(P_B + \Delta P)$

Simplifies to: $V_F = \frac{\Delta V}{\Delta P}(P_B)$ Solve for FRC

56

A 34-year-old female wants to work as Occupational Diver, prior recreational experience

- COVID in past ~ 5 months earlier
- Has had an emergency visit 2 weeks after for SOB, received antibiotic and Ventolin MDI for same
- Now wanting to pursue work as professional dive guide
- Feels "almost" normal – does find occasionally having a "cough" or tickle
- BMI is 35

57

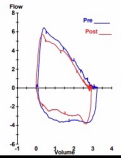
Height(in): 63 (cm) 159 Weight(lb): 241 (kg) 109.5 Tested by: JE

		Ref	(Normal Range)	Pre	% Ref	Post	% Ref	%Chg
Spirometry								
FVC	Liters	3.64	(2.9 - 4.3)	3.23	89	2.96	81	-9
FEV1	Liters	2.95	(2.4 - 3.5)	2.75	93	2.55	86	-7
FEV1/FVC	%	82	(71.8 - 91.5)	85		86		
FEF25-75%	L/sec	2.94	(1.8 - 4.1)	3.02	103	3.00	102	-1
PEF	L/sec	6.94	(5.4 - 8.5)	6.43	93	5.72	82	-11
Lung Volumes								
TLC	Liters	5.09	(4.1 - 6.0)	4.36	86			
VC	Liters	3.64	(2.9 - 4.4)	3.29	90			
FRC PL	Liters	2.63	(1.9 - 3.4)	1.38	53			
ERV	Liters	1.15	(0.9 - 1.4)	0.20	18			
RV	Liters	1.38	(0.8 - 2.0)	1.07	78			
RV/TLC	%	32	(19.9 - 44.6)	25				
Vtg	Liters	1.86	(0.9 - 2.8)	2.05	110			
Resistance								
Raw	cmH2O/L/sec	1.62	(0.5 - 2.7)	2.67	165			
Gaw	L/sec/cmH2O	0.619	(0.2 - 1.0)	0.374	60			
sRaw	cmH2O/L/s/L	3.84	(2.5 - 5.2)	5.47	142			
sGaw	L/s/cmH2O/L	0.580	(-0.2 - 1.3)	0.183	31			

Bronchodilator response is an increase in FEV1 or FVC by 12% and 200 ml
If larger than this may be predictive of more exacerbations and rapid decline in lung function

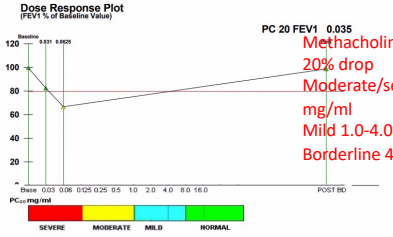
Technical Comments:
Pt had difficulty doing post FVL due to coughing.

Report:



58

	Ref	Pre	Baseline Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	Post
Concentration			0.031	0.0625									
FEV1	2.94	2.71	2.44	2.02	1.63								2.42
% Pred		92	83	68	55								82
% Change			-10	-17	-33								-1



Methacholine Challenge
20% drop
Moderate/severe <1.0 mg/ml
Mild 1.0-4.0 mg/ml
Borderline 4-16 mg/ml

Comments:
At 0.06 mg/ml patient did note some mild SOB and Cough. Pt's symptoms were relieved by Ventolin.
Pt met discharge criterian prior to release from the lab.

59

DLCO - Diffusion Capacity

- Not often ordered for diving medical
- Usually with single-breath technique
- Inspiration of gas mixture containing 0.3% Carbon Monoxide and 10% Helium
- After a 10 second breath hold, patient exhales
- First portion of exhaled breath is **dead-space** ventilation and is discarded
- Next liter is collected and analyzed, difference between original and final concentrations represents gas transported across lung alveolar surface
- ↓ in decreased pulmonary blood flow (pulmonary emboli, chronic pulmonary hypertension), reduced surface area for diffusion (emphysema, diffuse fibrosis), loss of alveoli or incomplete expansion (surgery, destruction from disease, atelectasis, pulmonary edema)
- ↑ in obesity, asthma, elevated number of binding sites for hemoglobin (increased pulmonary blood flow, alveolar hemorrhage syndromes, polycythemia)

60

Sarcoidosis

- Typically young adults
- 3 x more prevalent in African decent
- 2 x more prevalent females
- 7-11/100000 North America
- One or more:
  - Bilateral hilar adenopathy
  - Pulmonary reticular opacities
  - Skin, joint, and/or eye lesions

Associated with Pulmonary Barotrauma

40-70% abnormal PFTs

20% abnormal PFTs

61

Sarcoidosis

DIVING CONTRAINDICATED IN ACTIVE SARCOIDOSIS

CSA Z275.2 Required on initial medical

Long standing sarcoidosis

The chest radiograph shows interstitial opacities with upper zone predominance, volume loss, and advanced fibrosis (Stage IV).

- 90% lung involvement
- Usually diffuse interstitial lung disease
- May see pneumothorax, pleural thickening, chylothorax, pulmonary hypertension
- Presenting symptoms: cough, dyspnea, chest pain, fatigue, fever, malaise, weight loss
- Crackles are NOT commonly heard

62

CSA 275.2-20

- **Diving Medical History asks specifically:**
- Lung squeeze
- Ruptured lung (burst lung)
- Air embolism
- **Family Medical History:**
- Asthma
- Allergies
- Pneumothorax

- **Medical History:**
- Persistent/Chronic cough
- Shortness of breath or breathing trouble
- Wheezing, asthma
- Wheezing on breathing cold air/exercising
- Lung problems requiring inhalers/puffers
- Tuberculosis
- Pneumothorax/collapsed lung

63

Systemic Lupus Erythematosus

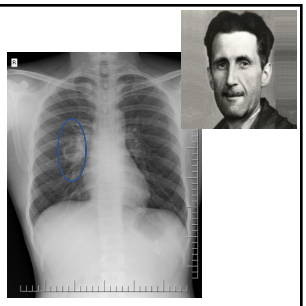
- Autoimmune disease
- Affects any body part
- At onset – arthralgia/arthritis, rash "butterfly rash"
- Describe fatigue, fever, weight loss, myalgia
- Increasing over time – nephritis, Raynaud's
- Risk of osteonecrosis
- Pleuritis with or without effusion, interstitial lung disease, pulmonary hypertension, alveolar hemorrhage

https://www.mayoclinic.org/diseases-conditions/lupus/symptoms-causes/syc-20365789

64

Tuberculosis

- Fever in 70%
- Pleuritic or retrosternal chest pain in 25%
- Rarely fatigue, cough, arthralgia, pharyngitis
- Risk of transmission
- Once treated can be deemed fit if no lasting impairment in lung function and normal investigations



Case courtesy of Dr Aditya Shetty, Radiopaedia.org, rID: 27747

65

Prevalence of Pulmonary Bullae and Blebs in Postmortem CT Imaging With Potential Implications for Diving Medicine

Henri M. de Bakker, MD; Melanie Tijstorman, MSc; Olga J. G. de Bakker-Tounisson, MD, PhD; Vidja Soerdjbalie-Maikoe, MD, PhD; Rob A. van Hulst, MD, PhD; and Bernadette S. de Bakker, MD, PhD

- Postmortem CT scans of 130 adults
- Group 1 (aged 21-30) 26 patients 4 with blebs
- Group 2 (aged 31-40) 28 patients 9 with blebs
- Group 3 (aged 41-50) 27 patients, 9 with blebs, bullae in 1, 4 with both
- Group 4 (aged 51-60) 28 patients, 7 with blebs, 2 with bullae and blebs
- Group 5 (61-70) 21 patients, 3 with blebs, bullae in 1, and 2 with both

- 58% male, 42% female
- Argue 1/3 of normal adult population has at least one pulmonary bullae or bleb
- 32% blebs (±bullae) and 2% isolated bullae
- Most are found upper lobes and apices
- None > 20 mm
- "*Common understanding of the pathophysiology and evidence from case reports should prompt us to be cautious declaring a subject with a known bulla fit to dive*" **Dr. Kay Tetzlaff et al**

66

Pulmonary Fibrosis

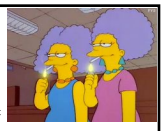
- Cycles of epithelial injury with dysregulated repair
- Familial < 5% (AD inheritance)
- Hermansky-Pudlak syndrome (AR inheritance) – early thirties and oculocutaneous albinism
- Telomeropathies – premature greying, transaminitis
- Risks from **cigarette smoking, stone, metal, wood and organic dusts, GERD** maybe through chronic microaspiration
- Usually over 60, **gradual dyspnea on exertion, non-productive cough**
- Symptoms of rheumatic disease (arthralgias, dry eyes, dry mouth, muscle weakness, numbness, Raynaud phenomenon, tingling)
- Therapeutic irradiation
- Medications (amiodarone, bleomycin, long-term nitrofurantoin, biologics)

Case courtesy of Dr Ian Bickle, Radiopaedia.org, rID: 50375

67

COPD

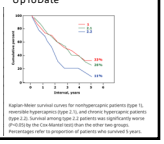
- 10% of individuals over the age of 40, prevalence increases with age
- Persistent respiratory symptoms and airflow limitation due to airway and/or alveolar abnormalities caused by exposure to noxious particles or gases
- Chronic bronchitis – cough for 3 months of 2 or more consecutive years after bronchiectasis and other causes ruled out
- Emphysema –abnormal and permanent enlargement of airspaces distal to terminal bronchioles, accompanied by destruction of the airspace walls, without obvious fibrosis to the naked eye, may not have airflow obstruction but more common among those with moderate or severe obstruction



- 3 symptoms:
  - Dyspnea, Chronic cough, Sputum Production most common
  - Dyspnea on exertion earliest symptom
  - May have chest tightness and wheezing
- Risks:
  - Smoking
  - Passive smoke exposure
  - Biomass fuel use (woodstoves)
  - 20% occupational exposure (fish-plant workers, smelters, wood dust)

Survival at 5 years

UpToDate



68

COPD

Case courtesy of Dr Andrew Dixon, Radiopaedia.org, rID: 9674

May consider BNP to rule out CHF
Check serum bicarbonate (may be elevated in CO2 retention)
Screen for alpha-1-antitrypsin deficiency
DLCO decreases in proportion to severity of asthma

COPD ≠ Professional/Commercial Diving

69

OSA

- Do you snore loudly?
- Do you feel tired, fatigued, or sleepy in daytime?
- Have you stopped breathing in your sleep?
- Have you been treated for high blood pressure?
- BMI > 35
- Age over 50?
- Neck circumference > 40 cm
- Male gender?

70

OSA

- Risk inattention, falling asleep during work
- Risk of stroke, CAD and sudden cardiac death, get repeated sympathetic nervous system activation
- Untreated Sleep Apnea is an absolute contraindication

71

Virchows Archiv (2021) 478:81–88
https://doi.org/10.1007/s00428-020-02943-0

REVIEW AND PERSPECTIVES

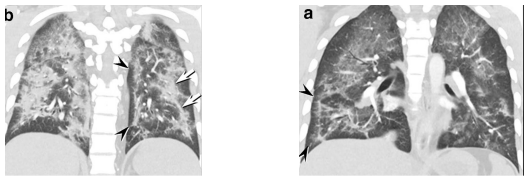
Vaping-related lung injury

Maxwell L. Smith[1] · Michael B. Gotway[2] · Laura E. Crotty Alexander[3] · Lida P. Hariri[4]

- EVALI - Lipoid pneumonia to alveolar hemorrhage
- Vitamin E acetate clear viscous solution added as cutting agent to THC oils (most commonly black and gray market devices) as heated forms Ketene gas
- Symptoms: shortness of breath, cough, chest pain, diarrhea, abdominal pain, fever and fatigue
- Hours to weeks prior
- Labs: ↑ESR, ↑CRP, ↑ Transaminases, ↑ Leukocytes
- CDC criteria: vaped within 90 days, bilateral chest infiltrates, negative infection

72

Coronal CT EVALI

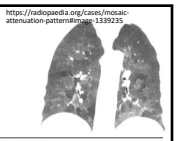


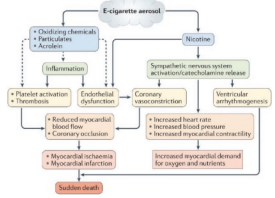
73

Cardiopulmonary Impact of Electronic Cigarettes and Vaping Products: A Scientific Statement From the American Heart Association

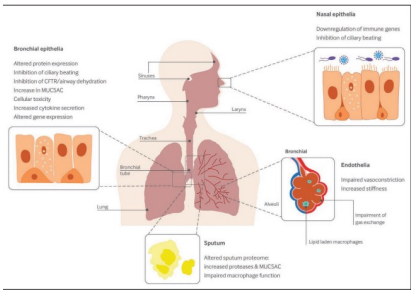
Jason J. Rose, MD, MBA, Chair; Suchitra Krishnan-Sarin, PhD, Vice Chair; Vernat J. Exil, MD, MBA, FAHA; Naomi M. Hamburg, MD, FAHA; Jessica L. Fetterman, PhD; Fumiko Ichinose, MD, PhD, FAHA; Miguel A. Perez-Pinzon, PhD, FAHA; Mary Rezk-Hanna, PhD, FAHA; Eric Williamson, MD; on behalf of the American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Epidemiology and Prevention; Council on Cardiovascular Radiology and Intervention; Council on Lifestyle and Cardiometabolic Health; Council on Peripheral Vascu... Council on Arteriosclerosis, Thrombosis and Vascular Biology

- Vaping lung injury >2800 admissions in 2019 in US
- Up to 27.5% high school students vape and use e-cigarettes
- Diacetyl and acetyl propionyl flavouring inhaled exposure is correlated with spirometry abnormalities and decreased FEV1, leads to bronchioloitis obliterans
- Flavourings (acetoin, diacetyl, ortho-vanillin, and maltol) increase IL-8 secretion when human bronchial cells are treated with them
- Cinnamaldehyde and menthol e-liquids increase apoptosis and inflammatory cytokines





74



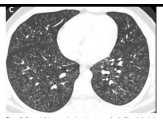
Circulation. 2023;148:703–728. DOI: 10.1161/CIR.0000000000001160

75

Life-threatening bronchiolitis related to electronic cigarette use in a Canadian youth

Simon T. Landman MBBS, Inderdeep Dhaliwal MSc(HQ) MD, Constance A. Mackenzie MD MSc, Tereza Martinu MD MHS, Andrew Steel MBBS, Karen J. Bosma MD

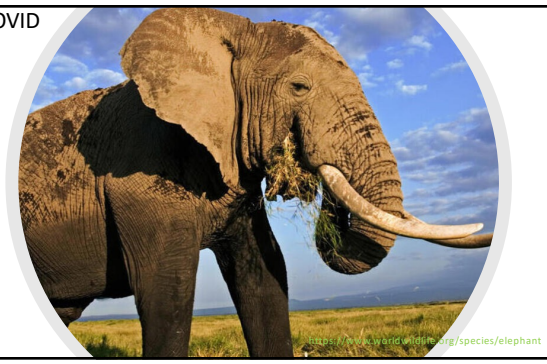
Cite as: *CMAJ* 2019 December 2;191:E1321-31. doi: 10.1503/cmaj.191402; early-released November 21, 2019



- 17 yo male – vaped for 5 months
- Flavoured cartridges – dew mountain, green apple, cotton candy, regularly added THC to vaping fluid, and occasionally from his bong
- Vaping heavily prior to admission given ceftriaxone and azithromycin.
- Day 5 intubated for RR 50
- pH 7.34 and pCO2 47 pO2 78
- Bronchoscopy bilateral frothy, mucopurulent secretions –repeatedly negative microbiology
- Iatrogenic pneumothorax requiring right chest tube
- Day 9 required initiation of VV ECMO, lack of response to corticosteroids (methylprednisolone 100 mg iv od)
- Tracheostomy day 16 due to intractable cough
- Day 21 transfer to lung transplant centre (high dose methylprednisolone 1g/d for 3 then taper) weaned from vent and ECMO 14 days
- 1 month follow-up: FEV1 31%, FVC 52%, FEV1/FVC 50%, RV 227%, TLC 91% predicted
- 2 month FEV1 44%, improved centrilobular nodules, mild bronchial dilation in basilar segments
- At 4 months FEV1 45%, no improvement with bronchodilators

76

COVID

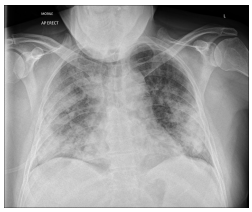


77

How to Return the Post-COVID Diver

Welcome to Endemic Phase

- Determined by symptom severity: (as Recommended by DMAC)
- Asymptomatic or mild symptoms and recovered with in 1 week: minimum time recovered no symptoms **1 month** (EUBS 3 months mild symptoms)
- Moderate symptoms (shortness of breath, may have been > 1 week, not bad enough to be hospitalized): minimum time recovered no symptoms, back to usual fitness: **2 months**
- Severe symptoms (hospitalization, intubated, ECMO): minimum time recovered no symptoms, back to usual fitness: **3 months**
- Concern is long-term structural changes to lung parenchyma such as fibrosis seen in SARS/MERS potentially increasing risk of barotrauma and decreased exercise tolerance



Case courtesy of Dr Ian Bickle, Radiopaedia.org, rID: 75844

78

Risks of COVID 19 to Diver

- Reduced exercise capacity because of residual lung disease
- Lung changes increasing risk to barotrauma (reduced compliance from scarring, fibrosis or development of bullae and blebs)
- May interfere with pulmonary vasculature to allow asymptomatic venous gas emboli across
- Isolated elevations in cardiac biomarkers (autopsy specimens showing myocyte necrosis, lymphocytic myocardial infiltrates and dilated right ventricles – mostly due to general inflammation/hypercoagulable state)
- Virus does invade endothelial cells
- Uses ACE-2 receptor to enter cells, down regulating them increasing Angiotensin-2 (vasoconstriction, inflammation, and prothrombotic state)
- Cardiac Manifestations: myocarditis, myocardial injury (high biomarkers), cardiomyopathy, arrhythmias, thromboembolic disease, ACS
- Want to ensure no issues with RV or LV function, any myocardial inflammation on MRI, epicardial coronary disease diagnosed?
- > 10 METS activity

79

COVID Categories

Category 0 *NO history of COVID-19-suspected illness*	Category 1 *MILD COVID-19-suspected illness*	Category 2 *MODERATE COVID-19-suspected illness*	Category 3 *SEVERE COVID-19-suspected illness*
Definition: Divers who have no history of COVID-19 suspected illness should proceed with normal evaluations. Additionally, we would use these criteria in those who may have had a positive screening PCR or antibody test, but without any history of illness or symptoms consistent with COVID-19.	Definition: ● Did not seek health care or received outpatient treatment only without evidence of hypoxaemia. ● Did not require supplemental oxygen. ● Imaging was normal or not required.	Definition: ● Required supplemental oxygen or was hypoxic. ● Had abnormal chest imaging (chest radiograph or CT scan). ● Admitted to the hospital but did NOT require mechanical (intubation) or assisted ventilation (BIPAP, CPAP) or ICU level of care. ● If admitted, had documentation of a normal cardiac work up including normal ECG and cardiac biomarkers e.g., troponin or CK-MB and BNP.	Definition: ● Required mechanical (intubation) or assisted ventilation (BIPAP, CPAP) or ICU level of care. ● Cardiac involvement defined as abnormal ECG or echocardiogram, or elevated cardiac biomarkers e.g., troponin or CK-MB and BNP (or absence of documented work up). ● Thromboembolic complications (such as pulmonary embolism, DVT, or other coagulopathy).

Diving and Hyperbaric Medicine Volume 50 No. 3 September 2020

80

Diving and Hyperbaric Medicine Volume 50 No. 3 September 2020

COVID Diver Suggested Evaluation

Category 0 *NO history of COVID-19-suspected illness*	Category 1 *MILD COVID-19-suspected illness*	Category 2 *MODERATE COVID-19-suspected illness*	Category 3 *SEVERE COVID-19-suspected illness*
● Initial/periodic exam per professional group or RSTC guidelines. ● Chest radiograph only if required per professional group or RSTC guidelines. ● No additional testing required.	● Initial/periodic exam per professional group or RSTC guidelines. ● Spirometry. ● Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ● If unknown (or unsatisfactory) exercise tolerance', perform exercise tolerance test with oxygen saturation.	● Initial/periodic exam per professional group or RSTC guidelines. ● Spirometry. ● Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ● ECG. ● Echocardiogram (if no work up was done as an inpatient. Can forgo if had negative work up). ● If unknown (or unsatisfactory) exercise tolerance', perform exercise tolerance test with oxygen saturation. ● Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines.	● Initial/periodic exam per professional group or RSTC guidelines. ● Spirometry ● Chest radiograph (PA and lateral); if abnormal, obtain chest CT. ● ECG. ● Repeat cardiac troponin or CK-MB and BNP to ensure normalization. ● Echocardiogram. ● Exercise Echocardiogram with oxygen saturation. ● Investigation and management of any other complications or symptoms per provider and professional group or RSTC guidelines.

81

General COVID rules

- No Diver should enter the water if they currently have or within 14 days:
  - Cough
  - Shortness of breath/difficulty breathing
  - Fever
  - Chills
  - Myalgias
  - New loss or taste or smell

- Exercise tolerance should be back to normal
- Minor deviations like getting more winded, longer recovery times suggest more investigation
- Exercise should get to **> 10 METS**
- Everyone gets spirometry and CXR
- Moderate add EKG, echo
- Severe add biomarkers, exercise echo
- If unsure of exercise tolerance add testing, get CT if abnormal CXR

82

Points to ponder

- No one should dive with URTI (especially asthmatic)
- Many people with contraindications to commercial diving have been cleared for recreational scuba
- Be suspicious of wheezing, hay-fever, family history
- Get methacholine challenge in asthmatic if you are thinking of clearing them
- Respirology consultation is reasonable in questionable cases
- ***HEAD OFF new divers with questionable pulmonary status***

Absolute contraindications for occupational diving
Bullae and blebs
Pneumectomy
Spontaneous or recurrent pneumothorax
Exercise-induced bronchoconstriction
Uncontrolled (obstructive) sleep apnea syndrome

Table 1: Absolute respiratory contraindication regarding fitness to dive.

THE LUNG AND DIVING – UHM 2025 VOL 52 NO 1

83

Questions?

84

Now that you are all asleep.

Questions?

gzbitnew@mun.ca

MEMORIAL UNIVERSITY

85

References

- British Thoracic Society Fitness to Dive Group, Subgroup of the British Thoracic Society Standards of Care Committee. British Thoracic Society guidelines on respiratory aspects of fitness for diving. Thorax. 2003 Jan;58(1):3-13. doi: 10.1136/thorax.58.1.3. PMID: 12511710; PMCID: PMC1746450.
- Bove AA. Diving medicine. Am J Respir Crit Care Med. 2014 Jun 15;189(12):1479-86. doi: 10.1164/rccm.201309-1662CI. PMID: 24869752.
- de Bakker HM, Tijsterman M, de Bakker-Teunissen OJG, Soerdjbalie-Maikoe V, van Hulst RA, de Bakker BS. Prevalence of Pulmonary Bullae and Blebs in Postmortem CT Imaging With Potential Implications for Diving Medicine. Chest. 2020 Apr;157(4):916-923. doi: 10.1016/j.chest.2019.11.008. Epub 2019 Nov 22. PMID: 31759963.
- Krzyżak J, Korzeniewski K. Medical assessment of fitness to dive after COVID-19. Int Marit Health. 2021;72(3):223-227. doi: 10.5603/IMH.2021.0041. PMID: 34604993.
- Sadler C, Alvarez Villela M, Van Hoesen K, Grover I, Lang M, Neuman T, Lindholm P. Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance. Diving Hyperb Med. 2020 Sep 30;50(3):278-287. doi: 10.28920/dhm50.3.278-287. PMID: 32957131; PMCID: PMC7755459. Peacher DF, Martina SD, Otteni CE, Wester TE, Potter JF, Moon RE. Immersion pulmonary edema and comorbidities: case series and updated review. Med Sci Sports Exerc. 2015 Jun;47(6):1128-34. doi: 10.1249/MSS.0000000000000524. PMID: 25222821.
- Morimatsu, Y. , Nasu, M. , Murata, Y. , Kitahara, Y. , Arakaki, J. , Fukumoto, T. , Nishikiori, H. & Ishitake, T. (2021). Severe immersion pulmonary edema in a novice elderly scuba diver after heavy alcohol intake. *Acute Medicine & Surgery, 8* (1), e703. doi: 10.1002/ams2.703.

86