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Inspire

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FIRST WORD

VOLUME 22, ISSUE 3. DECEMBER 2021

Hello and welcome to the final issue of Inspire for 2021, I hope you are well.

You know how it is, you wait ages for a number [insert bus route number here] bus to appear, then several appear at once. Something similar has occurred this issue, with articles concerning gas transfer testing. You may recall a strange question on the forum recently from a Dr Kendrick, who asked what physiologists told their patient, if asked about the gas they inhaled during the CO diffusion test. When I tested adult patients (back in the 1980s) I recall telling most this information at the start of the test, purely out of interest, and don't recall anyone ever questioning it. The reason for the question, and the responses, are revealed in a very interesting article on page 26. If that wasn't enough, shortly after this, Kevin Hogben produced a 'How it Works' concerning the 2017 ERS/ATS update on the CO single breath test. Be warned, this contains one page full of equations, so perhaps read it before the Christmas Day sherry.

Fresh Air is a comprehensive review, by Dr Stockley, of the Peripheral Arterial Tone (PAT) technology, used in the diagnosis of obstructive breathing during sleep. I recall several posters about this in the 2019 ARTP conference and its use was primarily in adults (>12yo) but this article suggests further investigation, in case paediatric algorithms become available.

A late addition was Prof. Cooper's article on Lung Function during the pandemic, part of a respiratory health campaign run by Health Awareness, which he has allowed to be reproduced in this issue.

Harry Griffin is on Top Forum, gently reminding us of the most popular posts on ARTP forum since August. An information resource for sure.

On the Blower is a little abbreviated this time, possibly by the lack of face-to-face conferences, which I believe may be addressed next year—see page 48 for details of how to submit YOUR abstract for next year's ARTP conference. There is a call for participation in ARTP Regional Groups plus details of a GIRFT respiratory report outlining measures to boost the physiology workforce. ARTP Chair, Julie Lloyd starts the issue with an update from the very top of ARTP!

My thanks to all the contributors for their planning and submitting timely and informative articles. Thanks also to the Editorial team, who provide much needed feedback to me and to EBS for helping to get this issue finalised. Wishing you all a Happy Christmas and here's to a better 2022. **Aidan Laverty**

A WORD FROM THE CHAIR

Julie Lloyd

ARTP Honorary Chair

Welcome again to 'Word from the Chair' and Seasons greetings to you all! The nights have certainly drawn in, the temperatures have dropped and we have already had the first two storms of winter as I write this. Some of you may have experienced travel difficulties and power cuts following Storm Arwen; I hope no one was without power for too long. Apart from the challenges of the winter weather, the NHS continues to face the challenges posed by the COVID 19 pandemic and more recently rising concerns about the newest variant named Omicron, which now seems to be sweeping the globe. It may mean many of us are called upon to rise to the challenges again, and whilst many of us are still recovering from our previous experiences, I know all of us will do whatever is required for our patients.

Despite all of the challenges we are currently facing, ARTP have been extremely busy since our last edition of ***Inspire***. I am very proud to have been part of the Virtual National Strategy Day on Friday 12th November 2021. This had a superb program and I am very grateful to Joanne Shakespeare and Laura Jess for their hard work in pulling this day together. The morning focussed on training and development, with sessions including the changes in the updated STP curriculum, the new graduate diploma in Respiratory and Sleep Sciences to develop a pathway for graduates with relevant degrees to enter our profession and updates on spirometry and the newly developed sleep qualifications. The morning concluded with a workshop on apprenticeships and a review of the ARTP workforce-planning document developed by the ARTP Standards committee. The afternoon maintained this extremely high standard, with an update on the upcoming Physiological Measurement Collection Plan and Stocktake and Covid related sessions exploring the use of air scrubbers to improve patient workflow and a review of the impact of COVID 19 on respiratory and sleep services.

As ever with ARTP, we saved two important and inspirational sessions until the end of the day and what sessions they were! To support the launch of the ARTP Equality, Diversity and Inclusion Policy, we were fortunate to have **Mehrunnisa Lalani**, an organisational culture disputer and consultant, give us her insights on equality, diversity and inclusion and ARTP.

Mehrunnisa's career has seen her serving in a number of equality and diversity related roles, along with governance and within the NHS.

This was preceded by a truly inspirational presentation from **Anthony Bennett**, talking about the incredible team of doctors, nurses, surgeons, nutritionists, and cleaners that came together to save his life.

He shared his story of a life-threatening infection where he was given only a 10% chance of survival, was resuscitated 12 times and spent seven weeks in hospital before making a full recovery. The take home message was to 'Say Yes' to every opportunity that presents itself, even when the opportunity seems like a challenge – such important words in the difficult times we are currently living through.

At this time of year, I would normally be encouraging you all to get your 'last minute' registrations submitted for our Annual Conference. I am mindful that this is an important event for ARTP as an organisation and both the Board and the Events Committee have debated at length about the format of our next Conference. We hope to update everyone about the plans for the next Conference over the next few weeks and I am confident that it will deliver to the same high standards that you have all come to expect from ARTP.

As always, I would really love to hear your feedback and suggestions for what you would like from your ARTP. Wishing you and your loved ones the best of the season's festivities and hoping you all enjoy some well-deserved time from work.

I really hope you enjoy this edition of Inspire.

Until next time, feel free to contact me at chair@artp.org.uk.

ON THE BLOWER

Matt Rutter
Alan Moore
Prof. Brendan Cooper

Welcome to a somewhat truncated OTB this issue. Firstly, I need to apologise to Medical Graphics UK as they sent an item for the previous issue of Inspire, which unfortunately was omitted from publication. The content has been added below and I thank them for their understanding. This OTB also contains a news update from Vitalograph. Since the previous Inspire, a face-to-face ARTP conference has been announced for next year and we look forward to being able to visit all the manufacturers in person again.

Matt Rutter

medical graphics UK LIMITED

Medical Graphics UK is a leading supplier of a complete line of cardiopulmonary diagnostic equipment and supplies. Based in Great Britain, Medical Graphics UK provides sales and service throughout the United Kingdom; specialising in products from MGC Diagnostics (USA) and Medisoft SA (Belgium).

With the release of **Ascent™ cardiorespiratory diagnostic software** for pulmonary function testing, we are excited to offer the next generation of diagnostic tools for the MGC Diagnostics Platinum Elite™ body plethysmograph as well as the CPFS/D USB™ spirometer. Built from the ground up to work with Windows® 10 operating systems and beyond, Ascent software offers features and functions that allow you to get the most from your patients and equipment.

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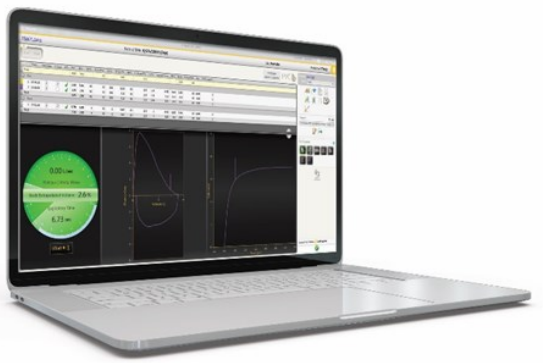
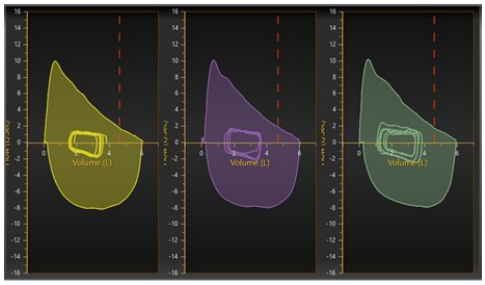


Ascent™ cardiorespiratory diagnostic software starts with a new user interface that guides you through every step of the test, beginning with Ascent software's **Insight™ quality control gauge**. The quality control gauge gives instant feedback in real-time, allowing you to coach your patient through every manoeuvre. If something does not meet the ATS standards, the Quality Control Gauge alerts the operator.

Enhanced Graphics

Ascent software's at-a-glance graphics provide an easy way to determine the status of tests throughout the software. Test icons are shown for each test completed.

Enhanced graphics display your test results with vivid colour and allows you to expand the graphs to see all the detail of each effort.



Visit us on our updated website: medicalgraphicsuk.com, or give us a call at 01452 617 150.

A Global Leader in Respiratory Diagnostics

Thank you!

We would like to thank everyone who attended the National Strategy Day and visited our virtual stand. Once again, the ARTP put on a high-quality programme.

Another fantastic opportunity to talk to users about their needs and discuss our solutions!

New Products, New Look, New Website – Same Dependable Quality!

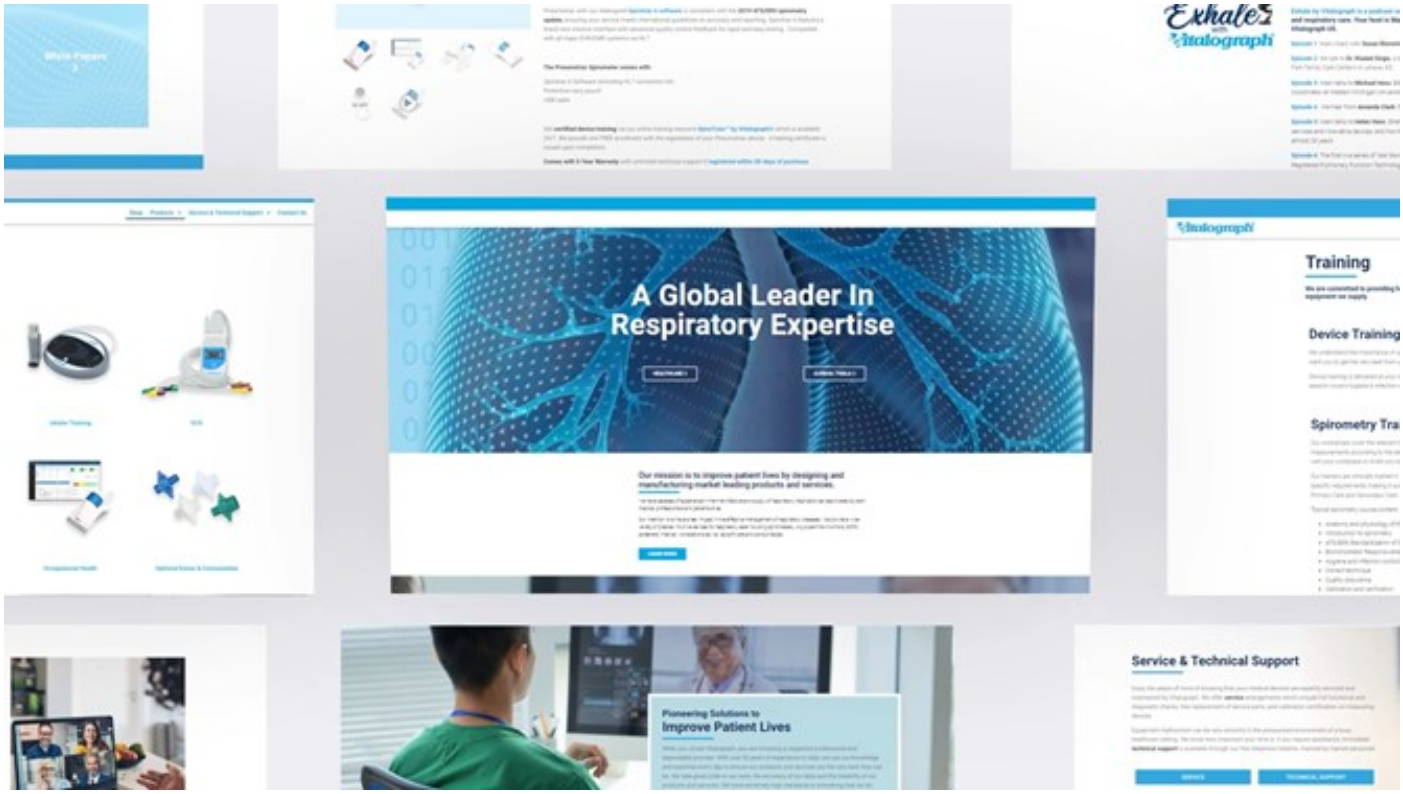
Over the summer we launched the first in our next generation, ATS/ERS 2019 compliant, spirometry devices. Pneumotrac with Spirotrac 6 and Alpha represent market leading PC based and desktop respiratory diagnostic solutions for the connected healthcare world. These new products represent the continuation of our industrial design work to meet the challenges of the future health service.

In line with this we have been working on the evolution of Vitalograph, building upon our rich heritage and decades of experience in the manufacture and supply of respiratory diagnostic devices and solutions. You will see this in not just our exhibition stands (below) but in all our customer facing materials and information.

We were lucky enough to showcase our new look at a recent face to face exhibition, which got extremely positive responses!

A Global Leader in Respiratory Diagnostics

Last month we launched our content rich, new website. Built from the ground up to bring all the latest information and resources together into one place. **vitalograph.co.uk** features new product videos, case studies, online shop and much more.



Pulmonary Function Testing Update

Covid has put a strain on every part of the health service, medical manufacturers, and regulatory bodies, making new product development a longer process than ever before. However, we are delighted to have accepted our first order of the new Vitalograph PFT equipment from Royal United Hospital, Bath. We are all looking forward to completing the installation of the multiple systems as part of a complete department upgrade early in 2022.

Royal United will become our reference site, so we want to focus all our efforts for the first half of next year into making this installation successful. Therefore, we have made a strategic decision to not promote our solutions until the Summer of 2022. We want to make sure that we have firstly a happy customer, and secondly to ensure we have a comprehensive support network for our next customers. Geraldine & team said that they 'are looking forward to providing our patients with a robust and up to date service'.

We are in this for the long haul, and we want to make sure we provide our customers with the solutions and support that they expect from Vitalograph, the go to people for respiratory diagnostics.

Enquiries and Updates

Contact us on **01280 827110** or **sales@vitalograph.co.uk** for further information on our respiratory solutions.

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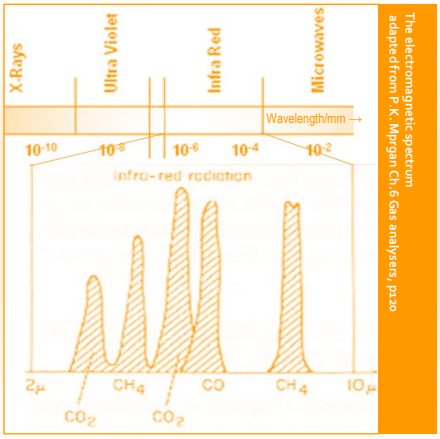
How it Works

By Kevin Hogben

Single Breath Diffusion - Technology over the years and 2017 ERS ATS Guidelines

The Membrane Diffusion (Dm) is directly linked to damaged lung surface area or membrane thickening and therefore is a valuable measurement for lung disease at the current time. In this article, I examine the 2017 ERS/ATS standards for single-breath carbon monoxide uptake in the lung (https://erj.ersjournals.com/content/49/1/1600016) and the equations it references, with a little historical context as to the application and conditions of measurement.



The electromagnetic spectrum adapted from P.K. Mprgan Ch.6 Gas analysers, pp.zo

The instrumentation used to measure gases started soon after WWII, during the 1950's. At the time it was typical to find the dilution of Hydrogen, in accordance with Boyle's Law, used to measure Lung Volumes in a water bath spirometer. Sometimes this was an explosive combination, when a spark from the circulating blower fan caused the Hydrogen to explode, expelling water from the bath across the room.

The Thermal Conductivity (Wheatstone) bridge analyser had been deployed in many of the new industrial chimneys in Germany to monitor Carbon Dioxide entering the atmosphere, a topical observation in light of the recent Climate Change congress.

Scientists also found other gases, with thermal conductivity properties, could be measured by the Wheatstone bridge and the arrival of Helium for use in Airships made this a likely contender for a gas analyser. However, as with any gas analysis, a general analyser of multiple gases is of less use than an analyser specific to the gas we wish to measure.

In the case of Thermal Conductivity it was the practice to eliminate interfering gases as follows;

* Carbon Dioxide absorbed by Soda line in the sample line
* Water vapour by Calcium Chloride and later Drierite in the sample line
* Oxygen, also an interference at high concentrations, of course could not be removed however an electrical compensation was applied at the high concentrations. This largely was only involved in tests such as Dm and Vc, by the dual oxygen level method, where the high level Oxygen test was at more than 65% Oxygen and presented an error in helium measurement of about 1.5%.

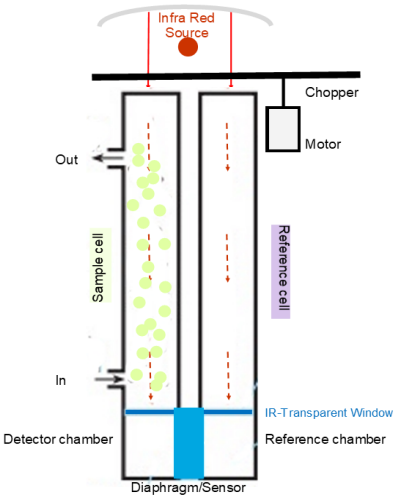
* Note that this article is the author's personal view and not all devices are covered. Please email the editor at inspire@artp.org.uk if you would like to write a history of your favourite(s).

The other commonly used gas was Carbon Monoxide, which could be measured by absorption. The method, again from German influence, used the Luft type Detector; this was a variable capacitor that formed part of a tuned circuit, the analyser had two tubes carrying the infra red beams, one side was totally reference, whilst the other side had one chamber of the gas to measure and the other reference again. In a standard infra red design the reference was considered to be 100% Nitrogen.

However, as in the case of the Helium measurement, the analyser was required to be specific because both Carbon Dioxide and Carbon Monoxide were also being measured and Carbon Dioxide, being the larger signal, sat almost superimposed over the Carbon Monoxide signal.

To combat this, the Luft detector was filled with 100% of the gas to measure, in this case 100% Carbon Monoxide. Furthermore, to remove any cross interference from Carbon Dioxide, the Reference chambers were filled with 100% Carbon Dioxide, therefore the 5% exhaled Carbon Dioxide could not be detected in a background of 100%.

In the case of Carbon Monoxide, the increased quantity, above 100% in the detector, would cause absorption of the infra red heat, the diaphragm in the detector would distort, changing the capacitance and the tuned circuit would then change frequency and this was scaled as % gas to read.



In practice, the Lung Function devices such as the RESPARMETER (J.E Cotes et al. 1965) measured simple spirometry, lung volumes by Helium dilution plus diffusion. The Lung Volume test could take >10 minutes to perform (the current end of test criteria) and it was perceived that the longer the test duration the more Carbon Dioxide levels might impact on the measurement of FRC. Whereas Carbon Dioxide was removed by a chemical absorber in the Closed Circuit Helium dilution test, 3-5 minutes of analysis time was required to reach equilibrium during the diffusion test.

The inhaled gas did not contain Carbon Dioxide, only the major components of Helium, Carbon Monoxide, Oxygen and Nitrogen. However, during the exhalation phase 5% Carbon Dioxide was introduced and the subsequent removal of this by the soda lime then brought *Dalton's law* into play, which states that the removal of any element will result in the other elements (e.g. Helium and Carbon Monoxide) to proportionally occupy the space to equal 100% total composition.

This was corrected by the formalised convention to assume 5% exhaled Carbon Dioxide and then to apply this as the Fractional exhaled correction to both Helium and Carbon Monoxide.

We are familiar with this in the Alveolar Volume Calculation as;

V_A = (Volume inspired – Total volume Dead space) x Helium inspired / (Helium expired x 0.95) x BTPS

(In the USA it was typical to elevate the gases to the same value by increasing the INSPIRED gases by 1.05. It was less obvious to think of this correction as related to the Diffusion equation; it was present but self-cancelled in the equation as Robert Crapo explained in the Intermountain Guidelines and ATS Guidelines).

Looking at the COTES Lung Function – ERS 1983-1993-2005 equations

$$DLCO\ (TLCO) = \left(\frac{Va\ BTPS\ x\ b}{EBHT}\right)\ x\ Log10\ \left(\frac{COin\ x\ (He\ exp\ x\ CO2corr)}{(COex\ x\ CO2corr)x\ He\ in}\right)$$

b was comprised of the corrections used and was represented by 53.6 SI units or 160 Trad units by the following relationship:

logs base e to logs base 10	(2.30)	$b = \frac{2.30\ x\ 60\ x\ 826}{22.4\ x\ 0.133\ x\ (760-47)}$
seconds to minutes	(60)	
litres BTPS to millilitres STPD	(826)	
pressure kPa to Torr	(0.133)	
Amount of substance mmol	(22.4) Avogadro's law	

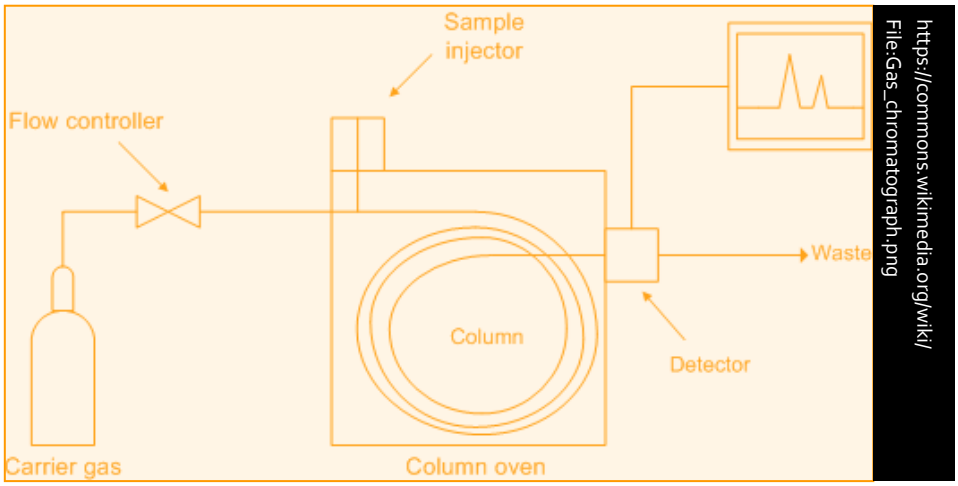
However we can see in the expression that the $CO2_{corr}$ is self cancelling and therefore can be ignored:

$$DLCO\ (TLCO) = \left(\frac{Va\ BTPS\ x\ b}{EBHT}\right)\ x\ Log10\ \left(\frac{COin\ x\ (He\ exp\ x\ \cancel{CO2corr})}{(COex\ x\ \cancel{CO2corr})x\ He\ in}\right)$$

Simplifying to the more common:

$$DLCO\ (TLCO) = \left(\frac{Va\ BTPS\ x\ b}{EBHT}\right)\ x\ Log10\ \left(\frac{COin\ x\ He\ exp}{COex\ x\ He\ in}\right)$$

Because any "Respiratory Inert" gas could be used as the tracer gas, there were other approaches to the measurement. Therefore systems were present that used Neon as the trace gas, measured by a gas chromatograph, also Methane had become a popular trace gas in the real time diffusion test. These



findings originated from the early works of many authors including Cotton and Graham, who used a mass spectrometer that could measure Helium to look at real time gas profiles. Because a mass spectrometer cannot be used to measure Carbon Monoxide concentration, as both Carbon Monoxide and Nitrogen have a molecular mass of approximately 28, a stable isotope with a higher molecular mass, C18O, was used. A mass spectrometer is an expensive gas analyser, plus C18O was also expensive and therefore out of reach of normal Clinical departments.

Work continued using a mass spectrometer to measure Helium however Carbon Monoxide measurement reverted to infra red methods. Andros, a USA company, had pioneered rapid infra red measurement techniques and could provide a response of 100 to 200ms that was usable with a mass spectrometer, which had a typical scan time of 70ms per gas to be measured.

Image by K. Hogben

It was soon recognised that Methane was another gas in the infra red spectrum that, during the 10 seconds of breath holding, could be considered "Respiratory Inert". This then opened the possibility of measuring multiple gases with infra red technology.

In the cases of both Neon and Methane, there was no need to remove the Carbon Dioxide from the sample line and therefore the application of a conversion factor to an expired gas of 0.95 or to an inspired gas of 1.05 was no longer applicable.

Infra red technology is now based on a single beam analyser with digital detectors, the exclusion of Carbon Dioxide can now be achieved with a simple optical filter equivalent to 100% Carbon Dioxide wavelength. The analyser then measures Carbon Monoxide and Methane by means of the specific frequencies or by using optical filters on an interrupter wheel rotating in the infra red beam.

More recently, work has also enabled the Wheatstone bridge design to be improved and incorporated into a rapid measuring analyser with a response time of 100–200ms; this analyser is sensitive to pressure and flow and is compensated for these conditions. The Carbon Dioxide interference can be ignored as the measurement of Carbon Dioxide by Thermal conductivity is a slow response with a long time constant, whilst the Helium is a fast response with a short time constant, therefore the two measurements do not conflict.

The ERS / ATS 2017 guideline addresses most of these issues of historical devices, recognising that perceptions have changed over time, however the good point is that Diffusion is a constant, and Constants don't change.

Initially a water bath spirometer, because of its water seal, was considered to be scaled in **ATPS** (***Ambient, Temperature, Pressure, Saturated***) condition, whilst a dry rolling seal spirometer, or other flow or volume based sensor, is neither wet or dry at the point of calibration when ambient air is drawn through the device. Therefore a correction of **ATPD (*Ambient, Temperature, Pressure, Dry*)** is more appropriate and relative humidity is typically controlled by the laboratory environment.

The early equation, that applied the simplified 160 for Trad or 53.6 for SI, incorporated Avogadro's correction to both units of measurement when it was accepted that this is a conversion of a gaseous substance to mmol, applicable to SI units.

The ATS has always considered the Diffusion with the Alveolar Volume in units STPD, whilst convention states that Volumes are reported at Litres BTPS.

The early equation (*160 Trad and 53.6 for SI*) corrected the Alveolar Volume in Litres BTPS back to Litres STPD using the fixed factor of 0.826, represented by 826 as it also converted Litres to millilitres in one step.

The Law of Diffusion states that the quantity (Q) of the gas transferred per unit of time (t) is proportional to the difference of partial pressure between alveolar gas (PA) and capillary blood (PC), where D is a specific Diffusion Constant

$$\frac{dQ}{dt} = D(PA - PC)$$

Therefore the measurement in a subject is constant, all that is changing is the mathematical interpretation of the measured data.

To take a typical example:

Volume inspired : 5.28 litres BTPS
Temperature : 22 degrees
Barometric P. : 765 mmHg
Helium insp : 14.00
Helium exp : 9.80
CO insp : 0.280
CO exp : 0.090
EBHT : 10.1
ATPD→BTPS : 1.12

Inspired ATPD from BTPS then is:
(Baro P. – 47) / Baro P. x (273 + T) / 310 = 0.893
This is the same as 1/ BTPS: 1/1.12 = 0.893
So, Volume inspired ATPD = 5.28 x 0.893
= 4.72

By convention, volumes are measured at the same condition and then corrected. In the days of kymograph paper, the system was calibrated and scaled in Litres ATPD.

Deadspace

The most common measurement of anatomical deadspace, in mL (ERS 1993) was based on the Subject Weight in Kg x 2.2. e.g. for an 84 kg person, estimated anatomical deadspace is 0.185 L

In the calculation of Alveolar Volume (using Boyles Law), take the known inspired volume, subtract any deadspace (the anatomical, plus that of the patient valve and filter used), then solve for the final volume by the ratio of the gases.

Anatomical=0.185 L Patient Valve=0.100 L Filter=0.060 L **Total=0.345 L**

Therefore, the Alveolar Volume (V_A) becomes:

V_{ABTPS} = (4.72 – 0.345) x 14.0 / 9.80 x (765 / (765 – 47)) x (310 / (273 +22))
= (4.37) x (1.43) x (1.065) x (1.0508)
= 6.99

V_{ASTPD} = 6.99 x ((765 – 47)/760 x 273 / 310)
= 6.99 x 0.832
= 5.82

If water vapour is removed from the sampled gas and Carbon Dioxide does not interfere with the analysers we can use the equations (right), *where VABTPS is the alveolar volume under BTPS conditions VIATPD is the inspired volume under ATPD conditions.*

$$VABTPS = (VIATPD - VDequip - VDanat).\frac{FITr}{FATr}.\frac{PB}{PB-47}.\frac{310}{273+T}$$

$$VASTPD = (VIATPD - VDequip - VDanat).\frac{FITr}{FATr}.\frac{PB}{760}.\frac{273}{273+T}$$

This applied to the COTES / ERS 1983 / 1993 / 2005 equations would then show;

DLCO sb(Trad) = 12.54 x 2.99
= **37.49**

TLCO sb (SI) = ((6.99 x 53.6) / 10.1) x Log10(0.280/0.090) x (9.80 / 14.00))
= **12.54**

The ERS / ATS 2017 Guidelines offer the following for current systems, converting V_A to STPD for DLCO using the traditional units (V_A mL(STPD).min^{-1}.mmHg^{-1}). The factor of 60000 arises from the conversion to the traditional units (60s to 1 minute and 1 L to 1000 mL).

$$DLCO = \frac{VASTPD}{tBH}.(PB-47).in\left(\frac{FICO}{FACO}.\frac{FATr}{FITr}\right).60\,000$$

Therefore

$$DLCO = \left(\frac{5.82}{10.1(765-47)}\right).\frac{\ln(0.280.9.80)}{0.090.14.00}.60\,000$$

= **37.47**

Or, in SI units (T_{LCO}: mmol.min^{-1}.kPa^{-1}, the factor of 22.4 arises from the conversion of mL (STPD) to mmol).

$$TLCO = \frac{VASTPD}{tBH.(PB-6.28)}.\ln\left(\frac{FICO}{FACO}.\frac{FATr}{FITr}\right).\frac{60000}{22.4}$$

Pressure is in kPa (or mmHg x 0.133322), i.e. 765 x 0.133322=101.99 and therefore:

$$DLCO = \left(\frac{5.82}{10.1(101.99-6.28)}.\frac{\ln(0.280.9.80)}{0.090.14.00}.\frac{60000}{22.4}\right.$$

= **12.55**

It is clear to see, then, that the use of the 1993 / 2005 equations or the 2017 equations based on current technologies should not affect any measured results other than at the least significant digit.

The main change in the technologies used today is the elimination of exhaled Carbon Dioxide as a source of interference in the gas analysis. This then influences the need to apply or not apply Dalton's law.

The current technologies provide more reliability and accuracy, even systems that measure Classic Diffusion with the average alveolar sample collected in a sample bag. This type of system typically uses chemical cells for the measurement of Carbon Monoxide and this type of analyser is specific to the gas it is designed to measure. The analysis speed is achieved by using the linear rise time of the analyser; if the analyser has a linear characteristic then a timed reading, for example at 20 or 30 seconds of the rise time, is equivalent to the final reading that would be achieved. This reduces the need of large sample volumes and decreases the time required to perform a test.

Real time measurement of expiratory gas analysis online, where the software develops a digital mean of the sample area, measuring Dm and Vc by the "double diffusion" method of TL_{co} – TL_{NO} is popular and in this method the two reaction rates for Carbon Monoxide and Nitric Oxide are measured. There are two ways to measure Nitric Oxide, the Chemiluminescence rapid gas analyser and the Chemical cell cost effective method. Because Nitric Oxide is volatile and wants to oxidise to NOx, this method requires a mixing method to deliver the gas, typically blending a traditional diffusion gas with an oxygen concentration of 21% with a volume of Nitric Oxide in Nitrogen.

This action of ADDING to a mixture again invokes Dalton's law and the other gases in the mixture are diluted by the addition of the Nitric Oxide. This is especially important with the Dm & Vc method as the typical addition of a volume of Nitric Oxide from a cylinder with 400 – 1000 ppm Nitric Oxide in Nitrogen, designed to dilute to 40 ppm in the inspired mixture, will drop the Oxygen level of the mixture.

During this test, the system must ensure the correct concentration of Nitric Oxide and also protect against the total mixture becoming Hypoxic, therefore the minimal Oxygen percentage in the inspired mixture must not fall to lower than 18%, typically. In addition, due to the volatility of the mixture, this should be prepared, and the test performed directly without delay.

In summary, the 2017 ERS/ATS standards for single-breath carbon monoxide uptake in the lung offered valuable insights into the improvements in the data we can obtain following changes in the measurement technology used.

Edited by

Dr. James Stockley

ARTP Chair of Research and Innovation

FRESH AIR

Dear Reader, welcome back to '***Fresh Air***'. These articles are designed to communicate novel trends in research, innovation and clinical practice from both respiratory and sleep sciences. Our aim is to provoke thought and conversation within the ARTP community that we hope will benefit the future direction of physiological practice.

For this issue, I have written a review article on **Peripheral Arterial Tone (PAT) technology for the diagnosis of sleep disordered breathing**. This technology is relatively new and may not be as widely understood as other diagnostic sleep devices. Through conversation, I have noted that clinicians may consider this technology "middle ground" between oximetry and multichannel devices, although the current evidence suggests that they may well provide a more robust assessment of sleep and ventilation than traditional multichannel devices (with a number of additional advantages). The aim of this article is to provide an objective summary of the available literature relating to PAT technology for your consideration. Although we have been using these devices for some time in our department, it is worth stating that I have not received any funding or other incentive from the manufacturer to endorse their use.

James Stockley

Introduction

Obstructive sleep apnoea/hypopnoea (OSAH) is a sleep disordered breathing condition characterised by narrowing of the upper airway that leads to episodic impairment (hypopnoea) or cessation (apnoea) of airflow (Figure 1) and intermittent hypoxia. It tends to be more pronounced in Rapid Eye Movement (REM) sleep, where upper airway dilator muscle tone is least active[1]. During periods of apnoea/hypopnoea, the drive to breathe endures then subsequently increases in the standard physiological response to impaired gaseous exchange. During sleep, this occurs with concurrent arousals to a lighter stage of sleep, which can disrupt the normal sleep architecture and result in a poor quality sleep despite a normal total sleep time. Consequently, it is common for patients with OSAH to experience a number of symptoms, especially unrefreshing sleep and daytime sleepiness[2] but also cognitive/mnemonic impairment, morning headaches (due to hypercapnia), nocturia, mood changes and decreased libido. In cases where OSAH occurs with symptoms of excessive daytime sleepiness, it is termed obstructive sleep apnoea/ hypopnoea syndrome (OSAHS).

OSAH is a relatively prevalent disorder that can occur at all ages[3], occurring in 3 - 7% of males and 2 - 5% of females. There is a linear correlation between obesity and OSAH[4] (although obesity is not the only cause) and the prevalence of OSAH is increasing with rising obesity. Aside from the symptoms that result directly from OSAH, several studies have reported a high occurrence of multiple co-morbidities, including diabetes, hypertension, ischaemic heart disease and depression[5,6,7,8]. The evidence that untreated OSAH (particularly moderate to severe) can lead to serious medical complications is mounting[9,10,11]. Therefore, accurate and efficient diagnosis is vital in identifying and treating patients with OSAH to prevent long-term sequelae that may have broad implications for healthcare services. There are a number of treatment options for OSAH, including weight loss, continuous positive airway pressure (CPAP), mandibular advancement devices, and novel neuromuscular stimulators. However, CPAP remains the first choice therapy[12] due to its effectiveness and, in the UK, its availability through the National Health Service (NHS). Because of the initial and ongoing cost of CPAP therapy to the NHS, it is important to correctly diagnose patients with OSAH and identify those who are most likely to benefit from the treatment.

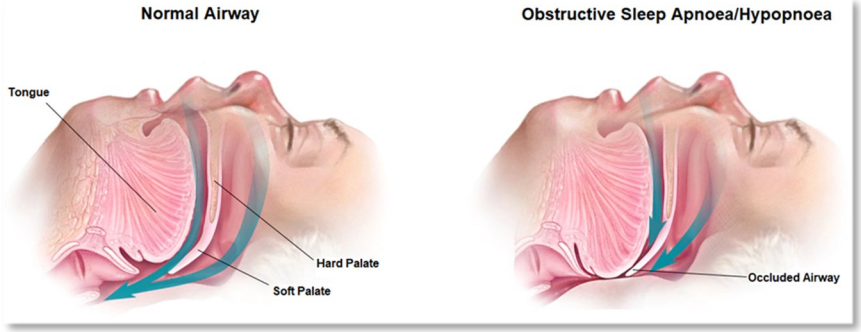


Figure 1: Illustrations demonstrating a normal, patent upper airway (left) and an occluded airway in obstructive sleep apnoea/hypopnoea, where the tongue base has contacted the soft tissue (right). Airflow is indicated by the blue arrows. Adapted from Mayo Clinic Online (2021)[13].

Diagnosis

OSAH is usually simple to diagnose. Indeed, it could be argued that, in many cases, clinical information alone is enough. However, OSAH is objectively diagnosed and subsequently classified (in terms of severity) based on the total number of apnoeas and hypopnoeas per hour; the "apnoea/hypopnoea index" (AHI). An AHI < 5 is normal and not suggestive of OSAH, AHI of 5 – 15 is mild OSAH, AHI 15 – 30 is moderate OSAH, and AHI > 30 is severe OSAH. It has been argued, however, that arbitrary AHI thresholds may not be that useful clinically (particularly from a single study) due to night-to-night variability in test results[14]. A holistic approach using a combination of clinical history, physical examination and objective diagnostics is likely to be more useful.

Polysomnography

There are a variety of overnight sleep investigations available for OSAH, although full polysomnography (PSG) is considered by many to be the "gold standard" diagnostic test. However, this has been disputed, as evidence suggests that PSG is no more useful than simple home sleep testing for identifying patients with sleep apnoea who will either comply or obtain benefit from treatment[14]. PSG involves the collection of diverse data from multiple channels, commonly including pulse oximetry (oxygen saturation and heart rate), electroencephalogram, electrooculogram, electromyogram, chest/abdominal movement, nasal airflow, body position, as well as audio-visual recording. PSG is the most robust assessment of sleep architecture and breathing available and yields an accurate AHI. However, it is costly and time-consuming and must be conducted in a sleep laboratory, requiring overnight monitoring by appropriately trained healthcare scientists. Therefore, it is rarely used as a first-line assessment for OSAH and tends to be reserved for more complex cases and neurological sleep disorders.

Traditional Home Sleep Tests

Several types of domiciliary sleep investigation are currently available, ranging from basic oximetry to more complex multichannel "polygraphy" studies. The advantages of portable home testing over PSG are well-evidenced and include lower cost and time/resource efficiency[15,16,17]. Simple overnight oximetry is generally the cheapest and easiest home assessment for OSAH. However, oximetry does not yield an AHI so the oxygen desaturation index (ODI) must be used instead. The ODI is the number of oxygen desaturations > 4% per hour but it is generally a good predictor of OSAH as diagnosed by AHI, with ODI > 5 being 87% accurate for AHI > 5, an ODI > 15 being 84% accurate for AHI > 15 and ODI > 30 being 94% accurate for AHI > 30[18]. Oximetry has been shown to provide a satisfactory outcome for OSAH diagnosis in most patients (especially those with moderate to severe OSAH)[19,20,21]. However, ODI alone can potentially yield a false negative result, particularly in mild OSAH and current UK guidelines recommend that oximetry alone cannot exclude OSAH[22].

Polygraphy is a more recent development that offers a detailed sleep investigation by incorporating the most relevant of the PSG data channels into a portable device for home use. It is a comparable but far cheaper alternative to PSG for patients with suspected OSAH[23,24]. However, polygraphy devices do not stage sleep and tend to underestimate AHI, which they calculate from the total study time and not time asleep[25]. In addition, it is a complex technique and requires careful set up by the healthcare professional and more cooperation from the patient at home than simple oximetry. As a result, polygraphy has a much higher rate of technical failure[26].

WatchPAT

The WatchPAT device (Itamar Medical, Amsterdam, NL) is a novel and innovative home sleep apnoea test that utilises the proprietary Peripheral Arterial Tone (PAT) signal to determine parameters of ventilation and sleep architecture. This not only provides a more accurate AHI than polygraphy but also information on sleep efficiency, sleep latency and REM latency[27,28]. The device (Figure 2) is as simple to use as an oximeter but provides information that has been shown to be comparable to full polysomnography[29].

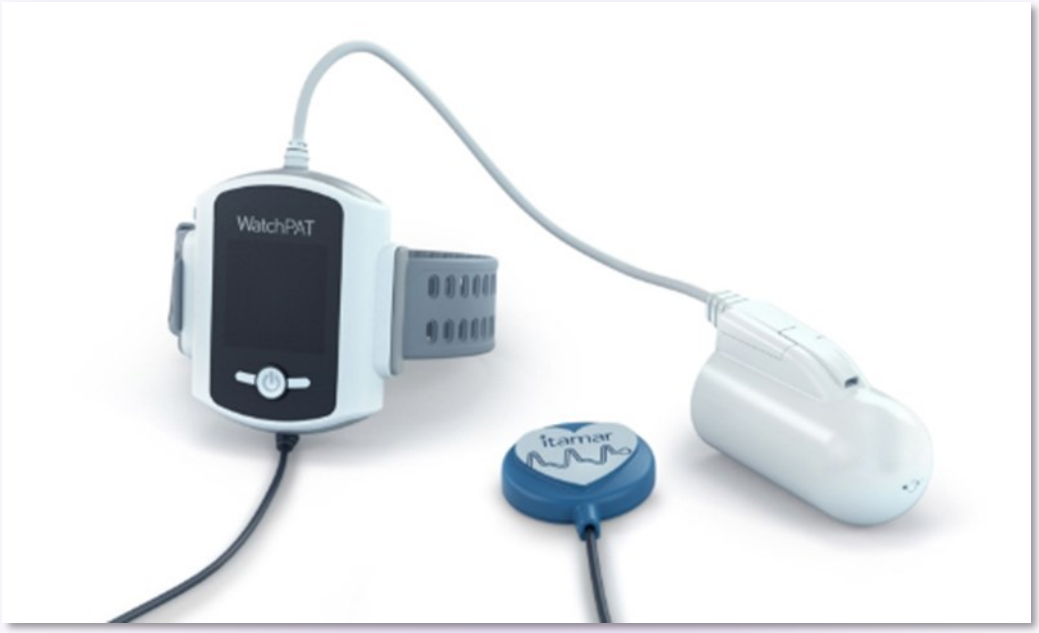


Figure 2: The WatchPAT 300 device showing the main unit that fits around the patient's wrist, the novel PAT finger probe, and the optional snore / body position sensor (Itamar Medical Online 2021 – image used with permission)

With the termination of a sleep disordered breathing event, there is an increase in heart rate, blood pressure and activation of the sympathetic nervous system. The latter is associated with vasoconstriction in the peripheral circulation. The PAT probe measures arterial pulse volume changes in the finger caused by vasomotion (vasoconstriction and vasodilation) (Figure 3). The WatchPAT algorithm analyses the PAT signal in conjunction with pulse rate and oxygen saturation to identify and classify both breathing events and sleep stages.

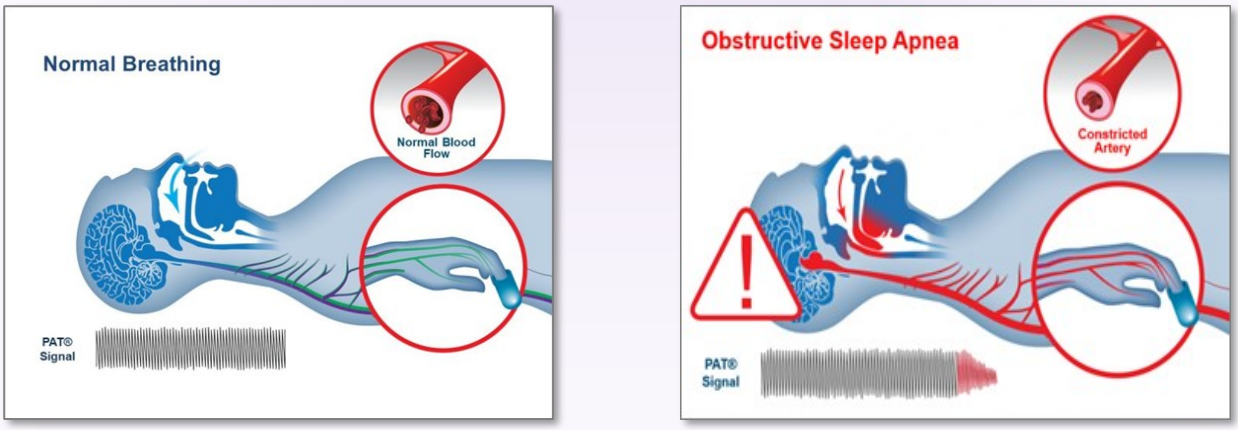


Figure 3: Illustrations showing normal arterial blood flow detected by the PAT probe during a period of normal ventilation (left) compared to the reduced PAT signal (due to vasoconstriction) at the termination of an obstructive event (right) (Itamar Medical Online 2021 – image used with permission).

The concept of using peripheral circulation as a marker of OSAH was pioneered by Schnall and colleagues over twenty years ago[30]. The authors utilised a finger plethysmograph to investigate transient vasoconstriction and tachycardia that were seen to occur in response to an apnoeic event. The results of this study acted as proof of principle that pulsatile finger blood flow can be used as a diagnostic parameter in the assessment of OSAH. The same group published the first article specifically describing the PAT probe and its complex technology soon afterwards[31]. The ambulatory WatchPAT device was quickly developed and first validated in 2003 by Bar and colleagues[32]. They compared AHI obtained from PSG to the respiratory disturbance index (RDI; comparable to the AHI but also includes other respiratory events) from WatchPAT in 102 subjects (69 with OSAH and 33 healthy volunteers) who undertook simultaneous sleep studies. Even in this early pilot study, the authors reported a strong correlation between the two parameters ($r2 = 0.77$, $p < 0.0001$) with an area under the receiver operator curve (ROC) of 0.82 and 0.87 for 10 and 20 breathing events per hour, respectively. This ROC outcome indicated that the WatchPAT of the time could effectively diagnose OSAH (particularly moderate OSAH) accurately when compared to the "gold standard" PSG. Penzel and colleagues reported almost identical findings in 21 patients that also undertook a PSG and WatchPAT in parallel[33] (although only 17 could be successfully analysed). The correlation between PSG AHI and WatchPAT RDI was also strong ($r2 = 0.79$, $p < 0.01$) despite limited numbers, although there was no correlation between total sleep time. A later study also compared AHI by PSG to that obtained by simultaneous WatchPAT in 75 individuals with suspected OSAH in an urban American population[34]. Overall, there was reasonable agreement between WatchPAT and PSG, with an intraclass correlation coefficient of 0.73, although the limits of agreement (2 x standard deviation) for AHI on the Bland-Altman were quite large (± 46.5). Using AHI thresholds of > 5, > 15 and > 30, the sensitivity of WatchPAT compared to PSG in this cohort was 96%, 90%, and 92%, respectively with specificity lower at 43%, 69%, and 77%, respectively (all reported to the nearest whole number by the authors). These data suggest that the WatchPAT may be more accurate at identifying patients with OSAH than excluding patients without OSAH. Importantly, this study included qualitative data in the form of a questionnaire that assessed preference between the two methodologies. 82% of participants preferred the home sleep study by WatchPAT over PSG, most commonly because of sleeping in their own bed but also the ease of WatchPAT operation. Primary reasons for preferring in-laboratory PSG testing included the presence of trained staff and that patients considered it a more informative test.

Other studies have investigated the ability of the PAT probe to stage sleep. Herscovici et al developed an automated WatchPAT algorithm to detect REM sleep[35] and compared it to the traditional PSG technique in 30 patients. They observed 78% sensitivity, 92% specificity of the WatchPAT with an 89% overall agreement between the two techniques in detecting REM sleep. Following the success of the WatchPAT in differentiating between wakefulness, non-REM and REM sleep, the same group then developed a new algorithm to differentiate between light and deep stages of non-REM sleep[36]. They initially developed the algorithm in a cohort of 49 patients before testing it on a separate cohort of 44 patients. As with their REM algorithm, the non-REM sleep staging algorithm demonstrated good and repeatable sensitivity (66% for training cohort (TC), 65% for the validation cohort (VC)), better specificity (TC 89%, VC 87%) and good overall agreement (TC 82%, VC 80%) when compared to full PSG. A later multicentre study involving 227 participants confirmed similar findings with an overall agreement in staging

non-REM and REM sleep of 88.6% and 88.7%, respectively[28]. Although these studies demonstrate that the WatchPAT is clearly not perfect at staging sleep, it is the only ambulatory device capable of doing so with at least moderate accuracy (Figure 4).

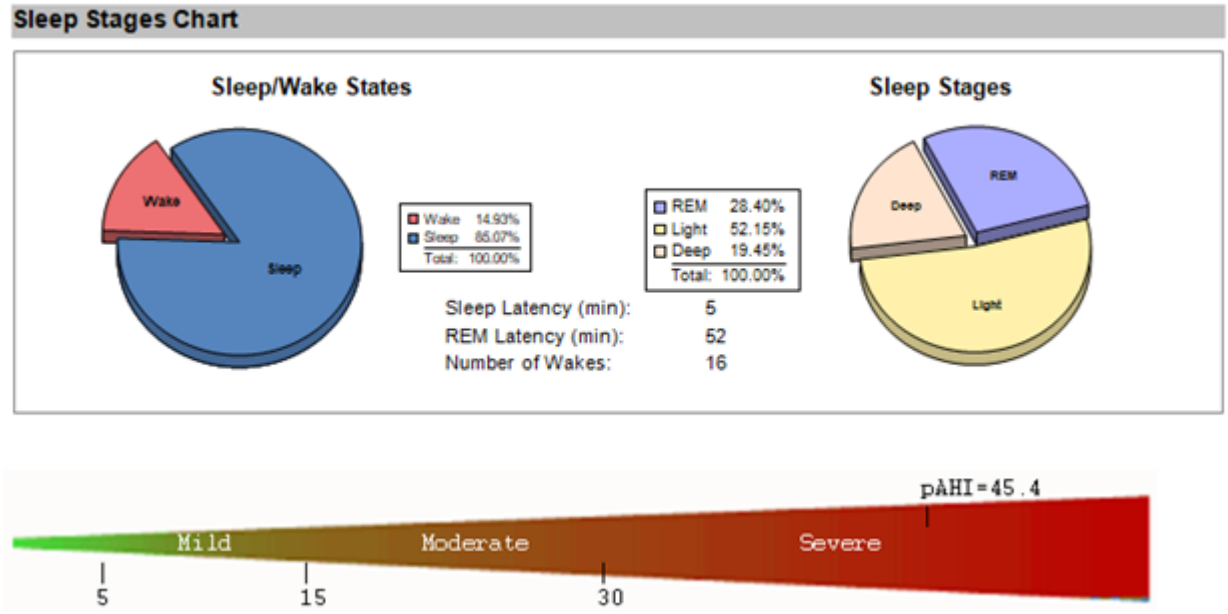


Figure 4: Sleep stages chart from the WatchPAT report, summarising the sleep stages both in terms of asleep vs awake (left pie chart) and light vs deep vs REM sleep (right pie chart). AHI is displayed on a spectrum (bottom) that includes thresholds for mild, moderate and severe OSAH. This patient's AHI is 45.4 (displayed towards the right of the spectrum), indicating severe OSAH.

The impact of WatchPAT on the treatment pathway is not currently well-evidenced, although one important study compared two clinical treatment pathways for OSAHS, the first utilising WatchPAT followed by unattended auto-CPAP titration on a separate occasion and the second utilising PSG for both the diagnosis and the treatment of OSAH[37]. For the PSG arm, patients with an AHI > 10 in the first two hours were titrated to CPAP on the same night, whereas those with AHI of > 5 (but < 10) underwent CPAP titration on a separate night. Patients in the WatchPAT/ auto-CPAP group had almost identical outcomes to the PSG in terms of CPAP adherence, nightly compliance and symptomatic improvement (quantified by the Epworth Sleepiness Scale).

There have also been a number of studies validating the WatchPAT in patient with different comorbidities. One recent multicentre study demonstrated that WatchPAT AHI correlated well with AHI measured from PSG done in parallel, both in 55 patients with cardiovascular disease ($r2 = 0.80$, $p < 0.001$) and 65 without ($r2 = 0.86$, $p < 0.001$[38]. However, the Bland-Altman plot showed cases where the AHI differed by more than 10, even in cases of OSAH towards the mild-moderate AHI threshold of 15, although WatchPAT was just as likely to overestimate AHI as underestimate it in relation to PSG. It is possible this could influence the decision to proceed to treatment for a small proportion of patients. A recent study investigated OSAH patients with concurrent Chronic Obstructive Pulmonary Disease (COPD), collectively referred to as "overlap syndrome"[39]. As with other studies, patients performed PSG and WatchPAT simultaneously. On average, the AHI was not significantly different, although the Bland-Altman plot also showed poor agreement in a number of patients, particularly in more severe OSAH. Using AHI thresholds of > 5, > 15 and > 30, the sensitivity of WatchPAT was 95.8%, 92.3%, and 88.9%, respectively

whereas the specificity was 55.6%, 65.0%, and 95.8%, respectively. These data support the work by Garg et al. [34] that WatchPAT is accurate at correctly identifying OSAH (in this cohort of COPD patients), even at low AHI thresholds (> 5) but may yield a higher proportion of false positives in patients with AHI < 10 (measured by PSG).

It is not just for sleep apnoea that the WatchPAT can be clinically useful. One early study investigated Cheyne-Stokes breathing (CSB) in patients with congestive heart failure and suggested that CSB detection by the PAT probe has a very high sensitivity (91%) and specificity (91%), although the study was limited by the small number of participants (n=10)[40]. Recently, the capacity of the WatchPAT to differentiate central sleep apnoea (CSA) from OSAH has also been validated in a multicentre study[41]. The study involved 84 patients and, as with this group's previous validation studies, WatchPAT and PSG studies were conducted simultaneously. Central AHI from WatchPAT and PSG correlated moderately ($r2 = 0.64$, $p < 0.001$) but this was notably weaker than overall AHI ($r2 = 0.77$, $p < 0.001$). Using an AHI threshold of >15, the sensitivity of WatchPAT for diagnosing CSA was only 66.7% but the specificity was 100% with an area under the ROC curve of 0.87. From these data, WatchPAT appears to be exceptionally accurate at ruling out clinically significant CSA.

WatchPAT clearly provides more clinically important information than oximetry alone, including AHI, sleep staging and differentiation between OSAH and CSA and other disordered breathing. Evidence comparing WatchPAT to portable polygraphy devices is limited, although one study that screened for sleep disordered breathing in patients admitted with myocardial infarction suggests they compare moderately well with an intraclass correlation of 0.72[42]. Agreement between the two devices at classifying the severity of OSAH was also only moderately good with kappa scores of 0.47, 0.55 and 0.49 for mild, moderate and severe OSAH, respectively (all $p < 0.01$). The weaker agreement between WatchPAT and polygraphy compared to WatchPAT and PSG is most likely because the polygraphy device (Embletta Gold, Natus Medical Inc.) scores AHI over the total analysis, rather than time asleep. The WatchPAT stages sleep and is, therefore, likely to yield a more accurate AHI in comparison to the "gold standard" of PSG.

There is a strong evidence base, therefore, that the portable WatchPAT home sleep test can reliably diagnose OSAH in the majority of patients, particularly those with moderate to severe OSAH, which is more likely to be clinically significant. An example of the WatchPAT output charts together with sleep stages is shown in Figure 5 .

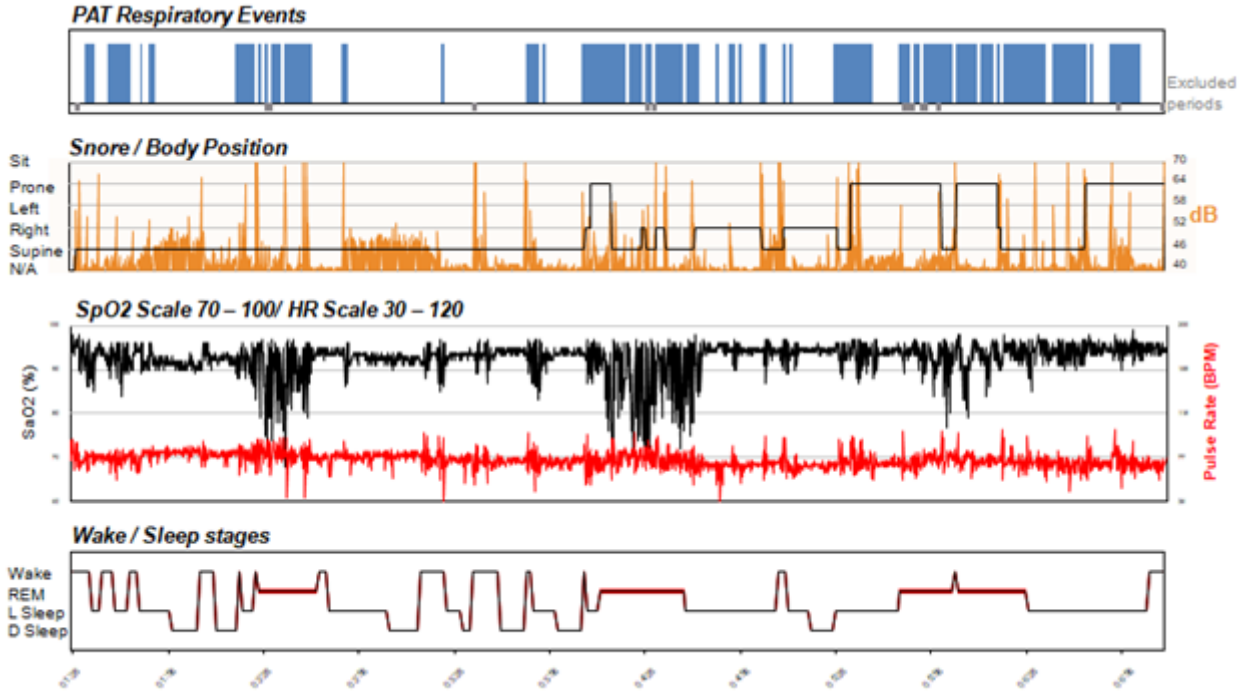


Figure 5: The output charts from a WatchPAT study showing (from top to bottom) respiratory events, combined snore and body position (measured by the optional sensor fitted to the chest), combined oxygen saturation and pulse rate (measured by the PAT probe), and sleep stages. The latter is useful in this patient as it highlights that the majority of the sleep apnoea is REM-related.

In theory, healthcare providers with minimal training in sleep physiology (e.g. primary care practitioners) could interpret the basic information on these reports, although interpretation from trained specialists would be favourable. To facilitate this, the Itamar Medical[43] WatchPAT software allows for data to be uploaded via a server, so that studies performed in the community can be downloaded and analysed by trained sleep physiologists in secondary care .

Summary

OSAH is a relatively common disorder with symptoms that can be extremely debilitating, although there are a variety of diagnostic tools and a number of effective treatments available. The rising prevalence of OSAH has resulted in an increased healthcare burden and presented challenges in providing timely diagnosis and access to treatments. PSG is the most robust assessment of sleep and ventilation but is rarely indicated or appropriate for the diagnosis of OSAH. Therefore, a variety of home sleep test kits have been developed that range in accuracy and complexity. Simple oximetry may be sufficient for many patients but can miss mild OSAH, whereas polygraphy equipment is more robust yet more complex and prone to failure. PAT technology could provide a viable solution with its simplicity, low failure rate, accurate sleep staging and AHI derivation, and recognition of other sleep disordered breathing phenomena. In addition, the current WatchPAT device data may be interpreted remotely (via the CloudPAT service), which is a promising feature that may aid the diagnosis of sleep disorders in primary care.

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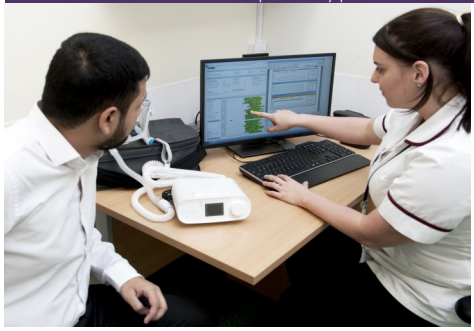

Professor Brendan Cooper
Consultant Clinical Scientist at the University Hospitals Birmingham on behalf of the Association for Respiratory Technology and Physiology

Behind the images of "donned" healthcare professionals has been an army of inspiring respiratory physiologists who have changed their roles to fight COVID-19 on the front line.

"I'd like you to take a deep breath in… right in and…blow! Keep blowing… keep blowing, keep going, right out… just a little bit more… and… relax!" These words are uttered by respiratory physiologists thousands of times daily in the UK.

This is spirometry, the basic lung function test that indicates normality from abnormality, detecting asthma, COPD or lung fibrosis and is the gateway measurement to many lung disorders.

There is something in the air

The 3,000 respiratory physiologists, trained from degree to doctorate level, provide most breathing tests investigating the state of the airways, lung size and the efficiency of gas exchange by testing the breathing system during rest, sleep and exercise. Largely unknown to the public, they mainly work in hospital outpatient departments. However, they have undergone a meteoric change in their roles as the result of COVID-19.

One consequence of the pandemic was the reduction of routine diagnostic services and outpatient activity, but respiratory physiologists weren't idle.

Firstly, a skeleton service was continued under stringent infection control procedures. This is because COVID-19 is an airborne vector and lung function testing is effectively an aerosol-generating procedure often inducing coughing and mass viral spread. Many services continued pre-operative testing for urgent requests such as lung cancer and fibrosis.

"One consequence of COVID-19 was the reduction of routine diagnostic services and outpatient activity, but respiratory physiologists weren't idle. "

A blow out in the car park

Secondly, because of decreased outpatients, innovative delivery included car spirometry, home remote monitoring and rapid room ventilation to clear the diagnostic backlogs. Physiologists, in full PPE in hospital car parks, performed testing through the windows of family hatchbacks. Some services used smart disposable spirometers to enable self-testing at home using smartphones.

Critical caring

Finally, COVID-19 is a respiratory disease, so senior physiologists were deployed to COVID-19 wards/ITUs to deliver ventilation and oxygen 24/7. Inpatients had no visitors; physiologists provided kindness, caring and moral support to sick and lonely patients. They are now established as "clinical reinforcements" in hospitals during "winter pressures." Innovative diagnostics are now embedded into routine services, enabling more community-based diagnostics and reducing the huge diagnostics backlog, using these incredibly hard-working teams."Taking a deep breath" after the pandemic has a whole new meaning for respiratory physiologists.

Thought of the Day

CO Diffusing Capacity, CO Poisoning & Informed Consent

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I was recently approached by a lung function laboratory in the UK regarding a complaint from a patient in relation to the measurement of CO Diffusing Capacity. The essence of the complaint related to two specific issues –

1. The patient had been asked to inhale an extremely poisonous gas, namely carbon monoxide
2. The patient was not asked to provide signed consent to undertake the CO Diffusing Capacity test, which uses carbon monoxide.

This review will explore the use of CO and the effects that this has on carboxyhaemoglobin as well at looking at the issues of consent to undertake a test which contains "*an extremely poisonous gas.*"

1. CO Diffusing Capacity Test - Background

This test was first described in 1914, using CO as a trace gas[1]. It was further investigated and developed in the 1950's,[2,3] when technology allowed the direct measurement of CO and the test was standardised in the seminal paper by Ogilvie et al, in 1957[4]. Further developments were undertaken, so that by the mid-1960's test kit was commercially available[5] and it became established as a standard test throughout the world from the late 1960's onwards. Published standards followed, in Europe (1983 and 1993[6, 7]), in the UK (1994)[9] and in the USA (2005)[8]. Further updates have been published in a joint 2017 European/US document[10] and most recently in the UK in 2020[11].

The actual test procedure requires inhalation of 0.30% CO, 0.30% methane, 21% Oxygen, the remainder Nitrogen. Previously either 10% or 14% helium was used instead of methane, but rising costs of helium and the use of infra-red analysers have allowed a switch to methane recently. The actual exposure to CO during the test is approximately 10.0 seconds (0.167 mins) which equates to the period of inhalation, breath-hold and exhalation. Thus, the exposure to this low dose of CO is short, time-wise.

The test is routinely undertaken in paediatrics from aged 5 years and in adults from aged 16 years to 90+ years. It is regarded as safe and I am not aware of any publication or national safety alert worldwide, in relation to an adverse outcome of this test over the past 45 years. The premise of the complaint is that CO is an extremely dangerous gas. This needs to be put into the correct context.

2. How Dangerous is this Test?

Carbon monoxide is a colourless, odourless, tasteless, flammable gas that is slightly less dense than air. It has important biological roles, and is a good example of hormesis, which is a characteristic of many biological processes, with often a biphasic or triphasic response to exposure to increasing amounts of a substance or condition. If within the hormetic zone, there is a favourable biological response to low exposures, but in higher doses can result in adverse events, including death (Figure 1). In terms of CO, low concentrations serve as an endogenous neurotransmitter and high concentrations are toxic, resulting in CO poisoning and potentially death.

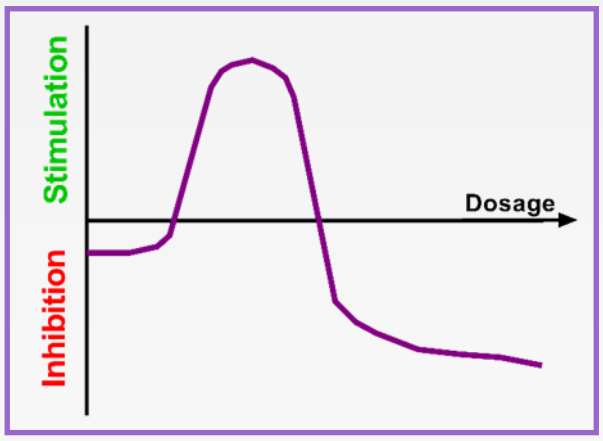

Figure 1. Relationship of hormetic dose response showing that certain levels of dosage result in stimulation, i.e., endogenous neurotransmitter, whilst lower doses function as an inhibitor. As the dosage level increases, there begins to be greater inhibition, which, with CO, may lead to poisoning and ultimately death.

Carbon monoxide is produced within the human body, and in particular in the breakdown of haemoglobin :

$$\text{Haeme b3}^{+} + 3O_2 + 9/2\ \text{NADPH} + 7/2\ H^{+} \rightarrow \text{biliverdin} + Fe^{2+} + CO + 9/2\ \text{NADP}^{+} + 3H_2O$$

where NADPH is Nicotinamide adenine dinucleotide phosphate.

CO is formed at a rate of 16.4 µmol.hr^{-1} in the human body, the majority (>80%) from haeme via haeme oxygenase and the remainder from non-haeme sources including: photo-oxidation, lipid and keto acid peroxidation, microbiome, and xenobiotics[12]. The average carboxyhaemoglobin (COHb) level in a non-smoker is between 0.2% and 0.85% COHb, whereas a smoker may have 4% to 10% COHb, although genetics, geographic location, occupation, health and behaviour are contributing variables.

Red blood cell recycling within the spleen accounts for ~80% of haeme-derived endogenous CO production. The remainder of the haeme-derived CO production is due to hepatic catabolism of haemoproteins (myoglobin, cytochromes, catalase, peroxidases, soluble guanylate cyclase, nitric oxide synthase) and ineffective erythropoiesis in bone marrow[13].

In addition to being a source of CO, haeme is a critical signal transducer involved in CO sensing[14, 15]. CO is involved in normal physiology and has therapeutic benefits with many indications such as ameliorating inflammation and hypoxia[16, 17]. In addition to physiological roles, small amounts of CO can be inhaled or administered in the form of CO-releasing molecules as a therapeutic agent[18]. By administrating low-doses of inhaled CO gas, the system can be protected against a wide range of pathological conditions, including inflammation[19], oxidative stress[20], ischemia/reperfusion injury[21], sepsis[19], and acute lung injury[22]. The importance of this type of therapy is to attempt to provide an optimal dosing level by increasing the COHb% above known baseline levels, but to remain within a safe range of 6% - 8%[23]. It is important to note that the safe range is 6% - 8% for COHb%.

Carbon monoxide occurs in the atmosphere –

Table 1: Examples of CO which can be breathed in various circumstances

Concentration	%	Source
0.2 ppm	0.00002	Natural atmosphere level
Up to 5 ppm	0.0005	Average level in homes
Up to 15 ppm	0.0015	Near properly adjusted gas stoves in homes
Up to 200 ppm	0.02	Exhaust from automobiles
5,000 ppm	0.5	Exhaust from a home wood fire
7,000 ppm	0.7	Car exhaust without a catalytic converter

The amount of exposure, and hence the magnitude of COHb% present depends heavily on a range of measures, including the length of exposure, the volume of air containing the %CO, the level of ventilation of the subject and their physical lung volume size. The effects of exposure to different concentrations of CO are highlighted in Table 2.

Table 2: Effects of different concentrations and resulting symptoms.	
Concentration	Symptoms
35 ppm (0.0035%)	Headache and dizziness within six to eight hours of constant exposure
100 ppm (0.01%)	Slight headache in two to three hours
200 ppm (0.02%)	Slight headache within two to three hours; loss of judgment
400 ppm (0.04%)	Frontal headache within one to two hours
800 ppm (0.08%)	Dizziness, nausea, and convulsions within 45 min; insensible within 2 hrs
1,600 ppm (0.16%)	Headache, increased heart rate, dizziness, and nausea within 20 min; death in < 2 hrs
3,200 ppm (0.32%)	Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes.
12,800 ppm (1.28%)	Unconsciousness after 2–3 breaths. Death in less than three minutes.

Acute poisoning is considered to have occurred at COHb% levels of over 10%. Severe poisoning is associated with levels over 20 – 30%, plus symptoms of severe cerebral or cardiac ischaemia, and where people begin to lose consciousness. Eventually, as COHb% reaches 60% and above, death ensues. Exact COHb% values depend on individual susceptibilities, the underlying state of health and, to some extent, the activity level of the individuals concerned. However, people living in areas of environmental pollution may have levels of 5%, and heavy smokers can tolerate levels up to 15%, as their systems have adapted over time[24 - 26].

3. Coburn-Foster-Kane equation (CFK)

The magnitude of exposure, in terms of changes in the COHb% can be modelled using the Coburn-Foster-Kane equation[26–28]. This equation is:

$$(A[HbCO]_t - B\dot{V}_{CO} - P_lCO) / (A[HbCO]_0 - B\dot{V}_{CO} - P_lCO) = exp^{(-tA/VbB)}$$

Where

$A = PCO_2 / M [HbO_2]$
$B = 1/DL_{CO} + PL/\dot{V}_A$
M = ratio of the affinity of blood for CO to that for O_2 and has a value of 218
$[HbO_2]$ = mL of O_2 per mL of blood
$[HbCO]_t$ = mL of CO per mL of blood at time t – the term we wish to solve for
$[HbCO]_0$ = mL of CO per mL of blood at the beginning of the exposure interval
P_CO_2 = average partial pressure of oxygen in lung capillaries, mmHg
$\dot{V}_{CO}$ = rate of endogenous CO production, mL/min - » 0.0176 mL CO/mL in a non-smoker
DL_{CO} = diffusivity of the lung for CO, mL/min/mmHg
P_L = barometric pressure minus the vapor pressure of water at body temperature, mmHg
V_b = blood volume, mL, » 74 mL/kg body weight
P_lCO = partial pressure of CO in the inhaled air, mmHg
$\dot{V}_A$ = alveolar ventilation rate, mL/min
t = exposure duration, min
$exp^{(x)}$ = exponential function e^x, where “e” is the base of the natural logarithm

We need to be able to calculate [HbCO]t, so we re-arrange the equation to:

$$[HbCO]_t = [\exp^{(-tA/VbB)} \times (A[HbCO]_0 - B\dot{V}_{CO} - P_ICO) + B\dot{V}_{CO} + PICO)] / A$$

Using this equation, we can then model, to a reasonable degree of accuracy, the approximate COHb% levels. The data from Table 2 is summarised in Figure 2.

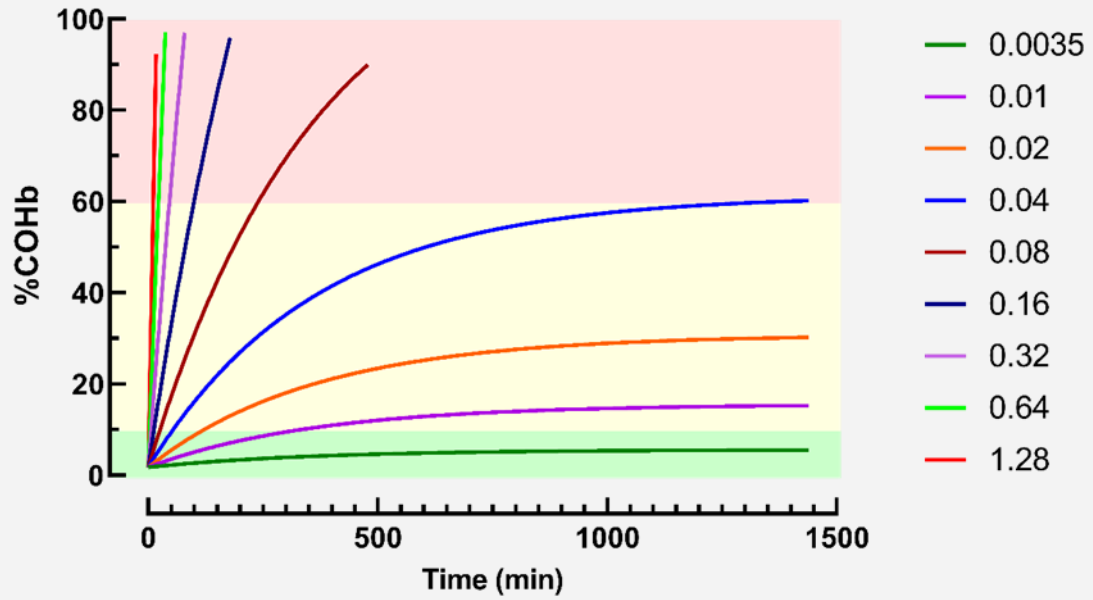

Figure 2. Modelling the changes in the levels of COHb over time in relation to the different inspired concentrations of CO given in Table 2. The subject is non-smoker, male, 67.4 kg, with an alveolar ventilation of 5250 L.min^{-1} and an [Hb] of 14.6 g.dL^{-1}. M = 218, V_{CO} = 0.007 mL.min^{-1}, F_IO_2 = 0.21. Breathing 0.0035% over 24 hours (1440 mins) shows the COHb remains at below 10%, whereas breathing in 1.28 % for 11.2 minutes results in a COHb of 60%, and hence death shortly thereafter.

Interestingly, if a patient were to accidentally breath 0.3% CO (from the CO Diffusing Capacity Test Gas cylinder) continuously over a 20 minute period, then the COHb% would rise to about 34% for the individual used in Figure 2.

So, what happens during the measurement of CO Diffusing Capacity? Current recommendations[11] state that a maximum of five manoeuvres should be completed, albeit that there is no specific reason given for this. Indeed, it is possible to undertake up to ten manoeuvres without significant effects on COHb% and where it is not a requirement to adjust for the capillary PCO[30].

Using the CFK equation allows us to model the effects of five manoeuvres undertaken at 4 minute intervals, assuming that there is no decrease in the PCO, which is unlikely as the half-life is three to four hours. The results are shown in Figure 3.

Also shown in Figure 3 are the effects of breathing 0.1% CO over a period of 6 minutes. This reflects the previous usage of the steady-state CO Diffusing Capacity measurement, where the subject breathed in a gas mixture containing 0.1% CO during resting tidal breathing and the exhaled gas was collected via an end-tidal sampler[31]. What is interesting is that although the inspired CO is one-third of that in the single-breath methodology, the patient is exposed for 6 minutes rather than 0.167 minutes. Clearly this results in a much higher level of COHb% - estimated at just over 4% in the modelling. From my early days of undertaking this test, we did everything in duplicate at least. Although not modelled, this would significantly increase the COHb% further and possibly into the acute poisoning range – but this was the

late 1970's to early 1980's. I do not recall any patient appearing to have an adverse event, we just assumed it was fine as it had been around for a long time!

In relation to the complaint regarding the inhalation of an extremely poisonous gas, namely carbon monoxide, this needs to be placed in the correct context. The use of 0.30% CO in the inspired gas has been used since the 1950's and forms a standard clinical test procedure. National and international standards clearly indicate that up to five measurements can be undertaken at one testing session. The modelling of the effects of repeated inhalation of 0.3% CO using the CFK equation indicate that the levels of COHB are sufficiently low, so as to be of little clinical concern, and therefore it is acceptable to state that this test is safe to undertake.

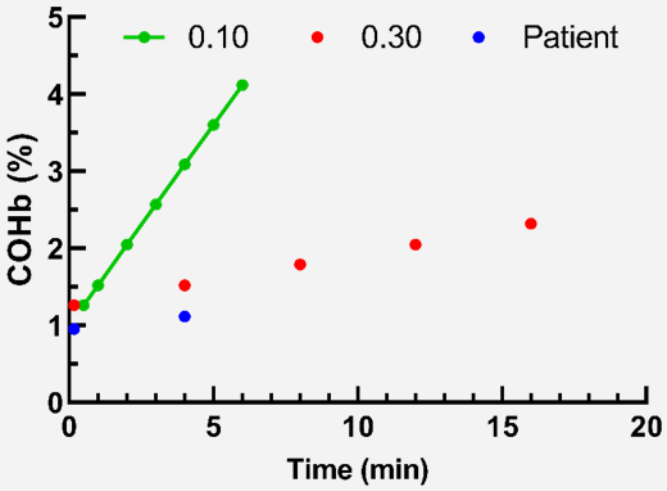

Figure 3. Modelling the changes in the levels of COHb% over time in relation to the inspired concentrations of CO used for single-breath (0.3% CO and for the patient) and for the steady-state CO Diffusing Capacity (0.1). For the 0.3 (red), this is the same subject as in Figure 2. After 5 inhalations of 0.3% CO, the estimated COHb% was 2.32%. For the patient, this was a female, 85.0 kg, with an alveolar ventilation of 5300 $L.min^{-1}$ and an [Hb] of 12.6 $g.dL^{-1}$. M = 218, VCO = 0.007 $mL.min^{-1}$, FIO2 = 0.21, and after 2 inhalations the COHb% was 1.114%. For the 0.1% over 6 minutes, this rises to an estimated 4.6% for COHb%.

4. Consent

Consent is an essential component of all clinical practice and research practice. Good medical practice states that doctors must be satisfied that they have consent (or other valid authority) before -

- Conducting any examination or investigation
- Providing treatment
- Involving patients in any teaching or research.

These principles are based upon guidance on the UK General Medical Council's website, and include issues of mental capacity[32], as well as guidance from the Department of Health[33]. For consent to be valid, the person giving consent should provide it voluntarily, be informed, and must have the capacity to make the decision.

In adults, Respiratory and Sleep tests (such as overnight oximetry), generally, do not require written consent from the patient, but verbal consent is necessary. This is obtained following a detailed

explanation to the patient of the tests and the procedures involved. After explanation, if the patient is happy to proceed with the tests, this may be taken as verbal informed consent being obtained. So, for instance if a patient agrees to have an arterial blood gas taken before, during and at the end of a cardiopulmonary exercise test, consent may be deemed as given if the patient sits on the bicycle with the associated equipment attached and provides his/her arm for the arterial blood gas – so long as the patient has been informed about the test procedure and has verbally consented to proceed.

If the patient does not wish to proceed with any test, then this must be noted in the report. At no time should any form of coercion be used. It is also important to recognize that a patient can withdraw consent at any point if they do not wish to continue. This should be noted on the report back to the referring clinician.

England, Wales, and Northern Ireland

The guidance on consent in England, Wales and Northern Ireland is -

Aged 18 and over: When an individual reaches their 18th birthday, they are assumed to be a competent adult and are therefore capable of consenting or refusing testing, vaccination or treatment, unless other factors prevent them from making these informed decisions.

Aged 16 and 17: A child's affirmative consent, known as "assent ", to investigation, having achieved the age of 16 years, cannot be overruled by anyone with parental responsibility. A 16 – 17-year-old is to be presumed capable of consenting to testing and to medical treatment. Consent will only be valid if it is given voluntarily by a young person who has received and understood the appropriate information. As with adults, a young person has the right to refuse to consent to a test procedure or treatment.

Under 16: Children under 16 years can consent to medical tests and/or treatment if they understand what is being proposed. It is up to the referring doctor to decide whether the child has the maturity and intelligence to understand fully the nature of the tests, treatment, the options, the risks involved and the benefits.

A child who has such understanding can be considered *Gillick competent*[34, 35]. The parents cannot overrule the child's consent when the child is judged *Gillick competent*.

Children under 16 who are not *Gillick competent* and young children who cannot either give or withhold consent require those with parental responsibility to make the decision on their behalf[35].

Scotland

Aged 16 and 17: The legal age of capacity in Scotland is 16 years therefore 16 and 17-year-olds can consent to medical tests, treatment or intervention without needing parental consent. If a 16 or 17-year-old in Scotland lacks the capacity to consent, they should be treated as an adult who lacks capacity. Healthcare staffs have a duty of confidentiality to 16 and 17-year-olds and should not usually disclose information to parents without the patient's consent.

Under 16: Children under 16 years can consent to medical tests and treatment if they understand what is being proposed. It is up to the doctor to decide whether the child has reached sufficient maturity to understand the nature and consequences of the test, the procedure or the treatment.

Parental Consent

It is very unlikely that parents would be able to overrule the wishes of a child deemed mature enough to make their own decisions. Young children, and those who are not considered capable of making their own decisions, cannot either give or withhold consent. Those with parental responsibility need to make the decision on their behalf.

If a child under 16 does not have capacity to consent to treatment, someone with parental responsibility can consent for them. The person with parental responsibility must –

- Have the capacity to give consent
- Be acting voluntarily
- Be appropriately informed

The child's welfare or "best interests" must be the first concern.

Parental Responsibility

The following people can have parental responsibility for a child under 16 and there are limits to this[36]:

- The child's mother
- The child's father if he was married to the mother when the child was born
- For children born before December 1st, 2003 – the child's father, if he marries the mother, obtains a parental responsibility order from the court, or registers a parental responsibility agreement with the court
- For children born on or after December 1st, 2003 – the child's father, if he registered the child's birth with the mother at the time of the birth, or if he re-registers the birth (if he is the natural father), marries the mother, obtains a parental responsibility order from the court or registers a parental responsibility agreement with the court
- The child's legally appointed guardian
- A person with a residence order concerning the child
- A local authority that is designated to care for the child
- A local authority or person with an emergency protection order for the child

Capacity

A small number of patients may be referred for tests or treatment who may be deemed as "*lacking capacity.*" The Mental Capacity Act (2005) provides the legal framework under which healthcare professionals must act and this has been summarised both in terms of the process but also as a flow chart[32, 37]. So, for instance, where a child or adult has Down's syndrome or Rett Syndrome there are potential issues of them understanding what is being done and whether or not they can consent to have tests undertaken or treatment provided. In both these examples, the parent or nominated carer would have responsibility for making the appropriate decisions – in the best interests of the patient. However, it is essential to assume that the individual does have capacity until otherwise indicated. In some cases, individuals may not be able to give verbal consent as they are unable to talk, i.e., as often observed in Rett Syndrome. This does not mean they cannot consent or do not have capacity - one just needs to

understand how they may consent and work with the individual at that time.

There are five statutory principles –

1. A person must be assumed to have capacity unless it is established that they lack capacity.
2. A person is not to be treated as unable to decide unless all practicable steps to help them to do so have been taken without success. Individuals should be given support to make their own decisions and all practicable steps should be taken to make that possible. Support might include: -
    - Different forms of communication e.g. non-verbal, such as sign language, Eye-Gaze technology, or eye contact
    - Information in different formats, e.g. photographs or flash cards
    - Treating a medical condition that may be affecting an individual's capacity
    - A structured programme to improve capacity to make decisions, especially relevant for individuals with learning disabilities
3. A person is not to be treated as unable to decide merely because she/he makes an unwise decision. People have a right to decide a result that others do not agree with. If there is concern a person is acting in a way that is not consistent with previous behaviour, or they are making decisions that may put them at risk of harm, then a mental capacity test should be undertaken.
4. An act done or decision made, under the Act for or on behalf of a person who lacks capacity must be done, or made in, the person's **best interests**.
5. Before the act is done, or the decision is made, regard must be had as to whether the purpose for which it is needed **can be as effectively achieved in a way that is less restrictive of the person's rights and freedom** of action.

A mental capacity assessment should be undertaken when the capacity of a patient to consent is in doubt. Lack of capacity is not demonstrated by referring to a person's age or appearance, condition, or any aspect of their behaviour. The fact that someone cannot talk, as in Rett Syndrome, does not mean they lack capacity!

Capacity is about the ability to take a decision at the time it needs to be taken. It is decision-specific and time-specific. Where a person's capacity to decide has come into doubt because of their behaviours, circumstances or concerns raised, this needs to be highlighted and further consideration and care needed before proceeding. For instance, where an individual is minimally conscious and so cannot directly consent, systems are in place that allow tests, procedures or even research to be undertaken on the basis of what the individual would have wished.

The important points about this, and in relation to this particular issue and complaint are -

Voluntary: the decision to either consent or not to consent must be made by the person themselves and must not be influenced by pressure from clinical staff, friends or family

Informed: the person must be given all of the information in terms of what is involved, including the benefits and risks, and what happens if the test/treatment does not proceed

Capacity: the person must be capable of giving consent, which means they understand the information given to them, and they can use it to make an informed decision.

Consent can be given -

Verbally: By saying they are happy to have a test.

Written: By signing a consent form for a complex test, such as a cardiopulmonary exercise test (CPET), that may carry increased risks.

Consent should be given to the healthcare professional responsible for the person's current tests or treatment. If the subject changes their mind at any point before the test commences, or even during the test procedure, the test must be stopped. For instance, if a patient shouts **STOP** during a CPET test, then the practitioners must stop the test immediately, even if the test is submaximal. If, for instance this was a test to assess fitness for surgery, the report can only report those results obtained, indicate that the patient requested to stop the procedure and leave it up to the surgeon and the patient to have a further discussion. The patient may agree to have another attempt at the CPET test.

In general terms, verbal consent is all that is required from patients undertaking routine, resting lung function tests[9, 11].

The issue that the complaint raises is one of the patient being informed. Thank you to those of you who completed an odd question of mine recently on the ARTP-forum. The purpose of this was to observe what other centres do in the case of informing a patient as to the presence of CO in the test gas. The results are summarised in **Figure 4**.

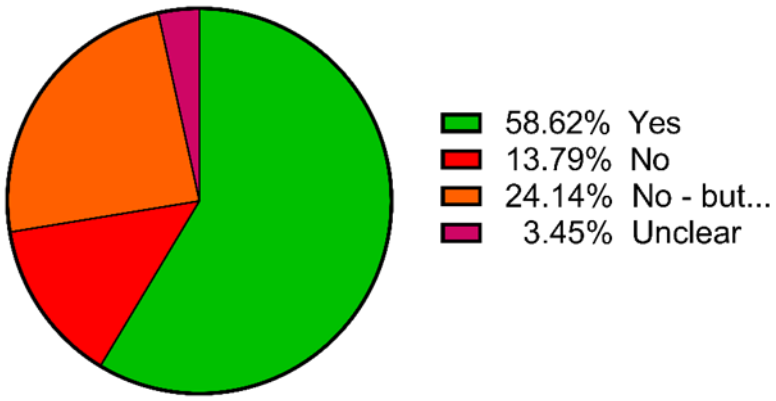

Figure 4. Summary of responses (n = 29) to an ARTP-forum question – "*When informing a patient about the measurement of DLco, do you normally advise the subject that they will be inhaling a small quantity of carbon monoxide?*"

Almost a quarter of the respondents said that they would not provide the information before the test procedure, but would if asked "*what is in the big green cylinder*" or a similar type of question. Of those that said they do inform the patient, one respondent stated that the patient would be informed that it is a "*small amount of CO but far less than you'd get from a cigarette, a dodgy car exhaust or a boiler!*", whilst another respondent stated, "*no more than walking besides a busy A-road for a while*".

So – who is right? For a patient to provide informed consent they must be provided with relevant and appropriate information. Technically this should include the relevant aspects of the methodology and any potential risks.

In terms of the methodology, this technically should include, in relation to CO Diffusing Capacity the gas mixture that is to be inhaled – i.e., 0.3% CO, 0.3% methane, 21% oxygen and the remainder Nitrogen.

In terms of the risks, an explanation in relation to CO given as "*it's less than if you had a cigarette or walking along a busy road in the rush hour*" indicates to the patient that it is highly likely, on the balance of probability, to be safe, and that no obvious harm is likely to occur.

This makes things much clearer, it is honest and upfront, and might avoid complaints such as this one from occurring in the future.

In the context of this particular complaint:

1. It is clear that the subject has capacity to undertake the tests as requested by their referring practitioner

2. The subject had voluntarily undertaken other tests i.e. spirometry, giving verbal consent and proceeding without concern or difficulty – further confirming that they have capacity.

3. The subject had been talked through each of the tests, as to what is required and they had agreed to undertake these tests – however, they had not been informed that they were going to be inhaling carbon monoxide.

The record shows that for the first test, the subject was not informed about the presence of a safe and small quantity of CO. However, in the 4 minutes between the two tests, the subject did ask what the gases were and was informed. The subject proceeded with the second test without any obvious concern. Clearly on reflection, she felt she had not been fully informed and hence made the complaint.

Should she have signed a consent form? Personally, I would suggest that this is not necessary and there are minimal risks to performing standard routine lung function tests – note that there is no such thing as zero risk – it does not exist! In saying that, one is fully aware of the current and increasing trends for litigation and complaints – all of which consume enormous amounts of NHS resources. Perhaps one way around this is to provide each patient, within their appointment letter, a weblink explaining the test. An excellent example is from the British Lung Foundation website - https://www.blf.org.uk/support-for-you/breathing-tests/gas-transfer-tlco -

"You breathe in air containing tiny amounts of helium and carbon monoxide (CO) gases. These are completely harmless at the very low levels used. You will be asked to take in a big breath through a mouthpiece while wearing a nose clip. You then hold your breath for a minimum of 8 seconds, then breathe out steadily into the machine.

You will need to do this a few times, with a pause of a few minutes in between. Don't worry if it takes several attempts to get a reliable reading."

5. Conclusion

In conclusion, this patient, who was a healthcare clinical worker, undertook a test procedure and then complained about the test. This centres around whether she was fully informed or not, and before the second attempt this would appear to be the case, she proceeded and then complained having gone away and reflected.

What is interesting is her complaint about being given carbon monoxide – does she think that a clinical laboratory, in a hospital setting, would be giving patients an extremely poisonous gas if it were not actually safe to do so?

Should we be providing all patients with the information about the presence of CO in the test gas – on balance the answer is “probably”, but it would be an interesting question to refer to your respective legal departments in terms of their interpretation of informed consent.

Do we need to get signed consent? If we were doing this for a research study, then the answer is that we would, after the patient has completed reading the patient information sheet (PIS) and had the opportunity to ask any questions. If the study included CO Diffusing Capacity, this would need to be explained in the PIS, perhaps in similar detail as in the BLF weblink.

Do we ….. or don’t we? I guess we are heading that way for absolutely everything we do with patients, so that we cover every possible, probable and remote aspect to avoid complaints and possible litigation.

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Dr Harry Griffin (PhD)

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Top Forum

The best of the ARTP Forum

Summarising the most popular topics in the ARTP forum since August Inspire.

Title: Transcutaneous CO2 monitoring

Date: 13/08/2021

Question: A senior Paediatric Respiratory Physiologist discussed that they were currently in the process of going through their Medical Device Unit and Medical Physics to get approval to use the TCM5 transcutaneous monitor in the home setting for vent check studies.

As part of the process, they needed to do a landscaper review which involved checking that there aren't any devices out there that can do the same thing and are already licensed for home use.

They asked if any physiologists aware of other devices or have gone through the process of performing a landscaper review could contact them with advice or documentation.

Replies: The first review from a senior physiologist raised a historical concern that these devices could cause skin burns after 3-4 hours use and could be tricky to use on children's skin. However, they suspected the technology has improved since they used the devices and they recommended reading the ERS Buyer's Guide (possibly now named 'RED') in case there were manufacturer's not well known in the respiratory physiology field.

The concerns about skin burns in paediatrics was echoed by another senior physiologist, who stated it doesn't matter what brand of tCO2 monitor you use, there will always be the issue of reddening and subsequent burning of the skin if the device is used at its optimum temperature of 43°C.

They reported that there were numerous articles which allege that you can obtain reliable monitoring by turning the temperature down to as low as 37°C but in adults at least this is a non-starter. In paediatrics they suggested there may be some leeway in infants with thinner skin but be warned if you caused burning as *Messrs. Sue, Grabbit and Rhunn*, Solicitors could come a knocking. To this end they suggested moving the sensor every 2 hours as recommended by AARC 2012. http://rc.rcjournal.com/content/57/11/1955

Finally, in regards to using the device at home they asked what steps would be put in place to ensure that the device is calibrated prior to each use and presumably this couldn't be delegated to carers?

Title: Healthcare science apprenticeship

Date: 26/08/2021

Question: A physiologist stated their trust is soon to be advertising for two HCS apprentices, one of whom will work in the lung function department. The idea is to delegate lower skilled tasks and so increase testing capacity. They will be undertaking apprenticeship level 2 and will be trained in house to perform spirometry and get them on the ARTP Spirometry register.

However, they reported struggling to get the JD to pass through job matching panel and asked if any physiologists minded sharing their JD and PS for what used to be called ATO roles now called assistant physiologists?

Replies: This post sparked some interest amongst physiologists with one asking what they envisaged the staff doing and another asking who would deliver the higher educational learning part of the apprenticeship.

The physiologist replied by stating they submitted an expression of interest to HEE and believed they has been successful in getting partial funding for the post and the training levy. They had hoped to entice neurophysiology to join them in taking on an apprentice but they were not interested and the HEE pilot is just for cardiorespiratory.

They stated that the two apprentices will learn to perform Spiro, ECG, CBG and BP. They hoped that by having respiratory and cardiology skills they would be able to utilise both staff members when their department is under pressure but accepted they might lose them both when cardiology were under pressure.

One physiologist replied that they had band 3 staff that work across cardio-respiratory services and they would share their JD and PS.

Title: Physiologist development

Date: 02/09/2021

Question: A physiologist was seeking the views of the forum as to whether they knew if physiologists would eventually be trained to be non-medical prescribers. They believed there was a proposal waiting for parliament to address this but wondered why nothing had materialised and whether a petition or direct contact with members of parliament could help?

They were concerned that without these prescribing rights it prevented the development of physiologist roles versus AHP's that were already allowed to prescribe

Replies: This received a detailed reply from the current chair of ARTP who worked on the project to allow Clinical Scientists to work within the Patient Group Directive (PGD) framework in 2019, via the CSO Office. She suggested that although this had been sent out to stakeholder consultation in 2019 she believed it was awaiting Parliamentary assent, but Brexit and COVID seem to have scuppered most work like this.

However, she stated that it would seem very, very unlikely that Clinical Physiologists will be allowed to legally practice under anything other than a Patient Specific Directive. The reason for this is statutory regulation; unless Clinical Physiologists are migrated from a voluntary register (RCCP/AHCS) to a statutory one (HCPC) this cannot happen. To this end she has been encouraging as many Clinical Physiologists to complete 'equivalence' on to the Clinical Scientist register so that when this piece of legislation is finally passed, they will have far more freedom to manage their patients effectively.

She highlighted that this situation is definitely not a 'them and us' thing between Clinical Scientists and Clinical Physiologists. Indeed, she described herself as a proud and vocal Clinical Physiologist for most of her career, but entry on to the Clinical Scientist register gave her the possibility of providing better care for her patients via PGD's once the legislation is finally passed.

Title: PFTs Prisoners

Date: 20/09/2021

Question: A physiologist discussed how they had been asked to perform a risk assessment for guards that arrive with their prisoners when performing PFTs, as it is an external person coming into a high-risk environment. They enquired if other physiologists had experienced similar?

Replies: One senior physiologist suggested the department should have all the relevant risk assessments in place already. They should be very similar for all physiological measurement

services.

Another physiologist stated that they assumed the risk assessment would be the same as for face-to-face translators who they provide an FFP3 and gown to.

Title: CPAP shortage and alternatives

Date: 24/09/2021

Question: Considering the recall and subsequent pause in manufacturing of Phillips CPAP machines, a physiologist wanted to know how people were handling the shortage and if they were using alternative brands or just building up their waiting lists.

They discussed how NHSSC had provided an alternative but that this approach would require checks by the medical engineering department, new IT systems requiring IG, cyber security approval and finally training in using the new devices.

Replies: This physiologist certainly wasn't alone with their concerns as several other physiologists discussed their troubles. Indeed, one physiologist stated they had just two devices left and a backlog of a couple of hundred patients awaiting a CPAP setup.

One physiologist discussed how they had also begun to swap suppliers but confirmed what the original physiologist foresaw about the large time commitment. Indeed, they had gained IG sign off, Medical Engineering agreement, changed paperwork, learnt to use the device but then advised that they needed to change to a third supplier and would need to go through the whole process again.

To limit the clinical impact of the lack of CPAP machines they stated they had prioritised their list according to severity/occupation etc and advised GPs of the situation in the hope that they will bear that in mind when deciding to refer.

The struggle to get CPAP machines wasn't just being felt by services previously using Philips. Indeed, one physiologist described receiving limited supplies from their normal supplier, ResMed, which is enough for their new CPAP setups but they had put on hold replacing older devices.

They discussed that even if they could get alternative devices it wouldn't be practical to swap to another supplier as, amongst other considerations, they extensively utilised remote monitoring. They had heard rumours that CPAP manufacturers might be prioritising the USA market over Europe and UK and asked if the ARTP Manufacture's Liaison Committee could investigate if this were true.

A senior physiologist recalled a conversation they were involved in with all CPAP manufacturers @ ARTP SAC about 9 years ago, when they asked the manufacturers to produce a generic CPAP software platform/ industry standard that would allow any device to be downloaded onto it. Alas, this never materialised as this would surely have been a great help now. However, the physiologist who asked the original question suggested it might not have been any help in Wales as Philips were the only CPAP provider added to the All Wales contract.

Title: Hypoxic Challenges

Date: 01/10/2021

Question: A physiologist stated they were getting asked to perform hypoxic challenge tests (HCT) more frequently recently and wanted to know how close to flying the assessment should take place?

They reported reading some information that stated if the patient is clinically stable the HCT result could last for a year but other [healthcare professionals] have said it is safer to have it performed closer to travel, such as a month beforehand.

Replies: The first physiologist to respond said that they perform HCT < 1 month before travel to

be as up to date as possible and reflect current health status. However, they stated they rejected referrals if the patient had had a HCT in the past year and their recent lung function showed their condition was stable. Another physiologist agreed and said it was safer to perform within a month although it depends on the flight company.

One physiologist thought BTS might be looking at updating their guidance on air travel and thus departments might change their practice depending on this document. Indeed, another physiologist confirmed that an updated version of the BTS Clinical Statement had been out for consultation early last year and suspected its publication might have been held up by the pandemic. However, they stated that they didn't remember reading any advice for a specific time frame for repeating a HCT, just that those having had HCT in the past should not need the test repeated unless there is a change in clinical condition, although the patient's plans should still be discussed with their respiratory team. Furthermore, they provided a link to the European Lung Foundation website which says HCT results are valid if a patient's condition doesn't change: https://europeanlung.org/en/information-hub/air-travel/are-you-fit-to-fly/

A senior physiologist suggested it would be a useful project for someone to produce a survey of ARTP departments comparing how often HCTs are repeated.

Title: Odd question!

Date: 04/10/2021

Question: One senior physiologist tried their hardest to fill up our inboxes by asking us to answer with just a yes or a no to the question *"When informing a patient about the measurement of DLco, do you normally advise the subject that they will be inhaling a small quantity of carbon monoxide?"*

Replies: I did a quick tally and 13 physiologists replied with a Yes. However, another 8 replied that they don't routinely tell the patient there is CO in the gas unless asked more specifically. They normally just say to the patient that they will inhale a test or a tracer gas. Finally, one physiologist answered with "*sometimes"…..there's always one, isn't there!*"

One very senior physiologist ☺ discussed that when they used to perform lung function tests many moons ago they would explain that it's a "*small amount of CO but far less than you'd get from a cigarette, a dodgy car exhaust or a boiler!*". Indeed, another physiologist stated they say "*no more than walking besides a busy A road for a while*" and another described it by saying "*less of a dose than standing in the Royal surrey carpark at peak parking*".

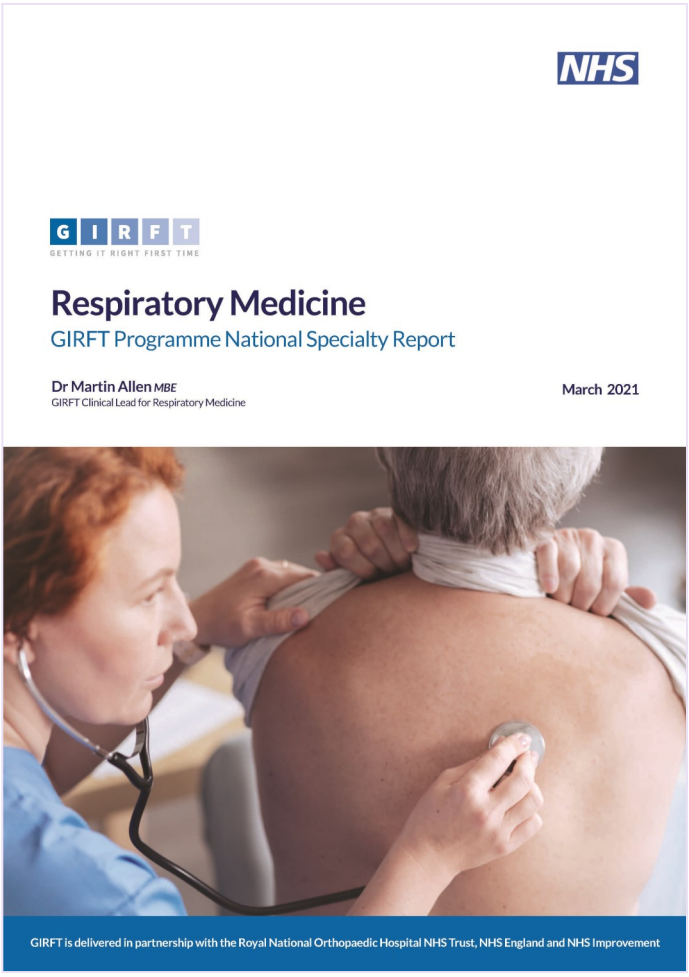
Editors note: you can read the article inspired by the original author of the forum question in this Inspire *on page .*

GETTING IT RIGHT FIRST TIME

The following article was sent to ARTP Chair by Michelle Carter, Communications Manager for the Getting It Right First Time (GIRFT) project, part of an aligned set of programmes within NHS England and NHS Improvement. It contains a summary of the key points raised by the GIRFT national report for respiratory medicine, authored by Dr Martin Allen MBE, consultant physician at the University Hospitals of North Midlands NHS Trust and the NHS national specialty adviser for physiological measurements.

The report features a series of wide-reaching improvement measures which aim to build on the experiences of respiratory teams during the pandemic, with recommendations for improving the provision of NIV services and establishing RSUs in all NHS hospitals.

The report itself can be accessed on the FutureNHS platform (https://future.nhs.uk/GIRFTNational/view?objectId=112161701)



GIRFT respiratory report outlines measures to boost physiology workforce

The need to staff respiratory departments with the appropriate number and skill mix of doctors, specialist nurses, physiologists and allied health professionals is among the recommendations in the new national report for respiratory medicine published by the Getting It Right First Time (GIRFT) programme.

The report is available for everyone working in the specialty to download, even if you do not have an NHS email address. Click here. You will need to register for access to this site, but permission is usually granted quickly.

GIRFT clinical lead and report author, Dr Martin Allen MBE – a consultant physician at the University Hospitals of North Midlands NHS Trust and the NHS national specialty adviser for physiological measurements – outlines the workforce requirements for running an effective and efficient service, including a focus on the physiology workforce.

Through its deep dive meetings, GIRFT found insufficient physiology staff in most hospitals to deliver the services for both general respiratory function tests (spirometry, gas transfer, lung

volumes) and sleep medicine. As a result, universal recommendations have been made to Trusts to consider appointing more junior and senior physiology staff.

The new report is based on questionnaires to the 128 Trusts in England with respiratory activity, as well as visits to 58 NHS Trusts. It shows that respiratory problems were among the most common reasons to consult a GP and for acute hospital admissions, even before COVID-19. Admissions for respiratory conditions are growing at around 13% annually, faster than other specialties.

The COVID-19 pandemic placed a particular strain on respiratory medicine teams and services, and outpatient services were also heavily impacted, with a 42% reduction in activity in May 2020 compared to May 2019.

The report contains practical steps and best practice examples to help Trusts better manage patient demand and optimise capacity as services are restored, with a focus on measures which can help meet the challenges of the post-COVID world. These include:

A dedicated non-invasive ventilation (NIV) unit in every trust. The report highlights a gap in provision of NIV – only 77 acute trusts in England had dedicated NIV beds at the time of the review and many reported not having enough nurses or equipment to support them. GIRFT recommends a series of actions to help all Trusts work towards a dedicated non-invasive ventilation (NIV) service to help improve outcomes for patients, with the right infrastructure to support them.

Establishing respiratory support units (RSUs) to provide the best possible care for COVID-19 and post COVID-19 patients. These units emerged as a key response to the pandemic, delivering improved outcomes for patients and allowing respiratory support for patients outside of intensive care, freeing critical care capacity for those patients who needed invasive ventilation. GIRFT aligns with the British Thoracic Society (BTS) in recommending RSUs in all NHS hospitals. The report also makes recommendations to enable remote monitoring of patients with post-COVID-19 syndrome.

Improving care for patients with asthma, COPD, pneumonia and pleural disease. These four most common respiratory conditions affect millions of people in the UK, and the report focuses on improving care, reducing the number of admissions and the time patients spend in hospital. Recommended measures include a target of one asthma nurse per 300 admissions, introducing seven-day COPD services in areas where there is high need and having a named respiratory consultant as a clinical lead for pneumonia in all trusts.

Developing a sustainable solution to deal with winter pressures. 80% more respiratory patients are admitted to hospital in January than in August, sometimes resulting to elective work being cancelled and increased waiting lists. The GIRFT report outlines how a systematic plan could help improve patient outcomes. This might include initiatives to prevent respiratory illness, reducing the number of outpatient clinics during winter months, and an expansion of staff and infrastructure to allow respiratory patients to be managed by respiratory teams rather than locums without relevant training.

Overall the report presents 26 recommendations and an opportunity for cost efficiencies of between £28.9m and £63.9m a year.

Report recommendations

Outpatient services

1 Optimise respiratory outpatient services by reducing DNAs, limiting unnecessary follow-up, considering increased virtual consultations, one-stop clinics and moving care closer to home.

Acute and inpatient care

2 Improve acute care for respiratory patients by reviewing patient flow and considering measures to increase ward productivity.

Activity and information flows

3 Improve education and relationship building for medical and coding staff within Trusts.

4 Ensure respiratory activity is coded using Treatment Function Code 340 (respiratory medicine).

5 Explore the reasons for variability in the number of respiratory patients being cared for by respiratory consultants.

Coding for physiological activity

6 Ensure physiology outpatient activity is accurately captured and remunerated using Treatment Function Code 341.

Cardiopulmonary exercise testing

7 Increase the use of Cardiopulmonary Exercise Testing (CPET) with interpretation by senior physiologists to manage breathlessness and determine patients' fitness for major or complex surgery.

Sleep medicine

8 Improve care for patients in sleep medicine by addressing delays in diagnosis of sleep problems and CPAP initiation, together with resolving gaps in infrastructure.

Managing pulmonary embolism

9 Improve experience and outcomes for patients with pulmonary embolism by reducing unnecessary tests and ensuring respiratory or joint clinician-led follow-up where possible.

Pleural services

10 Reduce acute admissions and length of stay, and deliver a high quality pleural service which achieves the Best Practice Tariff by addressing workforce and infrastructure requirements

Asthma

11 Review referral systems and patient pathways in collaboration with community, primary and acute services to improve care for patients with asthma.

12 Review departmental resourcing to improve outcomes, reduce length of stay and reduce the likelihood of readmissions for patients with asthma.

Pneumonia

13 Optimise care for pneumonia patients by ensuring the correct diagnosis (and that it is coded correctly), as well as reviewing patient pathways and infrastructure to enable care bundle delivery, reduce length of stay, readmissions, morbidity and mortality.

Chronic obstructive pulmonary disease (COPD)

14 Optimise care for patients with chronic obstructive pulmonary disease (COPD) to reduce length of stay, readmission rates, and overall mortality by using discharge bundles. Where demand exists, consider implementing seven-day services.

Non-invasive ventilation

15 Ensure a dedicated non-invasive ventilation (NIV) service is in place, with the recommended infrastructure to improve outcomes and reduce mortality.

Integrated Care

16 Review aspects of respiratory care integration and supporting infrastructure at system level to reduce variation in service provision, enable better care delivery and facilitate information flow between providers.

Improving treatment for tobacco dependency

17 Improve access to smoking cessation therapies and reduce tobacco dependence in patient populations through a comprehensive suite of interventions.

Specialised services

18 Review service infrastructure to ensure delivery against national specialised service specifications, reducing the likelihood of delays in treatment or discharge.

19 Consider hub and spoke models to amalgamate low volume specialised services.

20 Review how Trusts achieve and maintain specialised status; updating service specifications. Where service demands have changed over time, specifications and subsequent resources need to be aligned to deliver appropriate care.

21 Establish formal registries to capture patient-level information which can support monitoring and inform commissioning decisions.

Medicines optimisation

22 Improve patient outcomes by reviewing infrastructure to support appropriate medicines use.

Workforce

23 Address variations in service delivery and meet the needs of the local population by staffing respiratory departments with the appropriate numbers and skill mix of doctors, specialist nurses, physiologists and allied health professionals.

Litigation

24 Reduce litigation costs by application of the GIRFT programme's five-point plan. Share learning by ensuring claims, inquests and complaints are reviewed in regular M&M meetings.

Procurement

25 Enable improved procurement of devices and consumables through cost and pricing transparency, aggregation and consolidation, and by sharing best practice.

COVID-19

26 Ensure respiratory services are able to provide optimal care for patients with COVID-19 and post-COVID-19 syndrome by establishing respiratory support units, enabling remote treatment monitoring and optimising multidisciplinary expertise.

ARTP Association for Respiratory Technology & Physiology

ARTP Annual Conference 2022

Good news!

The ARTP is currently in the process of finalising the date and venue for our 2022 Annual Conference, which will most likely take place around the beginning of March 2022.

As this is only four months away, you may wish to begin thinking about **RESEARCH ABSTRACTS** that you could submit. The process for submitting abstracts will be the same as in previous years, via the online platform, which will be open as soon as the conference dates are confirmed.

The deadline for submission will most likely be 1st February 2022.

As always, if you have any questions or require advice about abstract submission, please contact the Research & Innovation Committee via conference@artp.org.uk.

James Stockley
ARTP Research and Innovation Chair

ARTP Association for Respiratory Technology & Physiology

Would you like to get your region talking and support other local ARTP members?

ARTP are looking to recruit Regional Leads in the following areas;

South East

West Midlands

Northern Ireland

East of England

East Midlands

As a Regional Lead, you will be responsible for facilitating Regional Network Meetings (a minimum of 2 per year) and will feedback any topics discussed and matters of interest to the ARTP Network Co-ordinator. The purpose of these meetings is to promote discussion on regional and national matters and offer an opportunity to share departmental practices and information such as SOPS, policies, audits and research. Questions and problems raised during these meetings can also be cascaded to the ARTP Executive board for advice and resolution, if needed.

ARTP would also like to hear from members who would be interested in attending Regional Network Meetings.

For more information, please contact the ARTP Network Co-ordinator, Geraldine O'Connell-Ramsay, at **networkcoord@artp.org.uk**

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