AO01 ACCURACY OF PULSE OXIMETERS AND THE INFLUENCE OF SENSOR TYPE IN INDUCED HYPOXIA.

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Modern pulse oximeters use advanced signal processing technology to measure SpO2 and may offer improved performance. The purpose of this study was to evaluate the accuracy of three newer pulse oximeters (Compumedics Vampire (V), Nelcor N595 (N) and Masimo Radical (M)) when used with digit sensors under conditions of induced hypoxia. A further two Nelcor N595s were used with an ear and forehead reflectance sensor to enable the effect of sensor type to be assessed. SpO2 was compared with direct measurement of arterial O2 saturation (SaO2) by CO-oximetry. **Methods:** Simultaneous measurements of SaO2 and SpO2 from the five pulse oximeters were obtained in eleven normal subjects over a range of inspired O2 fractions (FiO2 = 0.10 to 0.28). Results are presented as bias (mean difference), precision (SD of differences) and root mean square error (RMS). The US FDA performance specification for pulse oximeters recommends a RMS < 3%. **Results:** 212 samples were analysed. SaO2 ranged between 71.6 and 100%.

	SpO2 - SaO2				
	V-finger	**M-finger**	**N-finger**	**N-ear**	**N-reflec.**
Bias	-0.8	0.4	0.7	-0.6	0.5
Precision	2.7	2.8	2.3	2.7	1.2
RMS	2.8	2.8	2.4	2.8	1.3

V-finger and N-ear error showed statistically significant relationships with SaO2 with overestimation at low SaO2 ($p<0.001$). Removal of these biases by arithmetic correction reduces bias, precision and RMS to 0.3, 2.3 and 2.3% (V-finger) and 0.1, 2.2 and 2.2% (N-ear) suggesting potential for some improvement in accuracy with adjustments to internal calibration coefficients of these devices.
Conclusions: Average bias was negligible and RMS was within FDA specification for all pulse oximeter - sensor combinations. The forehead reflectance sensor showed superior precision and substantially lower overall error (RMS) compared with both finger and ear sensors.

Key Words: Oximetry, Saturation, Accuracy, Validation, Hypoxia.
This study was funded by an industry grant from Compumedics Ltd.

AO02 RESPONSES TO METHACHOLINE AND EUCAPNIC VOLUNTARY HYPERPNEA IN RELATION TO BASELINE LUNG FUNCTION

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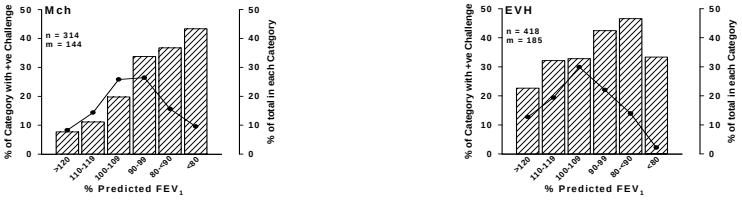
We note reports of negative test results to a pharmacological challenge in subjects giving a positive result to exercise or eucapnic voluntary hyperpnea (EVH) (Haby *et al,* ERJ 1995; 8:729-36, Holzer *et al,* JACI 2002; 110:374, AJRCCM 2003; 167: 534 & Backer *et al,* Clin Exp Allergy 1992; 22:741-47). We considered that these findings could be explained by the good lung function of the subjects studied. We investigated the distribution of +ve & -ve test results in relation to FEV_1 % predicted (% P) in those having a test with either methacholine (Mch) or EVH in a laboratory population. We proposed that, in those with a higher %P FEV_1, the proportion of subjects +ve to Mch challenge would be less compared with a population challenged with EVH.

Methods: The data for tests since 2001 were analysed in subjects $\leq$50 years.

Results: The distribution of % P FEV_1 was similar (Figures). Taking all subjects with $FEV_1 \geq 100\%$ P 15.1% were test +ve for MCh & 30.5% test +ve for EVH.

	Age (yr)	FEV_1% P	Gm/Mean	$FEV_1 \geq 100\%$ P (ECCS)	
				% of all test +ve	test -ve
Mch	34.6±10.3	98.9% ±15.1	1.9 (1.5, 2.3)	28% (PD_{20}<8.1µmol)	56%
EVH	23.5±9.5	103.6%±13.6	21.5% ± 11.5	53% (% fall $\geq$10%)	67%



The proportion of test +ve to Mch with an $FEV_1 \geq 100\%$ (28%) was half that of those test -ve (56%) & only half that test +ve to EVH with FEV_1>100%P (53%).

Conclusion: In people with very good lung function, a positive response to challenge by EVH is more common than a positive test to Mch.

Key Words: Methacholine, EVH, FEV_1 % Pred

Nomination for Young Investigator Award

AO03 THORACO-ABDOMINAL DISTENSION FOLLOWING GLOSSOPHARYNGEAL BREATHING USING OPTICAL REFLECTANCE MOTION ANALYSIS

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Glossopharyngeal breathing (GPB) can increase measured lung volume above TLC but the somatic volume distribution of this increase is undescribed. Optical Reflectance (OR) motion analysis is a non invasive measurement based on optical three dimensional (3D) tracking of surface movement in space. AIM: To use OR motion analysis to assess somatic distension and the contribution of the chest wall in a breath hold diver when performing GPB above TLC (TLC_{GPB}). METHOD: Subject was a male breath-hold diver experienced in GPB, age 31. The torso was evenly encompassed with 176 symmetrical 1cm^2 reflective markers from the suprasternal notch to below the iliac crest. The data was captured with 10 digital cameras and collected with EVaRT (Motion Analysis Corp, CA). Each image required manual identification of a 3D matrix of markers rendered at the sub millimetre level. Data was analysed with the subject at TLC and TLC_{GPB} . The thoraco-abdominal volume and distribution change was estimated by applying the Gauss theorem to surface tetrahedrons grouped into 4 thoracic and 4 abdominal 'biscuits'. RESULTS: Calculated volumes at TLC and TLC_{GPB} summed for thorax were 16.69L and 16.35L and abdomen 12.35L and 13.49L respectively. This equates to a 0.80L distension above TLC. CONCLUSION: OR motion analysis showed an increase in thoraco-abdominal distension estimated by this method during TLC_{GPB} in a breath-hold diver. This volume was distributed primarily to the abdomen. Upper chest wall distension was not observed.
Key Words: breath-hold diving, glossopharyngeal breathing, hyperinflation, thoracic displacement

AO04 THE ASSESSMENT OF MUCOCILIARY TRANSPORT USING NEAR-INFRARED LIGHT SCATTERING IN OVINE MODELS *IN VITRO* AND *IN VIVO*

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We have designed a method for using a near-infrared (NIR) light scattering probe for the experimental evaluation of the effects of physical or pharmacological interventions on mucus transport in conducting airways. The aim of the study was to assess the validity of the method both *in vitro* and *in vivo* by measuring of the Mucus Transport Velocity (MTV). This was achieved by timing the movement of fine reflective glass beads as contrast media in the mucus.
In vitro the preparation consisted of a superfused sheep trachea that has been described previously. It was ventilated by a lung simulator/ventilator with two humidifiers at both ends. In 9 experiments a NIR scattering probe was attached extraluminally and used to detect the movement of the mucus.
In vivo two NIR probes were attached in series to the trachea subcutaneously and the leads were exteriorized. MTV measurements were performed in chronic experiments by timing the contrast media infused through a tracheostomy.
The average MTV was 2.02 ± 1.13 mm/min. This continued for as long as the animal was maintained. *In vitro* mucociliary transport remained constant for at least 5 hours provided the temperature and humidity (T=38±0.1^{0}C / RH~100%) of the reciprocally moving air through the trachea was maintained. *In vivo* good signal to noise ratio proved the method to be reliable to distinguish artefacts from the genuine signal. However, further evaluation of the method with computer analysis of the data is required.

Key words: Mucociliary transport, near-infrared, light scattering.

AO05 THORACO-ABDOMINAL DISTENSION FOLLOWING BODY PLETHYSMOGRAPHY – WHEN TO PANT?

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Accurate, reproducible measurement of lung function is the aim of every respiratory laboratory. Our anecdotal evidence suggests that lung volumes measured by body plethysmography are greater if slow vital capacity (SVC) is performed after the panting manoeuvre because the volume at full exhalation (ie RV) is greater than FRC. We hypothesised whether this difference was due to equipment drift causing an increase in TGV rather than a physiological cause.
Methods: 27 patients presenting for routine respiratory function testing had lung volume measurement performed following two protocols – Prot A: tidal breathing at FRC, SVC manoeuvre, followed by panting at FRC against closed shutter; and Prot B: tidal breathing at FRC, panting against closed shutter followed by SVC (as per ATS/ERS Guidelines 2005). Two trials of each protocol were performed.
Results: All 27 subjects met ATS/ERS acceptability/reproducibility criteria for lung volumes within each protocol and were analysed. TLC (Prot A and Prot B: mean ± SEM = 5.20 ± 0.29L, 5.44 ± 0.28L respectively, p=0.0002), RV (Prot A and Prot B: mean ± SEM = 1.65 ± 0.13L, 1.93 ± 0.14L respectively , p = 0.00007) and FRC (Prot A and Prot B: mean ± SEM = 2.73 ± 0.20L, 2.81 ± 0.19L respectively, p=0.05) were significantly different between the two protocols. No significant difference was seen in SVC. Differences >10% in TLC between the two protocols were observed in 7 of the 27 patients (26%). The difference in TLC was related to body mass index (BMI) (R=0.45, p=0.01) but not to FEV1/FVC.
Conclusion: Measurement of SVC pre panting (Prot A) resulted in a lower mean TLC and mean RV, which occurred more in obese subjects, but with no change in SVC. This difference may be due to changes in lung mechanics in obese subjects that resulted in different TGV measurements when done before or after a deep inspiration. The mechanisms responsible for this need to be determined but the findings suggest that a protocol contrary to that in the ATS/ERS Guidelines be considered, especially in view of the increasing prevalence of obesity in western countries.

Key Words: Body plethysmography, lung volumes, BMI, lung mechanics.

AO06 IMAGING AIRWAY SURFACES NON-INVASIVELY AT HIGH RESOLUTION: NEW OPTIONS FOR LIVE-ANIMAL IMAGING AND MICRO-CT WITH SYNCHROTRON X-RAY.

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Non-invasive imaging methods for imaging live airways suffer from poor resolution; most systems have resolution reaching only ~50 microns. Poor contrast, and blurring due to long exposure times during respiratory movements prevent quantitative examination of airways and airway surfaces, e.g. for changes in diameter and mucus presence. We have established new methods of imaging using synchrotron Xrays that can improve spatial and temporal resolution, and be applied in live mice; the method can also provide three-dimensional whole-animal imaging of surprising detail.

Methods: Anaesthetised or dead C57Bl/6 mice were imaged at the SPring-8 synchrotron in Hyogo, Japan. Airway images were obtained on CCD detectors (1.1 to 6.6 μm pixels) at 17-25 keV, with a phase-contrast propagation distance between 60 and 90 cm. Exposure times were 100-300 ms. Effects of delivered agents expected to affect fluid levels in airways were tracked up to ~45 mins. Micro-CT images of mouse head and shoulders provided 3-D renderings of tracheal and nasal airways.

Results: Dynamic transit of airway-surface inclusions was detected in intact live airways, suggesting direct mucociliary clearance measurements may be possible without radio-labelled agents. The full circumference of gas bubbles located in the airway could be tracked dynamically along the airway. Trachea was imaged full-width, and after saline nebulisation revealed changes in airway-surface inclusions in some mice consistent with the rehydration and clearance of mucus plaques. Bone, soft and hard tissue, cartilage, and the airway surface was displayed in time-lapse video to a resolution of <5 um, able to reveal dynamic fluid changes on airways. 3-D micro-CT revealed impressive anatomical detail airways in the head and thorax.

Conclusions: These imaging methods have the potential to provide new non-invasive high-resolution measurements of airway function in live animal-models.

Keywords: imaging, mice, synchrotron, airways.
Support: NH&MRC, USA CFF, CF Australia, ANSTO, corporate donors. KS, IW & JC supported in part by the AMRF program.

AO07 SPIROMETRIC DIAGNOSIS OF OBSTRUCTION SHOULD USE THE LOWER LIMIT OF THE PREDICTION EQUATION. A PERSPECTIVE OF PULMONARY PHYSIOLOGISTS

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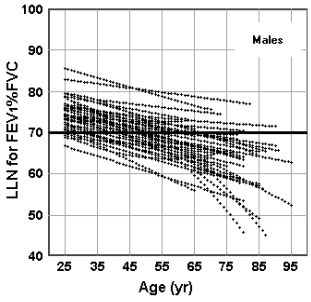
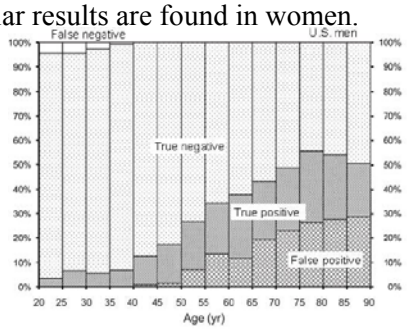
A low FEV_1/FVC ratio is the best index to detect airway obstruction. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines state that a ratio less than 0.70 defines Chronic Obstructive Pulmonary Disease (COPD). However, this ratio falls with age in healthy never-smoking adults. **Aim:** We investigated the performance of the 0.70 ratio, for defining COPD, using healthy population data. **Method:** We compared the lower limit of normal (LLN) range with the FEV_1/FVC ratio of 0.70 from 33 published population-based samples of healthy men and women from around the world. **Results:** All studies show the FEV_1/FVC ratio falls with age (figure on the left). The figure on the right illustrates the percentage of misclassifications using the fixed 0.70 ratio compared to LLN from NHANESIII data for men. Similar results are found in women.





Conclusion: The clinical application of the GOLD definition for defining COPD has an unacceptable misclassification rate, which increases with advancing age. High costs and unwarranted side-effects result from inappropriate inhaler therapy. The GOLD definition must change to one based on evidence and not expert opinion. We recommend that spirometry for COPD case-finding should be defined by a FEV_1/FVC ratio below the LLN of the normal range.

Key Words: COPD, GOLD, Lower limit of normal.

AO08 PULMONARY FUNCTION REFERENCE VALUES FOR ADULTS: A CORRECTION FACTOR FOR ASIANS MAY BE UNNECESSARY

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Aim: To assess the need for a correction to Caucasian reference values applied to Asian patients.

Method: Volunteers attended the laboratory for measurement of spirometry with reversal, lung volumes and transfer factor. Each volunteer completed a questionnaire to identify respiratory health, racial, lifestyle and developmental factors. Lung function data was expressed as percent of laboratory reference values and stratified for comparison (t-test) by Asian (As) and non-Asians (NAs).

Results: A total of 47 normal subjects were part of the study. Pulmonary function results met the ATS criteria for test quality.

Gender / Race	Male NAs	Male As	Female NAs	Female As
Age (N)	19-53 (15)	21-24 (7)	21-54 (10)	21-30 (15)
BMI	26.1 SD 4.4	24.9 SD 4.4	23.4 SD 2.7	21.3 SD 2.2
FEV1 %pred	97.9 SD 8.6	95.1 SD 10.0	94.9 SD 13.3	91.6 SD 10.4
SVC %pred	94.1 SD 8.6	89.3 SD 9.3	94.9 SD 12.6	86.5 SD 11.8
TLC %pred	93.2 SD 7.5	91.7 SD 7.8	98.0 SD 6.9	94.0 SD 8.8
TLCO %pred	101.9 SD 14.6	101.4 SD 7.8	88.4 SD 11.3	83.9 SD 11.0
KCO %pred	88.3 SD 10.2	93.4 SD 6.6	89.4 SD 9.5	90.9 SD 12.0

There was no difference in pulmonary function tests between As and NAs except in SVC ($p=0.048$) and KCO ($p=0.044$) of males. Four As and four NAs had FEV1 or FVC less than Lower Limits of Normal (LLN).

Conclusion: This data expressed as a percentage of reference values, from As and NAs normal subjects showed means within the LLN, with small, statistically non-significant differences between races. Determination of a correction factor for As and validation of current reference values will require assessment of substantially more normal subjects

Key words: Pulmonary Function Tests, Normals, Asian.

AO09 A CLASSIFICATION PATHWAY FOR OBSTRUCTION IS NOT VALID

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The American Thoracic Society and European Respiratory Society Interpretative Strategies for Lung Function Tests 2005 document contains a flow chart for classifying lung disease. One pathway, which has created discussion in the literature, allows a diagnosis of obstruction if the FEV_1/VC ratio ≥ lower limit of normal (LLN), the FVC ≤ LLN and the TLC ≥ LLN. Hence, the aim of this study was to investigate the validity of this classification criterion.

Methods: Our lung function database was searched for records containing spirometry and static lung volume measurements. These records were then interrogated for data that met the above criterion using FVC or VC, whichever was larger, as the denominator for the FEV_1/VC ratio. Results meeting the criterion were reviewed with attention paid to the upper limits of normal (ULN) for RV and RV/TLC ratio, technical comments and clinical notes from request slips to further elucidate and classify results.

Results: 27 337 sets of lung function were found, of which 2325 had spirometry and static lung volumes measured. Of these 2325 tests, 34 (1.5%) met the criterion and were investigated further. Three results were unable to be classified due to poor test performance. Obstruction was the likely diagnosis in five results with an elevated RV and RV/TLC and, in eight results where RV <ULN but RV/TLC was elevated. The remaining 18 results (13 normal RV and RV/TLC, 5 normal RV and elevated RV/TLC) were classified as being likely to have normal ventilatory function or ventilatory function at the LLN (11), ventilatory function at the LLN for a restrictive ventilatory defect (5) or borderline restriction with elevated RV/TLC due to neuromuscular complications (2).

Conclusion: The number of tests meeting the criteria, FEV_1/VC ratio ≥ LLN, the FVC ≤ LLN and the TLC ≥ LLN, in our population was small (1.5%). Only 13 (38%) of these tests were classified as having obstruction when RV and RV/TLC ratio, clinical notes from request slips and technical comments were used as additional classification tools. Individuals interpreting lung function should use caution when employing this classification pathway as its validity has not been proven.

Key words: Lung function, interpretation, airflow obstruction

AO10 WARM HUMID AIR CAUSES A LONG TERM EFFECT ON TEMPERATURE IN THE NASAL MUCOSA AND NEARBY SKIN

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The passage of conditioned air (Temperature=37^{0}C, Relative Humidity ~100%) through nasal prongs may change thermoregulation in the upper airways. Aim of the study was to asses the effect of blowing of warm fully saturated air into the nose of healthy adults.

Methods: In 11 volunteers (age range 21 – 39, 5 female/6 male) changes of facial temperature were assessed with a infra-red thermal camera and changes of nose temperature at the level of the nasal valve with thermocouples was analysed during and after 30 min application of the air flow through nasal prongs at low CPAP level (1 – 2 cm H_20). Mucosal temperature (T) was recorded continuously during the gas flow and for 1hr 30 min afterwards and analysed for 1 min every 10 min. Thermal images for thermal analyses were taken every 10 min during the study and core temperature every 30 min.

Results: Warm humid air produced an increase in nasal mucosal temperature. This showed significant ($p<0.05$) increase of median temperature from $T_{control}$=28.46 ^{0}C (range 26.99 – 34.8^{0}C) up to ($T_{50\ min}$=29.92 ^{0}C (range – 27.13 – 34.3^{0}C) after the exposure. It also produced significant increase of temperature in perinasal area - $T_{control}$=34.95^{0}C (0.44 (SD) during the procedure - $T_{10\ min}$=35.79^{0}C (0.39 (SD); p=0.0017; $T_{20\ min}$=35.94^{0}C (0.52 (SD); p=0.0001; $T_{20\ min}$=35.95^{0}C (0.69 (SD); p=0.0007. Average temperature of the face was increased by more than 0.5 ^{0}C up to 30 min ($p<0.05$) after the procedure.

Conclusion: Warm humid air, delivered to the nose, caused a significant increase of temperature in upper airways that was retained. This may have an effect on the nasal valve function.

Key words: Nasal CPAP, humidification, upper airways, temperature.

AO11 INTEGRATED MATHEMATICAL MODELS OF RESPIRATION IN MAMMALS

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Mathematical modeling of biological systems has long been recognized as a useful tool to study biological systems. Mathematical models can sometimes explain phenomena that otherwise look complex and provide a tool for conducting thought experiments that cannot be performed in the lab. The aim of this research is to develop a mathematical model of respiration in mammals and use it to study phenomena such as central sleep apnea and other aspects of the control of respiration.

The mathematical model integrates a reduced representation of the brainstem respiratory neural controller together with peripheral gas exchange and transport mechanisms. The neural controller consists of two compartments. One compartment represents the respiratory oscillator incorporating biophysical mechanisms for rhythm generation in the pre-Bötzinger complex (pBC) and neural activity of the Bötzinger complex. The other compartment represents the rostral ventral respiratory group (rVRG), which is driven by the pBC for generation of inspiratory (pre)motor output. The neural model was coupled to simplified models of the lungs incorporating oxygen and carbon dioxide transport. Some features of experimental data are captured by the mathematical model. For example, the model mimics and provides a possible explanation for the appearance of apnea when 100% O_2 is inspired following a period of 5% inspired O_2.

This research was partly supported by a Marsden Fund from the Royal Society of New Zealand.
Key words: Mathematical model, neural control, gas exchange.

AO12 BILATERAL MEASUREMENT OF SNIFF NASAL INSPIRATORY PRESSURE

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The sniff nasal inspiratory pressure (SNIP) measurement is a non-invasive test of inspiratory muscle strength. The procedure consists of measuring peak nasal pressure in one occluded nostril during a maximal sniff through the contralateral nostril. SNIP has been shown to be good predictor of the development of hypercapnia and mortality in disease associated with severe respiratory muscle weakness. SNIP is considered to be less variable than mouth pressure (MIP) measurements, but may be affected by nasal obstruction.

Aim: Determine the influence of nasal patency and selection of nostril on SNIP measurement.

Method: 40 subjects were recruited (33 control subjects; 7 with neuromuscular disease). Subjects were asked for a subjective score (0 – 5) of left and right nasal patency. A total of 8 SNIP trials were recorded for each nostril.

Results: Subjects included 23 females & 17 males aged from 18 – 80 years. In all subjects the mean (SD) agreement in SNIP between nostrils was 2.8 (18.1) cmH_2O, with a largest recorded difference of 64cmH_2O. A difference in SNIP between nostrils of greater than 20cmH_2O was observed in 8 subjects. The larger value was measured in the patent nostril in 5 of these subjects. The mean (SD) agreement in those subjects with a marked difference in subjective scores of nasal patency was 2.7 (6.3) cmH_2O, with the patent nostril giving the slightly larger value. The largest difference observed in this group was 17cmH_2O. In the neuromuscular subgroup (n=7), the mean (SD) agreement was 2.0 (11.7) cmH_2O. However in this group the blocked nostril gave the slightly higher reading. Two subjects in this group had a clinically significant difference in SNIP between nostrils – the maximum value was recorded from the patent nostril in one subject, and from the blocked nostril in the other.

Conclusion: In 20% of subjects there was a difference in SNIP measurement between nostrils of greater than 20cmH_2O. Subjective nasal patency was of no value in predicting this difference. To ensure the maximal SNIP value is accurately recorded, we suggest the measurement be routinely performed using both nostrils.

Key Words: Respiratory muscle strength, SNIP