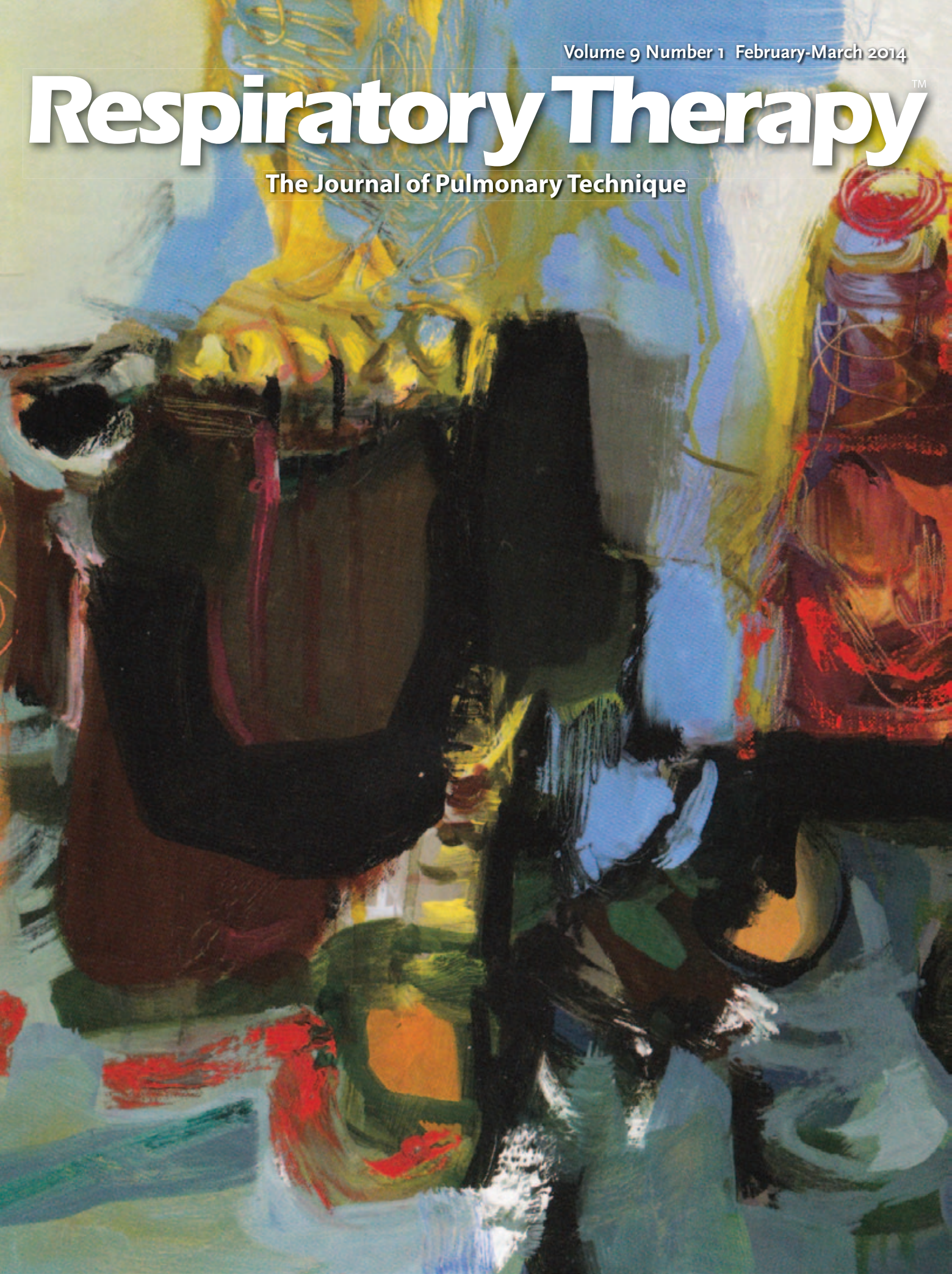


Volume 9 Number 1 February-March 2014

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## Table of Contents

### DEPARTMENTS

- 4 Editorial
- 10 News
- 15 Ventilation Roundtable
- 18 Company Profile
- 19 Interviews

### ARTICLES

- 24 Ventilator Data and Analytics
- 26 Comparing Ventilation Devices
- 27 Volume Ventilation for Neonates
- 29 The Convergence of CPAP and Auto-CPAP Devices
- 30 INOmax Ventilator Validation List (US)
- 31 Management of COPD
- 40 Studying First-Time Prescriptions
- 46 Hypersensitivity Pneumonitis
- 51 Airway Pressure Release Ventilation

## Editorial

### Would CPAP induce nasal inflammation in patients with obstructive sleep apnea?

Since the historical discovery of sleep apnea in Europe in 1965, early treatments focused mainly on eliminating upper airway obstruction using tracheostomy, which bypasses the upper airway obstruction. That was the only effective treatment for obstructive sleep apnea (OSA) until nearly 1980. In 1981, the introduction of continuous positive airway pressure (CPAP) therapy through a nasal mask remarkably showed another important discovery that boosted the practice in sleep medicine. Since then, nasal continuous positive airway pressure (CPAP) has become the gold standard management of clinically significant OSA.

It is a distending mechanical split pressure applied at a continuous level throughout the respiratory cycle to maintain an open airway, preventing airway collapse during sleep. However, despite its beneficial effects on airway patency, this therapy is associated with a high prevalence of side effects. The adaptation period is variable, some patients adapt to it within a few weeks, others struggle for longer periods, and some patients discontinue CPAP entirely with consequent detriment to their health. Although the long-term CPAP compliance rate is generally good, 8-15% of OSA patients refuse treatment after a single night of use in the laboratory setting. Nasal congestion, anosmia, sneezing, itchy nose, dry nose and mouth, throat and eyes, blocked ears, and dizziness are among the adverse symptoms occurring with CPAP use.

This high frequency of nasal symptoms among OSA patients suggests that CPAP treatment may be associated with the induction of nasal inflammation. Several clinical and experimental studies have reported on local and systemic inflammatory outcomes of nasal CPAP treatment. However, a comprehensive study investigating the impact of CPAP therapy on both nasal and systemic inflammatory parameters, clinical symptoms, and structural and functional outcomes has not previously been performed. Because little is known about the early induction of nasal inflammation with CPAP, we investigated in a short-term, dose-response study the effects of CPAP on airway and systemic inflammation in CPAP-naïve (alahmari et al, ERJ 2012). We reported a high prevalence of nasal symptoms following CPAP associated with changes in an inflammatory response in the nasal and systemic compartments. This study also suggested that CPAP triggers an early inflammatory reaction that may predict patients at greater risk of discontinuing CPAP therapy. How about humidification? The possible benefits of humidification with CPAP have been controversial in clinical and experimental studies. There is still a gap of missing randomized control trials.

There is no doubt that CPAP benefits those patients but these findings have implications for the adherence of patients to CPAP therapy, especially during the important timing of initiation phase of therapy. Would dose titration at the beginning of the therapy (i.e. a gradual increase of the pressure until optimal clinical benefits with minimal side effects are obtained) help?

I believe that novel strategies and modifications in nasal CPAP protocols to combat the initial side effects of this treatment modality and to improve compliance and retention might target the epithelial lining of the respiratory system in an attempt to address the origin of the inflammatory response. My unanswered questions: could the nasopharyngeal symptoms cause the nasal inflammation? Or is it the nasal inflammation that caused the nasopharyngeal symptoms?

Mohammed Al Ahmari, PhD, RRT  
Director, Respiratory Care Program  
Assistant Professor, Respiratory Care  
Prince Sultan Military College of Health Sciences  
Saudi Arabia

## Respiratory care at the crossroads

The next few years are going to present new challenges for all healthcare providers. Implementation of new healthcare laws, redistribution of re-imburement, and expanding roles of clinicians will challenge the current status quo of health providers. Our respiratory care profession will be at the crossroads. Does our profession embrace these changes or hold dogmatic to the past? I believe these changes will unlock opportunities for the respiratory care practitioner (RCP) and ensure a role for them in the future of healthcare design.

Today there is a greater emphasis on preventing emergency visits and hospital admissions more than in the past. Another area of enhanced emphasis is patient readmissions. If a patient is re-admitted within thirty days of discharge the institution may face penalties and/or lack of medical payments. One disease etiology that will be closely scrutinized in the next few years will be Chronic Obstructive Pulmonary Disease (COPD). Another disease entity that is at the forefront of concern is asthma. The number of asthmatics is increasing and the cost to medical institutions to manage these patients is ballooning.

Several strategies have been proposed to combat the above problems. One intervention that appears to be gaining momentum and has produced some positive outcomes is the utilization of the Respiratory Care Practitioner as a front-line educator for COPD and asthma management. The ideal patient environment for this interaction is the emergency department (ED). The respiratory care practitioner can help assess, treat, and educate patients and family on disease management, and provide device training pre-discharge. These interventions could have the potential to reduce ED visits, hospital admissions, and re-admissions. The RCP could continue the ED care acting as a case manager post discharge to ensure patient stabilization and adherence to prescribed drug and device regimen.

Other responsibilities the RCP could perform include: obtaining arterial blood gases, administering continuous aerosolized therapies, provide mechanical and non-invasive ventilation management, and provide airway management. The RCP would be viewed as an added-valued team member.

As the future in healthcare evolves the RCP will have a role in patient management. The exact role places the onus on us to shape and define. The future is now and it's a time of action and change.

Kenneth Miller MEd, RRT-NPS, AE-C  
Educational Coordinator  
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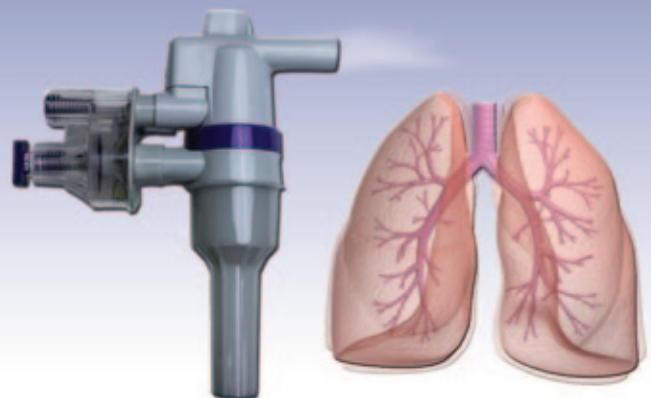
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## Software for clinicians

Clinicians have the opportunity for more detailed reporting with a whole raft of trends with the release of a new software package. The software comes from 3B/BMC, a global supplier and leader in sleep diagnostics and sleep therapy products, which introduced its nPAP Data Analyzer. The nPAP Data Analyzer works in conjunction with 3B's line of CPAP and Auto-CPAP devices. The software allows clinicians to generate detailed reporting and graphing of pressure (cmH<sub>2</sub>O) trends, leak level trends, apnea-hypopnea trends, flow level trends, tidal volume trends, and respiration rate (bpm). The nPAP Data Analyzer software is available at no cost by direct download from 3B's website at [www.3Bproducts.com](http://www.3Bproducts.com). 3B/BMC specializes in the development, manufacturing and marketing of medical products for the treatment and management of sleep disordered breathing.

## Modems made obsolete

A cloud-based information management system called iCode Connect has been launched by 3B to make transferring sleep reports seamless. iCode Connect integrates with 3B's free smart phone app, which decodes and sends sleep reports with the snap of a photo. iCode and iCode Connect manage patient records, develop patient reports and track overall treatment progress of CPAP and sleep apnea patients. iCode Connect makes treating sleep disorder patients easier and more efficient. It provides accurate, timely data, is HIPAA compliant and cloud-based, so the information can be sent to various health-care providers with no additional costs. iCode Connect eliminates the logistical challenges of inventorying and retrieving modems and SD cards from patients. In addition to modem costs, monthly service fees and the \$75-100 cost of a home visit, iCode Connect works with only a smart phone. If a patient can take a picture, a sleep compliance report can be produced quickly and retrieved by the entire health-care team. iCode Connect utilizes optical character recognition technology to process a photograph and extract sleep data from the display to produce a full sleep report. iCode Connect's web portal also archives patient sleep data. In addition to capturing all sleep reports, iCode Connect also acts as a convenient way for physicians and home medical equipment supplier to trade patient notes, maintain prescription information and monitor patient progress. iCode Connect works with 3B's iCode application for Android and iPhone and online report generation. Collected data includes device, mask and accessory prescriptions; model numbers and sizes; contact information; a log of past patient interactions; patient photo; primary and secondary insurance; medical care team; reminders and notes.

## Exercising some independence

The American Journal of Respiratory Critical Care Medicine published a peer-reviewed article about the clinical effectiveness of the Non-invasive Open Ventilation system by Breathe Technologies to reduce dyspnea while significantly prolonging exercise endurance time and improving oxygen saturation (SpO<sub>2</sub>) levels in 15 COPD patients. The clinical research paper showed that COPD patients using the NIOV system were able to exercise 245% longer as compared to breathing on regular air (17.6 mins on NIOV vs. 5.5 mins on air). When compared to traditional oxygen therapy, the NIOV system improved exercise endurance by 54% (11.4 mins on O<sub>2</sub> therapy vs. 17.6 mins on NIOV). NIOV is a one-pound, wearable, ambulatory ventilation device. The article found patients' heart rate and respiratory rate were also markedly reduced while using the NIOV system. Patients reported significant improvement in their dyspnea score while at rest using the NIOV System. Another outcome of this clinical research article was the "substantial reductions in respiratory muscle activation" of patients using the NIOV system during exercise, "apparently a result of ventilator support provided by the device." The NIOV system was shown to reduce the activity of scalene, intercostal, and diaphragm muscles by 48%-67%. Although the authors indicated the need for additional studies, they did acknowledge the impressive clinical outcomes achieved by the NIOV system. They concluded that the NIOV system "substantially improved exercise tolerance accompanied by respiratory muscle unloading and dyspnea reduction in patients with severe hypoxemic COPD. This study further confirms our belief that the NIOV System has the capability of improving the lives of patients living with respiratory insufficiency." By reducing symptoms and improving patients' endurance and oxygenation levels, the NIOV System enables patients to take back some of their independence lost due to their chronic health issues. The system, which is FDA-approved for clinical and home care, increases tidal volume by providing positive pressure ventilation to patients.

## Let's make a (big) deal

CareFusion Corp., a global medical technology company, announced the signing of a definitive agreement to acquire the Vital Signs division of GE Healthcare for \$500 million. With annual revenue of approximately \$250 million, Vital Signs is a manufacturer of single-patient-use consumables for respiratory care and anesthesiology. The company also markets products for temperature management and patient monitoring consumables. The acquisition will significantly expand CareFusion's Specialty Disposables business by adding global scale and new products for anesthesiology, establishing the company as a leader in the more than \$3 billion market for respiratory and anesthesia consumables. With approximately one-third of its revenue coming from customers outside the US, Vital Signs will advance CareFusion's goal to expand in international markets. CareFusion expects to complete the acquisition for the Vital Signs business in the United States, China and certain other countries by Dec. 31, 2013, and to finalize the remainder of the transaction during its third quarter, ending March 31, 2014, subject to regulatory review and customary closing conditions. Upon completion of the transaction, Vital Signs will be CareFusion's eighth acquisition since 2010.

## Obesity and sleep apnea

About 4% of children in the US are diagnosed with sleep apnea, according to the American Sleep Apnea Association, yet experts agree it's a health condition that's becoming more of a problem,

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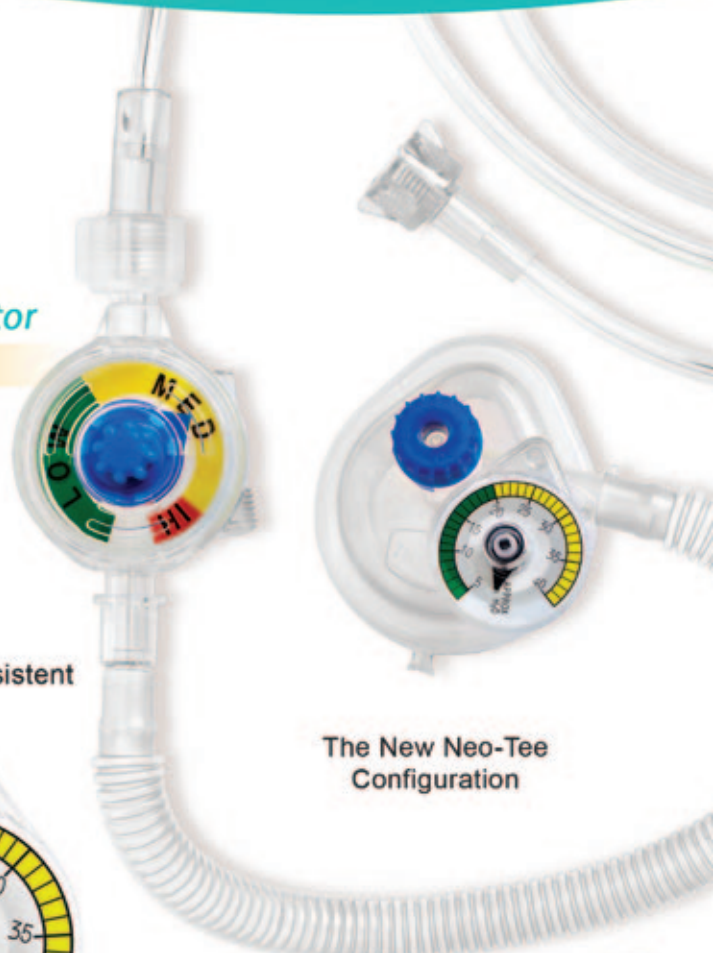
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particularly because of the childhood obesity epidemic. What's more, some kids who are left undiagnosed or who are using medications for their symptoms are suffering unnecessarily. Parents need to recognize the signs in their children. Obstructive sleep apnea is a condition that causes the throat or upper airway to collapse, preventing oxygen from going through the lungs and causing shallow breathing or breathing pauses. Sleep apnea can happen at any age, but it's most common in children ages 3 to 7 and during middle school. While enlarged tonsils and adenoids are usually the culprit, obesity is also a major reason why kids get sleep apnea. In fact, up to 60% of obese children have obstructive sleep apnea, according to Sleep Medicine Reviews. Children with sleep apnea may also be restless sleepers, wake up multiple times throughout the night, experience morning headaches and daytime sleepiness. Obstructive sleep apnea has also been linked to attention deficit-hyperactivity disorder, irritability and behavioral problems. Children with the condition are more likely to have learning problems and poor academic performance, according to a recent study in the journal *Sleep*. And children with severe sleep apnea may even have high blood pressure and heart conditions. Surgery is usually the best option for children with enlarged tonsils and adenoids, yet studies show that sleep apnea can't be diagnosed with a physical exam, so an overnight sleep study in a pediatric sleep laboratory is recommended. During the non-invasive, painless test, sensors are placed on your child to monitor his or her breathing. For children who don't have enlarged tonsils or adenoids, or for whom surgery either isn't appropriate or doesn't cure the sleep apnea, a continuous positive airway pressure (CPAP) mask that opens the upper airway may help. If your child is overweight or obese, losing weight can greatly reduce sleep apnea symptoms. Information is from an article that appeared on foxnews.com written by Julie Relevant. Copyright Fox News.

### **Virus cited as IPF cause**

New research shows that idiopathic pulmonary fibrosis (IPF), a fatal progressive lung disease, might be caused by a virus. Gerard Nuovo, MD, of Ohio State University Comprehensive Cancer Center in Marion, and colleagues found evidence of the pathogen, herpesvirus saimiri, was in all tissue samples from a cohort of patients with IPF, but in none of those from patients with fibrosis with a known cause. The finding might be useful in diagnosing IPF, a disease for which there is no diagnostic test, Nuovo reported online in *Modern Pathology*. And interventions aimed at stopping the proliferation of herpesvirus saimiri might stabilize IPF, which is typically fatal within two years of diagnosis, the researchers argued. IPF affects about 200,000 in the US, which is about a fifth of those suffering from all forms of pulmonary fibrosis. The virus does not cause disease in its natural host, the squirrel monkey, but causes fatal T-cell lymphomas and leukemias in New World monkeys, the researchers noted. Importantly, a productive infection with herpesvirus saimiri is associated with viral expression of four "pirated" mammalian proteins—interleukin-17, cyclin D, thymidylate synthase, and dihydrofolate reductase. Other gamma-herpesviruses express some but not all of the four, Nuovo and colleagues noted. For this study, Nuovo and colleagues first tried to see if IPF was associated with any herpesvirus, including such pathogens as Epstein-Barr virus, cytomegalovirus, and herpes simplex viruses. They screened tissue from 13 cases of IPF and found that all were positive for herpesvirus saimiri DNA, but none was positive for DNA from the other viruses. That finding led them to expand the study to 21 cases of IPF and 21 controls—cases of pulmonary fibrosis

of known etiology, including seven cases of fibrosis-related adenocarcinoma of the lung, five cases of lung fibrosis associated with emphysema, and nine cases of interstitial pneumonitis and fibrosis with a known viral cause. In the expanded study, analysis blinded to the diagnosis showed that again all of the IPF cases were positive for herpesvirus saimiri DNA, but not one of the other cases, Nuovo and colleagues reported. The four pirated proteins—cyclin D, thymidylate synthase, dihydrofolate reductase, and interleukin-17—were strongly expressed in regenerating epithelial cells of the IPF cases, but not in the epithelia of the controls, they found. Real-time polymerase chain reaction testing showed that the cyclin D RNA in active IPF was viral, not human, in nature. And when the researchers cloned and sequenced part of the genome corresponding to the herpesvirus saimiri DNA polymerase gene, using an IPF tissue sample, it was an exact match for the published viral sequence.

### **Patient safety increased**

Rainbow Acoustic Monitoring (RAM) has the potential to increase pediatric patient safety, according to a new study in *Pediatric Anesthesia*. The study found Masimo's RAM had similar accuracy, yet better patient tolerance compared to capnography (nasal cannula) in post-surgical pediatric patients. The study, which compared the performance of RAM to capnography in a pediatric patient population, adds to the growing body of evidence that shows the efficacy of RAM (including accuracy, precision, and better patient tolerance) in adult and pediatric patient populations. RAM is a respiration rate (RRa) measurement used with a cloth adhesive sensor worn on the neck that allows clinicians to noninvasively and continuously assess patients' breathing, facilitating earlier detection of respiratory compromise and patient distress. In the multicenter study at Cincinnati Children's Hospital Medical Center, University of Arizona Medical Center, and Children's Medical Center at Dallas, researchers found when compared to nasal capnography, RRa showed "good agreement and similar accuracy and precision but was better tolerated in post-surgical pediatric patients." The difference in bias and precision between the two test methods was not statistically significant ( $p=0.41$ ). Six of the 40 patients in the study immediately removed the nasal cannula and would not permit it to be reapplied (and were not included in data collection); nine of the remaining 34 patients removed it prior to study completion (but were included in data collection). Only one patient removed the RRa sensor after 80 minutes of monitoring time. The reliability of capnography was 92% of total monitoring time and the reliability of RRa (used with a Masimo Rad-87 bedside monitor) was 90% of monitoring time; the difference was not statistically significant ( $p=0.54$ ). Total duration of monitoring time and average per patient was 2,650 minutes and 76 minutes for capnography and 2,849 minutes and 83 minutes for RRa.

### **Tiotropium and asthma**

The latest data from Boehringer Ingelheim about tiotropium in asthma was presented at the 2013 American College of Chest Physicians annual meeting (CHEST 2013) in Chicago. The CHEST session "Tiotropium and Asthma" features a total of four oral presentations from Phase 2 and 3 studies of tiotropium delivered via the Respimat inhaler in severe asthma patients. Tiotropium is currently being evaluated to determine the efficacy and safety in treating asthma patients and is not currently approved for this indication. Pooled Phase 3 data being presented from the replicate PrimoTINa-asthma studies provide further evidence for tiotropium delivered via the Respimat

inhaler as a possible add-on treatment for severe persistent asthma. Data presented at CHEST show that in adult asthma patients who remain symptomatic despite treatment with at least inhaled corticosteroids (ICS)/long-acting beta-2 agonists (LABA), tiotropium delivered via the Respimat inhaler reduced the risk of severe asthma exacerbations and any asthma exacerbation. These results add to data from the ongoing Phase 3 trial program that has previously shown positive results for tiotropium in severe asthma patients who remained symptomatic despite treatment with at least ICS/LABA. Asthma exacerbations (or attacks) occur in patients across all degrees of asthma severity and are an important cause of asthma-related morbidity and mortality. Spirometry pulmonary function tests were conducted to evaluate whether once-daily dosing resulted in sustained improvements in lung function over 24 hours. Data from these spirometry tests demonstrated that tiotropium delivered once daily via the Respimat inhaler showed statistically significant improvements in lung function versus placebo and were sustained over the 24-hour timeframe.

### **Sleep apnea linked with death risk**

The risk of death goes up with the severity of a person's obstructive sleep apnea, according to a new study out of South Korea. The *Journal of Clinical Sleep Medicine* study is the first to find that sleep apnea severity is linked with death risk in an Asian population, said researchers from Chosun University Hospital, Seoul National University College of Medicine and the Seoul National University Bundang Hospital. Previous studies had only looked at Western populations. Researchers analyzed data from 2,240 people ages 40 and older with sleep apnea or snoring who visited the Sleep Center of Seoul National University Bundang Hospital at some point between 2003 and 2009. All the study participants underwent a full-night polysomnography testing, through which researchers were able to deduce the number of times they stopped breathing throughout the night due to their sleep apnea. They were then grouped into categories based on sleep apnea severity. All the participants who had at least mild sleep apnea were assigned to undergo surgery, CPAP, a mandibular advancement device, or a combination of the three. The average participant was observed for 61.4 months, or a little more than five years. Of those with at least mild sleep apnea, 735 received treatment for the condition, the other 1,065 were not treated either because they refused treatment, they became lost during the follow-up period, they wanted to try losing weight, or they wanted to try sleeping in a different position. Over the study period, 69 people (3.08% of the study group) died. Researchers found that the death rate was higher in the groups of people with more severe sleep apnea, compared with less severe or no sleep apnea. Specifically, 1.81% of people with no sleep apnea died over the study period, 2.18% of people with mild sleep apnea died, 3.54% of people with moderate sleep apnea died and 4.2% of people with severe sleep apnea died. Heart disease and strokes were the cause of about a third of the deaths. Overall, the risk of dying was 2.47 times higher among people with severe sleep apnea compared with people without sleep apnea.

### **Daytime helped by nighttime treatment**

Treating obstructive sleep apnea (OSA) modestly brought down some measures of resistant hypertension beyond what blood pressure medications could achieve alone, a small, randomized trial showed. Six months of continuous positive airway pressure (CPAP) treatment cut daytime ambulatory blood pressure by 6.5/4.5 mm Hg whereas it rose by 3.1/2.1 mm Hg among controls on medical therapy alone ( $P < 0.05$ ), Dr Geraldo

Lorenzi-Filho of the Heart Institute at the Universidade de São Paulo, Brazil, and colleagues found. However, nighttime and 24-hour pressures didn't differ significantly between groups, the researchers reported in the November issue of CHEST. The impact of CPAP on blood pressures in these patients with confirmed resistant hypertension and moderate-to-severe OSA was in the range of that expected from treating other causes of secondary hypertension, they noted. Based on prior research, the magnitude of blood pressure reduction achieved with CPAP in the trial would be expected to reduce cerebrovascular events by more than 30% and cardiovascular events by more than 20%, Dr Malcolm Kohler, of University Hospital Zurich, and Dr John R. Stradling, from the NIHR Biomedical Research Centre in Oxford, England, noted in an accompanying editorial. However, no single intervention is likely to normalize blood pressure in this complex condition, Lorenzi-Filho's group cautioned. Even renal denervation, which achieves blood pressure reductions in the range of 28/10 to 32/15 mm Hg, leaves many resistant hypertension patients well above the threshold for hypertension. Roughly 80% of resistant hypertension patients are estimated to have OSA, and the trial results support a causal link, Kohler and Stradling noted. Patients presenting with resistant hypertension should be evaluated for OSA, they concluded. Their trial included 40 patients with hypertension uncontrolled despite use of at least three medications, including a diuretic, newly diagnosed with moderate to severe OSA by full polysomnography (apnea-hypopnea index of at least 15 events/hour). Four patients were excluded from analysis because of poor medication adherence and one other because of acute myocarditis. This group of predominately middle-age, obese (median body mass index 32 kg/m<sup>2</sup>) men was randomized to hypertensive medical therapy alone or with CPAP for 6 months. The CPAP group averaged 6 hours a night on the machine. Medication regimens were not changed during the study.

### **Protecting patents**

ResMed, which develops products for the treatment of sleep-disordered breathing and respiratory conditions, has won preliminary injunctions in Germany against several alleged patent-infringing activities by Taiwanese medical device manufacturer APEX Medical Corp., and Chinese medical device manufacturer BMC Medical Co. The initial orders, entered by the Munich District Court, prohibit APEX and BMC from selling or marketing certain products in Germany without a further court order. Those products are the APEX WiZARD 210 and WiZARD 220 mask headgear, BMC's RESmart CPAP devices, and BMC's Willow/FeaLite nasal pillows patient interface. ResMed has also filed patent infringement lawsuits in Munich seeking damages and permanent injunctions to stop infringement of ResMed patents by the products listed above, as well the APEX iCH and XT Fit CPAP devices, the APEX WiZARD 210, and WiZARD 220 masks. Earlier this year, ResMed pursued similar legal actions against APEX and BMC in the US with the International Trade Commission. The US government investigation started at ResMed's request against APEX resulted in an ITC consent decree against APEX stopping the importation and sale of infringing APEX products. Proceedings against BMC are ongoing.

### **Men healthier than women?**

When it comes to the healthier sex, a new study, presented at the Annual Scientific Meeting of the American College of Allergy, Asthma and Immunology suggests that adult males are healthier than adult females. Renata Engler, an allergist, presented the findings and said that adult females are at higher risk for

allergies, asthma and autoimmune diseases. More prepubescent males have rhinitis, asthma and food allergy than females, said Engler, adding that when females enter young adulthood, they outnumber men in these chronic illness categories. The reasons for this difference in disease risk and immunity are complicated. While the IgG (antibody) immune response to vaccines is enhanced in women compared to men, IgG levels are higher in asthmatic men. This, she said, means that doctors will have to look at more personalized treatments and a one-size-fits-all approach won't work. The importance of sex differences in the practice of allergy-immunology cannot be overstated, said Engler, adding that improved sex/gender based medicine and research practices will benefit men and women alike.

### **Fur flies with cat allergies**

The number of people with asthma who are also allergic to cats has more than doubled in less than 20 years, a new study has revealed. Researchers at the New Jersey Medical School also found asthma sufferers are a third more likely to be allergic to cats than those without the respiratory disease. They said people with asthma planning to stay with family over the Christmas period should pack an extra inhaler if a pet cat is also going to be there. The number of people with asthma who are also allergic to cats has more than doubled in less than 20 years. The researchers say itchy noses and sneezes do not just happen in winter, with asthma sufferers more likely to be allergic to environmental triggers in autumn—such as ragweed, ryegrass and alternaria fungus. The US researchers compared the results to the 'Thanksgiving Effect'—where students return home to a pet they did not have symptoms to before and are now allergic. They discovered that from 1976 to 1994, the number of people with asthma who are also allergic to cats has more than doubled. The study also revealed that an estimated 60 per cent to 85 per cent of people with asthma have at least one allergy. Asthma sufferers are a third more likely to be allergic to cats than those without the respiratory disease. While the latest research shows that cats can aggravate asthma, previous studies have suggested that dogs guard against it. Researchers at the University of California found that the dust in homes with dogs offers protection against a common respiratory virus linked to the development of asthma in children. The respiratory syncytial virus (RSV) is common in infants and the more severe the symptoms the more likely the child is to develop in asthma. Previous research, from the Henry Ford Hospital in Detroit, has also shown that children born by C-section are five times more likely to develop an allergy as those born naturally. Scientists believe this is because the babies are left vulnerable by avoiding the journal through the birth canal, which could expose them to their mother's bacteria. Information is from an article that appeared in the Daily Mail written by Emma Innes. Copyright Daily Mail.

### **Device cleared for saline use**

Kimberly-Clark has introduced the first subglottic suctioning ETT to be FDA cleared for saline use. It's called the KimVent Microcuff Subglottic Suctioning Endotracheal Tube, and the company says it provides for more effective clearing of potentially harmful clogs. The device offers more effective subglottic suctioning and prevention against microaspiration. It also provides more effective prevention against cross-contamination to both patients and health-care professionals. Suction lumens are often clogged by subglottic secretions, preventing effective suctioning and increasing the risk for infectious secretions in the lungs, a leading cause of VAP.

Microcuff Subglottic ETT features an ergonomic subglottic suction valve and integrated rinse port, enabling controlled rinsing and suctioning of the lumen in a single cycle, without the need to open the suction circuit. This unique feature provides for more effective clearing. A recent study conducted on behalf of Kimberly-Clark by Clinimark Labs found that using saline to loosen secretions and clear the lumen is both more effective at preventing and clearing clogs, and more efficient for suctioning secretions when compared to air bolus. The same study also found Microcuff Subglottic ETT's unique design allows medical professionals to provide periodic saline rinsing as a preventative measure against clogging, improving suctioning effectiveness to ventilated patients. The advanced cylindrical shape of the polyurethane cuff provides a superior tracheal seal, preventing leakage up to 93% and enables the use of saline. Polyurethane cuffs prevent fluid leakage, demonstrating 93% less microaspiration than competitive products.

### **Asthma delays pregnancies?**

Danish researchers have found that women with asthma seem to experience delays in getting pregnant. Whether this trend is because asthma has a direct biological effect on fertility or because having asthma reduces the frequency of intercourse isn't clear, however, the researchers said. The report was published Nov. 14 in the online edition of the European Respiratory Journal. Dr Len Horovitz, a pulmonary specialist at Lenox Hill Hospital in New York City, said the association between asthma and delays in pregnancy is clear. Asthma is an inflammatory disease and inflammation can happen anywhere in the body, Horovitz said. The inflammatory part of asthma may well be affecting not only bronchial tubes but also fallopian tubes, he said. This theory is supported by the fact that when women were treated for asthma, their ability to get pregnant improved, Horovitz said. Dr Avner Hershlag, chief of the Center for Human Reproduction at North Shore University Hospital in Manhasset, N.Y., said, however, that the explanation might be much simpler. Citing a British study of more than 500,000 women published in 2007 in the American Journal of Epidemiology, he said there is no difference in the fertility rates between women with and without asthma. For the new study, the team collected data on more than 15,200 Danish female twins who were up to 41 years old. The women completed questionnaires that asked about asthma and fertility. Using the data, the researchers were able not only to compare the twins, but also use them as a model for the whole population. The team divided the women into those with and without asthma, as well as those whose asthma was being treated and those whose asthma wasn't being treated. In addition, the women were asked whether they had been trying to get pregnant for more than a year without success and how many children they had. Nearly 1,000 of the women had asthma. More of these women had a harder time getting pregnant than women without asthma (27% versus 21.6%), the researchers found. Delayed pregnancy was significantly longer among women whose asthma was not treated compared with women whose asthma was being treated (30.5% of the untreated asthma group versus 23.8% of those receiving treatment), the researchers said. In addition, women over 30 with asthma were more likely to experience delays in getting pregnant (32.2% of women over 30 versus 24.9% of women under 30). Overall, however, women with asthma ultimately had the same average number of children as women without asthma, as those with asthma tended to have children earlier in life than those without asthma, the researchers said. Information is from an article from WebMD News written by Steven Reinberg. Copyright WebMD News.

## Studying ventilator-associated pneumonia

UHC—an alliance of the nation's leading non-profit academic medical centers—announced its selection as a co-ordinating entity for a 3-year, \$7.3-million contract from the Agency for Health-care Research and Quality that has been awarded to the Johns Hopkins Armstrong Institute for Patient Safety and Quality to reduce ventilator-associated pneumonia in hospitals. The Armstrong Institute will lead the Comprehensive Unit-based Safety Program for ventilator-associated conditions and work in partnership with the Michigan Health & Hospital Association Keystone Center and coordinating entities such as UHC to extend this research project's reach. Ventilator-associated pneumonia is the most lethal of all hospital-acquired infections and affects about 250,000 patients each year. Through UHC's involvement, CUSP can bring its proven checklist for reducing ventilator-associated pneumonia to hospitals nationwide. UHC leaders in performance improvement will serve on the project's planning committee and study design group. The project correlates with performance-improvement efforts currently being led by UHC's work as a national Hospital Engagement Network, in which 79 hospitals currently participate. Since UHC's Hospital Engagement Network launch in 2012, these hospitals have made significant strides in performance improvement, including a 16% reduction in ventilator-associated pneumonia. UHC will use its specialized services in performance improvement to support CUSP and aid the Department of Health and Human Services' national action plan to prevent health-care-associated infections. The CUSP project for ventilator-associated conditions will begin in early 2014 and has an estimated duration of 2 years. It will use National Health-care Safety Network data when possible.

## VENTILATION ROUNDTABLE

### Covidien

#### What ventilation products does your company offer?

Our Puritan Bennett ventilators, heated filtration systems, ventilation accessories and software from Covidien help reduce asynchrony and the risk of infections in ventilated patients from neonates to adults. Newport ventilators are designed with advanced features and simple, intuitive user interfaces to help clinicians improve patient outcomes and comfort. Specific devices include:

- The Puritan Bennett 840 ventilator, which features a full suite of software options, safety features and accessories to fit a variety of patient needs from neonate to adult. Our PAV+ software provides a breath type that helps clinicians to better manage a patient's work of breathing and supports more natural breathing compared to conventional mechanical ventilation.
- The Newport HT70 Plus ventilator combines ruggedness, ease of use and clinical proficiency with exceptional mobility for patients from 5 kg to adult. All models of the Newport HT70 ventilator can be used for home care, transport, hospital, long-term care and emergency preparedness, as well as for invasive or noninvasive ventilation. In addition to standard clinical features, the Newport HT70 Plus ventilator offers an on-airway flow sensor that provides expanded monitoring with alarms and the choice of flow or pressure trigger. With waveform graphics, an oxygen cylinder usage calculator and internal battery use time estimator, the Newport HT70 Plus ventilator goes beyond standard portable ventilation.

#### Tell us about your company's current or recent R&D efforts.

One of the struggles that clinicians face is dealing with leaks during mechanical ventilation, which occur with cuff leaks, uncuffed tubes, chest tubes and noninvasive approaches. These leaks can cause a mismatch between the patient and the ventilator, specifically, auto-triggering and delayed cycling.

One of our latest innovations is Leak Compensation software, which attempts to quantify the leak within a couple of breaths and stop auto-triggering. It can be used with invasive and noninvasive ventilation.

In a recent study by Oto et al. using a lung model, our Leak Compensation software required fewer breaths to synchronize than any other ventilator in the study.

#### Discuss the training and support services you offer.

We partner with customers to ensure our respiratory solutions and other products best meet the needs of clinicians and patients. Specific support includes in-service programs, in-house continuing education (CE) programs, field-based technical training and Web-based tools. We've also recently launched a new Professional Affairs and Clinical Education (PACE) website (<http://www.covidien.com/pace/pages.aspx>), which features clinical education on a variety of topics, including ventilation. The ventilation training module is available at <http://www.covidien.com/pace/pages.aspx?page=ClinicalEducation/Channels/Ventilation>.

#### Where are your products used?

Covidien offers a range of ventilation solutions for neonate, pediatric and adult patients across all hospital care settings. Many of our ventilator products are also used in hospital-type facilities, at home and during intra-hospital transport.

#### What developments do you foresee for ventilation products and applications?

Covidien is working closely with the Integrating the Healthcare Enterprise (IHE) initiative to develop medical device interoperability standards. Medical device interoperability and electronic medical record (EMR) connectivity are becoming increasingly important in healthcare. For instance, the Vital Sync virtual patient monitoring platform connects to bedside devices for remote continuous patient monitoring. We can now send images of waveforms, settings, alarms and patient data to the clinician's smartphone, tablet, laptop — or any device connected to the Internet through the hospital network. This enables surveillance of the patient even when the clinician is not at bedside.

### Flight Medical

#### What ventilation products does your company offer?

Flight Medical has been developing and manufacturing ventilators for more than 15 years. We are the original developer and manufacturer of the world-known HT50 (for Newport). Our new Flight 60 line of ventilators was launched late 2010 and have been regularly updated and upgraded since.

Flight 60 line of ventilators are intuitive and easy to use, and offer high-end features and capabilities (volume guarantee, B Level, synchronized nebulizer port), without compromising

ventilator independence (12-hour battery, both O2 low flow and high pressure, and more). All our ventilators connect to information systems and enable remote monitoring.

### **Tell us about your company's current or recent R&D efforts.**

Flight Medical invests heavily in R&D work which is focused on addressing both current and long-term market needs.

We are releasing new features and capabilities four times a year, on a quarterly basis. Agile development strategy enables us to manage a very short R&D cycle, while maintaining thorough testing and validation, keeping patient safety at top priority.

We listen to our customers' developing needs and use the input collected to update our quarterly product upgrade plans. Flight Medical has added features and capabilities to customers' requests and needs in a matter of few months. Our customers can upgrade their ventilators, and continuously add capabilities to their existing fleet.

Flight Medical is working on our next line of ventilators, further improving the simplicity of use, independent use and sophistication our current line is well-known for.

### **Discuss the training and support services you offer.**

Flight Medical is helping distributors and customers to get the most out of the Flight 60 line of ventilators. Technical training and clinical support throughout the world enable our distributors to keep high level of competency in both operation and maintenance of our ventilators, as well as train our customers' biomed to maintain Flight Medical equipment themselves. Online operating videos, video conferences, webex and remote access and monitoring are used to enhance our presence with customers and shorten our reaction time.

### **Where are your products used?**

Flight 60 line of ventilators are being used in over 50 countries worldwide, including the US, Russia, Canada, Italy, Germany, India, Brazil, Colombia, and many more.

In hospitals, our Flight 60 iO2 (with integrated mixer and synch nebulizer port) ventilators are used for acute care, sub-acute, and for transport. Recently we are witnessing the penetration of Flight 60 ventilators into the ICU market, 'blended' with high-end ICU ventilators for better capital utilization.

In home care — Flight 60 has been broadly used. The 12-hour battery life gave patients independence and mobility that could not be achieved by other ventilators before.

Long-term care, assisted nursing and nursing homes are natural markets for our Flight 60. The combination of ease of use, reliability, low energy and oxygen consumption, together with the advanced modes added to our vents help our customers receive more patients.

### **What developments do you foresee for ventilation products and applications?**

At Flight Medical, we believe that portable ventilators are climbing up the ladder, and by adding capabilities are replacing higher end ventilators in more and more applications. Size matters in ventilators too, as smaller-size ventilators are delivering same features as yesterday's larger vents.

Tomorrow's vents provide remote monitoring and connectivity capabilities, like those presented by Flight Medical in AARC and Medica conferences, November 2013. Remote monitoring and connectivity span from internal hospital systems to wireless monitoring in transport, all the way to home care. Continuity along the care cycle enhances the level of care and saves readmissions, expenses and resources.

Independence is another important feature that starts playing a key role. Battery life, internal compressor, data connectivity and low/high pressure oxygen enable moving patients from ICU to different care points inside and outside the hospital, and gives more critical patients mobility while keeping the patient on the same ventilator.

## **Impact Corp**

Impact Instrumentation, Inc. is a US-based manufacturer of world-class Portable Critical Care Ventilators, Portable and On-Board Aspirators, Specialty Mounting Systems and test equipment. The new 731 Series ventilators include Eagle II for hospital and MRI use, EMV+ for military and mass casualty use and the AEV for non-invasive mask CPAP ventilation. These vents are rugged, weigh less than 10 lbs., offer AC, SIMV (EMV+ and Eagle II only) and CPAP/BiPAP modes with automatic leak compensation, a simple intuitive user interface, reduced O2 consumption, a battery run time of 10+ hrs, built-in rapid charger and SpO2 and can be used on patients as small as 5 kg. The Eagle II ventilator is an ideal solution for intra-hospital transports as well as ER and ICU bedside ventilation. The Eagle II MRI ventilator can be used in MRI suites with magnets as large as 3 Tesla and can be placed as close as 2 meters (6.6 feet) to the magnets bore opening. Available 12-foot patient circuits are designed to optimize performance in the MRI suite. Workhorse ventilators that have been on the market and serving the medical, military and mass casualty community for many years include the 754 Eagle and the 73X ventilators.

Impact has grown from a start-up company occupying a small office 38 years ago with 2 founding members to 3 large manufacturing facilities and over 160 employees in West Caldwell, New Jersey. Impact has had many significant product introductions over the years completely focused on the medical industry.

Impact re-invests millions of dollars into research and development each year and has a commitment to continuous improvement in manufacturing and new product development. R&D is the largest investment for Impact.

Impact offers both on-line and in-person technical and clinical training for its products. Respiratory therapists employed by Impact as well as paramedics and nurses are principally responsible for on-site training at the customer's facility at no charge. On-line training is supported by video, Power Point and competency presentations.

Impact's products can be found in hospitals, ambulances, stockpiles, ships and aircraft, fire and rescue services, and over 20 military services world-wide including the US, Israel, Singapore and Australia.

Future ventilation products will continue to focus on ease-of-use,



communication capabilities, built-in advanced technologies and clinical functional capabilities

## Breathe

### What ventilation products does your company offer?

Breathe Technologies, Inc is the manufacturer of the NIOV System, a 1-lb, wearable, ambulatory ventilation system for the treatment of symptoms associated with variety of respiratory conditions which result in severe respiratory insufficiency. Providing positive pressure to increase tidal volume, the NIOV System has been shown to significantly: Improve ventilation; reduce dyspnea; decrease CO<sub>2</sub> levels; increase oxygenation; significantly enhance exercise endurance; unload respiratory muscle activity.

### Tell us about your company's current or recent R&D efforts.

We listen to our customers and patients and keep current on market and industry, so that we can continue to offer products and solutions that can reduce costs while delivering clinical efficacy and a great user experience.

### Where are your products used?

The NIOV System is designed for applications such as supporting activities of daily living, patient ambulation, physical therapy, and pulmonary rehabilitation in either home or institutional environments.

### What developments do you foresee for ventilation products and their applications?

Clinicians are becoming more aware of benefits of using Non-Invasive Ventilation and oxygen therapy in reducing dyspnea and increasing physical activity. We see increasing exercise endurance and improving quality of life for patients living with chronic respiratory conditions becoming more important. With the recent reforms and changes in healthcare, clinicians are looking for solutions to cut down on frequent emergency room visits, hospital re-admissions, and ICU costs. Therefore, ventilation products that can offer a combination of cost reduction and clinical efficacy will be in higher demand.

## Hayek

### What ventilation products does your company offer?

Hayek Medical is the exclusive provider of BiPhasic Cuirass Ventilation (BCV) therapy options in the US. The current products that provide BCV are: • United Hayek RTX, previously our only model designed for critical care but which we used frequently for in-home applications • United Hayek HRTX, this is our newest ventilator designed for primarily home or basic level use. The HRTX will offer patients portability with an ability to operate for extended periods on battery power with all the important therapeutic benefits of the RTX with somewhat less graphics or screen display.

### Tell us about your company's current or recent R&D efforts.

United Hayek's technology for moving air, currently, in and out of a cuirass is phenomenal, almost needing to be seen and felt to be believed. The development and future application of this capability means United Hayek will be a very important part of

the future of pulmonary support. Also on the horizon for us at the time of this interview, perhaps released for distribution by its publication is our Secretion Clearance-only device, the SCS. All of the very potent high frequency chest wall oscillation and assist cough functions that the RTX can apply through the cuirass will be available at a much lower cost profile for patients needing only the airway clearance functions.

### Discuss the training and support services you offer.

BCV, even though it is a far more natural way to support patients, is for most clinicians a totally new set of concepts. All of the side effects of ventilation we have been taught for so long are turned upside down with BCV and are non-existent. This is a method of support that is actually therapeutic to the lungs and other systems. Additionally due to our similarity to previous generations of negative pressure ventilation (NPV) devices most clinicians feel they know our devices' capabilities. The Hayek so greatly exceeds the capabilities of those devices it is astonishing to those experienced with the old NPV systems. The patients this can serve are not limited to those with basic support needs. This means we need to educate caregivers on the concepts of this new type of support and how it works differently. We routinely provide full staff training on initial installation with follow up all the way to advanced training as users gain experience with the interventions available with BCV. As to support, we have clinical specialists who are available to our users through our company support line at any time. We also have a BCV discussion group on LinkedIn where users can discuss and relate their experiences with these devices.

### Where are your products used?

The United Hayek vents and secretion clearance products are used across the spectrum of care. If applied in the ER, ICU or even hospital, admission may be prevented. If used as part of ICU care, support can be non-invasive, fluid intake, nutrition and communication with the patient is not impaired and duration of critical care needs can be decreased. One of the most challenging and perhaps expensive patients hospitals deal with are the patients who move out of ICU, decompensate for lack of pulmonary support some time later and have to return to ICU more critical than when they were originally admitted. If patients are moved to the floor or step down unit with the Hayek, they will be more likely to achieve discharge on schedule. Since the Hayek can be prescribed for patients at home and is much simpler to use with less side effects than either invasive positive pressure ventilation (PPV) with trach or non-invasive PPV with mask and it includes airway clearance functions built in to the vent, patients who discharge with this device may return to acute care in the future, but the potential of their return being for reasons of pulmonary exacerbations is greatly decreased thus preventing frequent readmissions for these causes. So as you see the Hayek covers the entire spectrum, resulting in improving the patient's experience and saving money by decreasing intensity and duration of intensive care and also allowing care to continue in the home.

### What developments do you foresee for ventilation products and applications?

We have made great strides as an industry in meeting the pulmonary support needs of our patients and we have seen advances in technology toward the end of protecting the lungs and enhancing patient/ventilator synchrony that I believe make real difference in patient comfort and outcomes. I foresee one major shift that can have a profound effect on future outcomes

for patients needing support in the future. As people realize what Hayek Medical Devices has to offer with these products they will include this therapy in standard treatment protocols to improve results. The RTX can be used as a totally stand alone non-invasive support device that provides the advantages of far more natural support of lung inflation and deflation without mask or artificial airway, which is far more comfortable for most patients and preserves their ability to eat, drink and speak. It can also be used non-invasively in conjunction with PPV to dramatically decrease side effects and improve on clinical results. The use of BCV to facilitate weaning from PPV, shorten duration of intubation, and potentially prevent need for trach is another advancement that is on the increase. Early in my career, I was taught natural ventilation is always better than PPV but we did not have a good way to provide that type of support. Now with these devices from Hayek there is a good way. It all becomes clear when placed on a patient in distress because it's just better!

## COMPANY PROFILE

### LIFE Corporation

For well over a decade, the focus of public access and first responder emergency cardiac care has been on defibrillators and AEDs, and more recently on chest compressions, most importantly, and especially for increased cranial blood circulation during necessary and immediate resuscitation and survival during SCA (note: only SCA). Unfortunately, that focus has been at the expense of successful first-aid treatment during non-SCA cardiac and pulmonary emergencies where the standard of care for many decades has been the administration of first-aid Emergency Oxygen.

There has also been occasional weak controversy regarding possible or supposed detrimental effects of non-titrated Emergency Oxygen therapy administered without adjunct diagnosis available from oximetry for SpO<sub>2</sub> and capnography for EtCO<sub>2</sub>. Whereas simple-to-use first-aid Emergency Oxygen units have been commonly available for use for many years, the newer oximetry and capnography adjuncts may not always be available in public access or first responder emergency care, and not practical for lack of training and practice by the rescuer in such situations. Therefore, immediate administration of first-aid Emergency Oxygen continues to be the standard of care in a wide variety of emergencies, with or without the adjunct diagnosis.

Awareness of the previous narrow focus on treatment of only SCA has increased rapidly, resulting now in greater emphasis and demand for first-aid Emergency Oxygen units to provide the previous standard of care of administering Emergency Oxygen in a wide variety of cardiopulmonary emergencies, besides SCA, such as cardiac infarction, stroke, shock, and toxic inhalation or drowning instances, among others. Similarly, the controversy over use of oxygen without adjuncts of oximetry and capnography has increased the demand for utilizing these adjuncts, if available by use of trained EMTs (which adjuncts are available on almost all current 12-lead defibrillators). The need is obvious for linking the care capacities of defibrillators, oximetry and capnography with administration of Emergency Oxygen, for which combinations LIFE Corporation holds patents.

For the past 28 years LIFE Corporation has continually evolved product designs to maintain superiority. Recently designed, patented, and manufactured is the LIFEStartSystem. It combines an AED defibrillator and LIFE02 Emergency Oxygen in an easy-to-carry 6-pound unit, smaller than a briefcase. The durable and water-resistant case fits nicely in standard-size AED wall cabinet and is complete with a 113-liter cylinder of LIFE-O<sub>2</sub> Emergency Oxygen for a 15+ minute supply of oxygen. First-aid Emergency Oxygen administration should be used if needed before the onset of fibrillation and after successful defibrillation, and in the other cardiopulmonary emergencies previously listed. Having the choice of both a defibrillator or AED and Emergency Oxygen together may increase the survival rate of a victim, at a time when minutes may determine LIFE or death. An AED is necessary for treatment of SCA, whereas Emergency Oxygen is recommended for a wide variety of cardiopulmonary emergencies. The LIFEStartSystem features the LIFE612 regulator that delivers both the FDA minimum of 6 LPM, and the AHA recommended 100% inspired oxygen at 12 LPM, in just two simple settings which read "NORM" & "HIGH". Only LIFE Corporation offers the easy-to-use LIFE612 regulator with the two simple flow-rate choices. LIFEStartSystem is designed to include both the Philips Onsite or FRx AEDs, purchased separately. Additional adequate space is available in the LIFEStartSystem to include any common Pulse Oximeter for SPO<sub>2</sub> diagnosis, also purchased separately.

The original product LIFEoxygenPac is an easily portable, wall-mounted Emergency Oxygen unit for occupational workplace first aid & safety programs in industry, offices, government, schools, and public places, as well as residences. It continues to be world-wide recognized as the superior easy-to-use oxygen unit. The cylinder contains 566 liters of oxygen for a 90-minute supply at 6LPM. The LIFE CPR mask invertably fits both adult and child and can serve as an inhalator for breathing victims and a resuscitator adjunct for non-breathing victims. A clear, protective cover shows the constant reading supply gauge with simple full-to-empty symbols for clear recognition and accessibility with external two-step instructions always in view.

The LIFEsoftPac is a lightweight 6-pound Emergency Oxygen unit, preferred for frequent carrying with a shoulder strap, foam handle and padded case. A knurled-knob On/Off valve prevents accidental opening in transit. The unit supplies a 40-minute supply of oxygen at 6 LPM. It is an ideal AED companion to provide supplemental oxygen for non-breathing victim, or continued supplemental oxygen after successful defibrillation.

All of LIFE Emergency Oxygen units are shipped full of USP Grade 99.5% Pure Medical Oxygen which is safe, stable, does not expire, and provides oxygen delivery at all temperatures. A 6 & 12 LPM ("NORM" & "HIGH") regulator comes standard on our "612" models to provide the FDA minimum 6 LPM, and 12 LPM to deliver the AHA recommended 100% inspired oxygen. Variable flow 0-25 LPM regulators are available in all models if preferred by EMTs.

## The Changing Times of Respiratory Therapy

For this edition of Respiratory Therapy, we decided to go old school for an interview with Ann Ellison, who at the age of 84 is the oldest Respiratory Therapist in the United States. Ellison currently works at Maui Memorial Hospital in Hawaii. She has worked in the RT field for more than 36 years. Originally, she was a lab tech hired by an anesthesiologist to work in a blood gas lab and pulmonary function department, where she received on-the-job training. In 1985, Maui Memorial Medical Center took over that lab and she went to Arizona and, in 1986, she graduated from Apollo College and earned her CRTT. She once joked that since her fingertips are very sensitive, she would be either a safe cracker or a Respiratory Therapist — because she can get blood gases from the tiniest of patients. When not working, she travels with her husband of more than 50 years, swims, and dotes on her grandchildren and great-grandchildren.

**Respiratory Therapy:** What do you love the most about the job?

**Ann Ellison:** I do love the satisfaction of having helped patients and their appreciation.

**RT:** How has the working relationship between RTs and their physician colleagues changed since the early days of the profession?

**AE:** The working relationship between RTs and physicians has changed as pulmonologists now respect and value RT suggestions and general physicians rely on results.

**RT:** Rightly or not, clinically practicing RTs are often compared to clinically practicing nurses in terms of educational background and clinical responsibility, yet it sometimes seems that compensation for nurses in any hospital far exceeds compensation for RTs. In your estimation, what is the single most important factor that might help RTs achieve the level of compensation enjoyed by our counterparts in the nursing profession?

**AE:** I am not normally a union person, but union and management working together should help.

**RT:** What role do you think respiratory care research by RTs will play in the future development of the respiratory care profession?

**AE:** The RT profession will definitely gain respect with research and development of new techniques.

**RT:** What would you say is the key to professional longevity in a profession like respiratory care?

**AE:** RT as a profession will continue and expand as long as it maintains high standards and keeps up with technology.

**RT:** If you could re-enter the profession as a brand new RT, what RT specialization would you select and why?

**AE:** If I were young and entering the RT profession, I would select the neonatal field. Helping a baby get a good start would be rewarding and interesting.

**RT:** How was respiratory care carried out when you started and how has it progressed over the years?

**AE:** RT care has developed through the years from “oxygen tech” to respiratory care practitioner. My first blood gas machine was a two-piece crude analyzer and everything from syringes to ambu-bags had to be cleaned, sterilized and reused. We even sharpened our own needles. Today equipment is computerized, pre-packaged and disposable.

**RT:** How do you think the affordable health care act will affect you in the next two years?

**AE:** The “affordable health care act” is still a mystery to me. At 84, on Medicare and with a medical supplement I hope I am covered and can continue to afford my medical.

**RT:** What has been the most challenging change that has occurred being a RT over the tenure of your career?

**AE:** With the technology now and in the future, continuing education will be the most challenging.

**RT:** What has been the most significant technological advance over the course of your career?

**AE:** The most significant technological advance over the course of my career is computerized equipment — from charting to ventilators.

**RT:** What was your greatest moment as a RT?

**AE:** My greatest moment as an RT was stepping in at a barbecue, seeing someone collapse, checking he had not choked, performing CPR and getting the heart rate back before the ambulance got there. Yea! Yes, everyone clapped, no they did not comp our meal. Thank you for this opportunity to look back over my career in respiratory therapy. It has been good.

# High Flow Heliox Therapy vs Traditional Heliox Therapy

In this interview, Chris Benitez, RT Director, BSRT/RRT, Educator, Respiratory Care Services, reports his experience using high flow nasal cannula therapy (HFT) using helium-oxygen gas mixtures (heliox) versus their previous experience providing aerosol therapy by non-rebreather mask. Chris relates his first-hand experience with how the gas delivery was streamlined using the Vapotherm Precision Flow Heliox device using new specialized heliox cylinders and cylinder cart.

**Respiratory Therapy:** What was your old heliox set-up like?

**Chris Benitez:** We used a standard heliox tank from Praxair with the yoke. The hospital provided the regulator. Then Heliox was delivered via a non-rebreather mask at 11 lpm. Recently we were able to use a mask with a side port for Aerosol but this always resulted in confusion about what gas to drive the nebulizer with.

**RT:** Were there any challenges you and your staff experienced with that set-up?

**CB:** Recently we were able to use a mask with a side port for aerosol but this always resulted in confusion about what gas to drive the nebulizer. The other biggest issue was keeping the mask on the patient, finding a correct fitting mask. Issues also arose from needing to adjust Fio<sub>2</sub> since we were coming directly from a tank with no blender.

**RT:** How would you compare the Precision Flow Heliox HFT to CPAP/NIV by mask?

**CB:** We have never used CPAP/NIV with Heliox due to demand and number of Heliox tanks on site. However in considering HFT to CPAP/NIV the comfort and convenience factor of the HFT far outweigh CPAP if the patient's condition allows for heliox only and not a need of pressure.

**RT:** Can you tell us about a patient you have used the Precision Flow Heliox on clinically?

**CB:** Yes, this was an infant that was extubated in our pediatric ICU.

**RT:** What was the specific disease state?

**CB:** Patient was extubated, demonstrated stridor with suprasternal retractions. A racemic epinephrine aerosol was given, but still exhibited stridor with moderate retractions. We place 80/20 Heliox through the Vapotherm system using 8 lpm flow.

**RT:** How did the patient tolerate the treatment?

**CB:** Tolerance was very good.

**RT:** How does this differ from other methods of delivery you've given in the past?

**CB:** No comparison. The device allowed control of gas flow, Fio<sub>2</sub> and Heliox, along with temperature. Patient also tolerated the setup much better than the traditional non-rebreather mask.

**RT:** What were the end results?

**CB:** Patient was on Heliox heated high flow for about 8 hours.

**RT:** Were nebulizer treatments given inline?

**CB:** An additional racemic epinephrine was given using Aerogen device in-line.

**RT:** Do you feel the length of stay or need for intubation was affected by the use of PFH?

**CB:** I think it provided symptom relief and eased the work of breathing while the steroids took effect. I believe this allowed us to avoid a reintubation and lengthened therapy.

**RT:** Will you continue to order the use of this therapy in the future for patients requiring heliox?

**CB:** Yes.

**RT:** Are there any other disease states you've used high flow heliox therapy with positive results?

**CB:** It works very well for true croup patients as well. We have tried it on bronchiolitis and pneumonia patients, but with less success.

**RT:** Overall from a patient safety perspective, do you have any comments on Vapotherm's technology vs your legacy setups?

**CB:** Having a built in analyzer for Fio<sub>2</sub>, variable temperature control and accurate flow rates is important safety aspects for our patients. I also think the device reduces the amount of Heliox required to treat the patient.

**RT:** Has the use of the LCQ cylinders changed practice at your facility?

**CB:** We have ceased ordering the standard yoke 80/20 Heliox tanks. Having a pressure visible combined with not having to search for a regulator has resulted in increased efficiency

**RT:** How would you compare the Medipure cart to a cylinder dolly?

**CB:** We had a Medipure cart 2 tank system during the trial. RTs complained that it was too bulky for practical use so we did not keep the Medipure cart. The functionality of the cart itself regarding tank loading was great.

## Passy-Muir Valve Gives Patients a Voice

Gaylord Specialty Healthcare is one of Passy-Muir, Inc's Centers of Excellence for utilizing the Passy-Muir Valve as their standard of care for tracheostomized and mechanically ventilated patients. Gaylord Specialty Healthcare is a premier provider of long-term acute care hospital services. Gaylord's pulmonary program is a comprehensive program providing therapy and training for individuals with various respiratory conditions and diseases at both the inpatient and outpatient level of care. This program includes individual treatment sessions, as well as group pulmonary rehabilitation services.



**Respiratory Therapy:** What made you incorporate the Passy-Muir valve into your weaning and decannulation protocols?

**Peggy Bartram:** All patients should have a voice. We investigated and read studies which indicated that in-line Passy-Muir Valve (PMV) use can aid in weaning by strengthening the muscles associated with swallowing and the respiratory muscles. We also felt that enabling our patients to have a choice and communicate was essential to their weaning process. The biggest gain is the patient is able to interact during rounding with the physician and the care team.

**RT:** How did you go about the process to educate your staff on in-line application of the Passy-Muir Valve?

**PB:** We began the educational process by making January 2013 Passy-Muir month. We worked with clinical specialists from Passy Muir to provide every staff member with a one-hour live webinar reviewing in-line PMV use with our specific ventilator equipment (the Puritan Bennett 840). The format allowed staff to ask questions and receive feedback. We made this webinar mandatory for all staff. After the webinar, we began bedside observation of staff. We worked side-by-side putting the valve into use and providing pointers for success while answering any questions. As the supervisor and director of respiratory care, we worked collaboratively with our speech-language pathology supervisor, Kristine Provost, to re-write our PMV policy. The clinical specialist from Passy Muir reviewed this policy and provided feedback as we crafted it. The clinical specialist from Passy Muir visited Gaylord and educated staff and patients at the bedside. Passy Muir was wonderful in staff training, providing tips and hints to help transition patients seamlessly to a PMV.

**RT:** What is the value of including multiple disciplines in your approach to the care of tracheostomized and ventilated patients?

**PB:** Including multiple disciplines allows us to focus on the whole individual and helps to address all of the patient's needs. We meet weekly as a multidisciplinary team and discuss ventilator-weaning plans on all our vent patients. This allows the team to be aware of the barriers that other disciplines may have in their treatment and allows us to determine how this may be affecting the weaning process. Our weekly discussions allow us to problem-solve these barriers and then plan for decannulation and discharge. We have worked to ensure decannulations are done in a timely manner. This has positively affected our outcomes including length of stay.

**RT:** What advice would you provide to clinicians who want to implement the valve at their facility? What is the key to success?

**PB:** To implement the valve at their facility, getting staff buy-in is key. The bedside clinician needs to be educated on appropriate placement of the valve, understand the benefits, and advocate for its use. It is so important for an individual to be able to have a voice. The Passy-Muir Valve restores the patient's voice. It also works to strengthen the muscles of the throat and respiratory system, restoring the intrathoracic pressures seen with normal breathing.

**RT:** What patient and hospital outcomes have you realized after implementation of the valve into your weaning protocol?

**PB:** We have seen great weaning results in recent months with over 75% of our patients weaned in the last four consecutive months. This is well above the benchmark of 50% set by the National Association of Long Term Hospitals. We have seen a dramatic drop in our ventilator-associated pneumonia (VAP) rate and our decannulation rate. We have decannulated over 60 patients from May 1, 2013 to July 31, 2013. We have also seen an impact on the emotional well-being of our patients. They can speak to their caregivers to express their needs and communicate with their families. They go from feeling helpless to feeling empowered. Being able to give them this voice is a great experience. Every patient on the ventilator should be given the opportunity to see if the valve will work for them.

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Peggy Bartram is the Director of Respiratory Therapy at Gaylord.

# Hospital Benefits of Using the Neo-Tee®

In this feature, Respiratory Therapy interviews clinicians and healthcare providers about the actual application of specific products and therapies. Participating in the interview from Bryn Mawr Hospital: Kim Esposito, RRT-NPS, Clinical Coordinator Respiratory Care Department.

**Respiratory Therapy:** What areas/departments could the hospital benefit from using the Neo-Tee?

**Kim Esposito:** Pediatrics, NICU, Labor and Delivery, ER: These are all places that now would have a tool to deliver a safe preset constant PIP and PEEP when resuscitating.

**RT:** What device do you use as your primary resuscitation?

**KE:** Neo Puff but we supplement with Neo-Tee. We also use Neo-Tee solely in areas like ER and Peds where we do not have NeoPuffs.

**RT:** When a baby starts to spontaneously breathe, how do you deliver blow-by? (Control FiO<sub>2</sub>)

**KE:** With a continuous flow device like the Neo-Tee or NeoPuff.

**RT:** What do you do to reduce a baby's work of breathing?

**KE:** With the Neo-Tee we can easily deliver NCPAP until we get the baby to a unit.

**RT:** How does the Neo-Tee assist clinicians in providing better patient outcomes?

**KE:** It can be preset to deliver a preset PIP and PEEP, reducing the cognitive load in stressful situations. It can also help prevent the high pressures that contribute to BPD.

**RT:** What is a standard setting you use on the Neo-Tee for PIP and PEEP pressure?

**KE:** 25/5 flow of 12 is our starting point with blended gas at 21% FiO<sub>2</sub>.

**RT:** Could you share with us any specific incidents where Neo-Tee had a direct impact on patient outcomes?

**KE:** Yes, there was a case in the ER with a very small baby. It was a discharged preemie now back 4 days later with labored breathing and it was great to have this in the ED. It made transport easy and safe.

**RT:** What advantages do you see using Neo-Tee versus previous resuscitation devices?

**KE:** It is a continuous flow that allows you to have preset safety ready to go and it can do NCPAP.

**RT:** How has the manometer benefited you from a clinical standpoint?

**KE:** It's a must have. It guides you and lets you feel confident it is what you are delivering breath to breath.

**RT:** Many clinicians have stated that feeling "lung compliance" with a resuscitation bag is very important. What are your thoughts on this considering that Neo-Tee does not allow for the "feel"?

**KE:** It's true to some degree, but chest rise is key so looking at the chest during breath delivery is very important and the old mapelson required much more work and concentration (cognitive load) and in an untrained hand can cause damage to the lung. The feeling can sometimes distract you from looking at the chest rise as well. Neo-Tee is always safe and easy [because] it allows you to remain focused on the patient.

**RT:** Has the Neo-Tee prevented intubations that may have occurred by the use of other resuscitation devices? If so, how does this help support reducing healthcare costs? Can an actual dollar savings be applied to your facility?

**KE:** Hard to say. The Neo-Tee does help with the cost in other ways such as preventing lung damage, it is a more economical solution than the NeoPuff and is a more flexible tool.

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Input on questions was provided by Scott Horowitz of Mercury Medical. If you would like to participate in this feature, as a company or healthcare provider, please contact Christopher Hiscox or Steve Goldstien at [s.gold4@verizon.net](mailto:s.gold4@verizon.net).

# Experiences Using the EasyOne Pro in Pulmonary Function Tests

In this feature, Respiratory Therapy interviews clinicians and healthcare providers about the actual application of specific products and therapies. Participating in the interview from Providence Medical Center, Wayne Nebraska: Diane Thompson, CRT, Manager of Respiratory Therapy Department.

**Respiratory Therapy:** Can you tell us how you heard of the EasyOne Pro?

**Diane Thompson:** From a former colleague.

**RT:** Approximately how many tests per week were you sending out prior to the machine? How many are you doing now?

**DT:** Not necessarily sending out, but the facility had an antiquated machine and nurses did the testing mostly for the screening. We have tripled our numbers of tests due to respiratory therapists doing the testing, having pulmonologists coming routinely, and our local doctors getting more knowledge on how to use the results.

**RT:** How has the Pro had a financial impact on your facility?

**DT:** It's helped us increase the number of tests.

**RT:** What has the device provided to your patients? In terms of improving patient care?

**DT:** The device has provided us with comprehensive testing and the ability to be able to stay close to home for the patients.

**RT:** How have you been able to keep a better eye on your COPD and asthma patients?

**DT:** We've been able to compare patient results from the same machine.

**RT:** What was the deciding factor for choosing this unit?

**DT:** This unit is compact, portable, comprehensive, and easy to use.

**RT:** What would you like to highlight about the EasyOne Pro machine to others who are looking at PFT machines?

**DT:** The Pro is a nice, user-friendly and portable unit that allows our facility to do a complete pulmonary function test without our patients having to travel elsewhere.

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Input on questions was provided by Bianca Jacques of NDD. If you would like to participate in this feature, as a company or healthcare provider, please contact Christopher Hiscox or Steve Goldstien at [s.gold4@verizon.net](mailto:s.gold4@verizon.net).

# How Ventilator Data and Analytics Started Mission Regional Medical Center on a Journey of Continuous Quality Improvement: Variability Identified and Addressed

Susan Barlow, MHA, RRT-NPS, CPFT, CPHQ

In September 2012, the clinical leadership team at Mission Regional Medical Center worked to define an initiative to improve outcomes and reduce costs in mechanical ventilation. Shortly thereafter, early 2013, the National Healthcare Safety Network of the Centers for Disease Control and Prevention rolled out new expanded standards and definitions for ventilator-associated event (VAE) surveillance. This new requirement expanded our data collection and process improvement challenge. It became evident that we did not have the tools we needed to accomplish meaningful change.

We identified and implemented a new analytics system. This report identifies the initial impact of that system and the encouraging beginning of our quality improvement journey.

## Identification and implementation of new technology

Surveying the marketplace we identified the Respiratory Knowledge Portal as the best solution for our needs. The Respiratory Knowledge Portal (CareFusion, Yorba Linda CA) is a surveillance, analytics, and reporting tool that helps hospitals measure and reduce clinical process variability in ventilator therapy. The four areas of focus are ventilator weaning, lung protective strategies, alarm policy compliance and VAE surveillance. The CareFusion team helped us interface with our Avea ventilators and configure the Respiratory Knowledge Portal with our best-practice guidelines, so we could begin measuring and reporting. The rules in the Knowledge Portal are in the form of thresholds related to weaning, lung protection and alarm policy compliance. The VAE algorithm is programmed into the Respiratory Knowledge Portal and did not need to be configured.

## Weaning analytics

Weaning patients from the ventilator at the earliest possible moment is almost always in the patient's best interest, and it is a primary concern of respiratory care practitioners. In addition, mechanical ventilation is very costly. On average in the US, ventilator therapy costs hospitals \$2296 a day for the first three days and \$3917 a day after that.

At Mission Regional Medical Center, our goal was to reduce ventilator days through improved compliance with our weaning policies and protocols. The Respiratory Knowledge

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Susan Barlow is the Director of Cardiopulmonary Services at Mission Regional Medical Center in Mission Texas. She has extensive experience in clinical respiratory and cardiopulmonary care and management. She is also a certified healthcare quality professional (CPHQ). Since 1954, Mission Regional Medical Center, a nonprofit community hospital, has provided inpatient and outpatient acute medical care for the residents of Mission and the surrounding area, including parts of Mexico. Mission also experiences a large influx of seasonal patients during the winter months. Approximately 1,300 staff members serve at the 297-bed facility.

Portal provided us with detailed, actionable information. Over the course of an initial study of 96 patients between March 12 and July 2, 2013, we examined variability in the weaning process and found the data, in the aggregate, revealed many opportunities for improvement. The most striking opportunity was the delay between when a patient is identified as a possible candidate for weaning and when the patient experiences their first spontaneous breathing trial (SBT). As seen in Figure 1, variability was also evident. Also apparent in the figure is a reduction in variability and a trend towards more timely SBT. Over the 4 months the initiation of SBT's within 24 hours of meeting criteria increased from 27% to 96%. This exceeded our initial goal of 80% and our stretch goal of 95%. We intend to establish a higher benchmark focused on getting the time interval to 12 hours.

## Improving alarm policy compliance

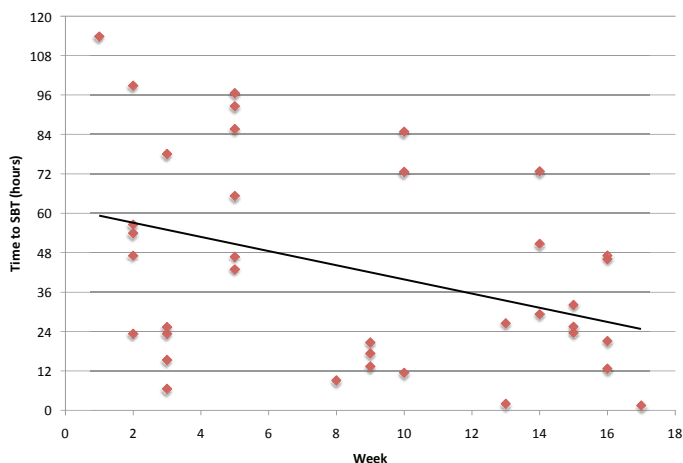
Mission Regional has also addressed compliance to its existing ventilator alarm policy. Hospitals face pressures from heightened emphasis by the Joint Commission to improve compliance with ventilator alarms response goals. Meaningful progress in this area is contingent on actionable data.

Initially, we found that compliance to setting alarms within policy thresholds was low. When reporting compliance did not improve the performance, we discovered that a key issue was that our alarm policies were not clearly defined. This resulted in great variability in clinician interpretation. We also learned that improvement is not a one-time event but a new way of doing things requiring constant reinforcement. This has resulted in an improvement in alarm policy compliance. This experience has also motivated new educational and awareness initiatives to sustain that change. According to A.J. Garcia, Jr., BSRC RRT-NPS, educator at Mission Regional Medical Center, the new program is valuable in fostering a culture of accountability dedicated to compliance with best practices. "Performance improvement must be tied to knowing you're being observed and measured," he said. "When we've got actual numbers to work with and can document improvement to the staff, it's much easier to secure buy-in and sustain it over the long haul."

## Lung protective strategies

The Knowledge Portal includes three types of thresholds and markers related to lung protective strategies. These are tidal volume/kg limit, plateau pressure limit and transpulmonary plateau pressure limit. We found that only about a quarter of patients were managed within our guideline. We have not seen marked improvement in management to these lung protective strategies. However the objective feedback has provided excellent opportunities for discussion and education, which will result in improvement over the longer term.





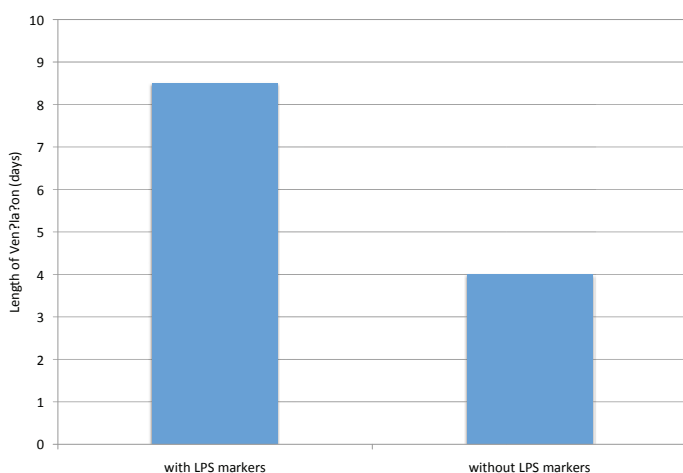
**Figure 1:** Hours from ready-to-wean marker to first spontaneous breathing trial. This graph displays the hours between patient identification by the Knowledge Portal as a weaning candidate and the patient’s first spontaneous breathing trial. Mission Regional was able to act on this data to achieve a dramatic improvement, which is depicted in the trend line.

In addition, we also found an interesting correlation between lung protection markers and length of stay (LOS) as shown in Figure 2. Those subjects managed within our guidelines spent less than half as many days on mechanical ventilation. This has helped us communicate the importance of these policies with physicians and staff, and we now have a renewed focus on improvement in this area.

### Conducting actionable VAE surveillance

The first reportable event in the new VAE algorithm is a ventilator-associated condition (VAC). VAC surveillance represents a big change for Respiratory and Infection Prevention because it requires us to collect the daily minimum values of PEEP and FiO<sub>2</sub> for every ventilator patient every day and apply the VAE algorithm to those values.

“The definition change also created a steep learning curve from infection prevention because we had to learn about new terms like PEEP and FiO<sub>2</sub> values and how they effect patients,”



**Figure 2** Increased ventilator days for patients who exceed lung protection markers. As this graph demonstrates, patients who exceed lung protection marker thresholds experienced increased time on mechanical ventilation as compared to patients who did not exceed lung protection markers. A lung protection marker is generated when the patient’s tidal volume/kg limit, plateau pressure limit or transpulmonary plateau pressure limit exceeds the configured set limits.

said Hector Contreras, MT (ASCP), CIC, Infection Prevention Manager for Mission Regional. “Without the Respiratory Knowledge Portal, this would have been overwhelming to try to collect and analyze all of this data.”

The VAE surveillance feature in the Respiratory Knowledge Portal automates the collection of this data and applies the VAE algorithm to it. This capability not only made it simple for us to see when changes to these variables occurred or met the reporting threshold, but also permitted interventions before a VAC occurred. This was the first time we were able to use data to be proactive versus retrospective in patient care.

“It was an eye-opening experience for us,” continued Contreras. “By being proactive, we are now better off in both outcomes surveillance and process surveillance. Now we deal with objective measures that can be automated to tell us which patients might be at risk for VAE, not just when one occurred.”

### Unexpected Cross-functional teamwork improvement

Perhaps the biggest change after implementing the Respiratory Knowledge Portal is the collaborative cross-functional relationships we have been able to foster.

The VAE dashboard has really enabled us to unite around the prevention of VAEs. When we have a ‘red arrow’ on the VAE dashboard indicating that a patient is at risk of a VAC, we get together with Nursing and Infection Prevention to help determine what is wrong and how we can address the issue before it becomes a reportable event.

“For the first time, we interact with respiratory care practitioners to ensure all measures are being taken to get the best outcome as we look at the data together,” said Contreras. “If outliers are identified or trends are noted in the aggregate data, the outcome surveillance shifts into a discussion of process surveillance. It’s a good tool to have a conversation with respiratory care practitioners in a timely manner when intervention can make a difference,” Contreras said.

An additional bonus of this project has been the effect the Respiratory Knowledge Portal data has had on our respiratory care practitioners. While this group was slightly hesitant at the outset, they have now fully embraced the Respiratory Knowledge Portal, and the data at their fingertips has enabled them to have more meaningful discussions with our physicians. The data makes it easier to have a constructive conversation with physicians when reviewing patient orders. The Knowledge Portal has heightened awareness that we are looking at metrics, and it helps us all speak the same clinical language.

### Conclusion

Mission Regional’s initial experience with continuous quality improvement for ventilated patients using the Respiratory Knowledge Portal has presented an exciting opportunity to improve outcomes for ventilator patients and to foster unprecedented cross-functional teamwork.

We have begun to instill a data-driven culture of accountability. This system allows us to be proactive and sets the stage for a new way of doing things. It gives respiratory care practitioners the information they need in order to have constructive conversations with physicians, so we can make even more of a difference.

# Comparison of the T-piece Resuscitator With Other Neonatal Manual Ventilation Devices: A Qualitative Review

CP Hawkes, CA Ryan, EM Dempsey

**AIM:** To review published literature regarding the use of a T-piece resuscitator (TPR) for neonatal resuscitation, with a focus on data comparing TPR with other manual ventilation devices (self-inflating bag [SIB] and flow-inflating bag [FIB]).

**DETAILS:** The proportion of infants requiring resuscitation at birth is approximately 5-10%. Three devices are currently recommended by neonatal resuscitation guidelines: SIB, FIB and TPR. TPR provides pressure-controlled, flow-delivered positive pressure ventilation, and modification of positive end-expiratory pressure (PEEP) is possible by rotating the PEEP valve. A number of different TPR devices are available, but data suggests that the most popular of these is Neopuff (Fisher & Paykel Healthcare); other options are Tom Thumb (Viamed) and Neotee (Mercury Medical).

A literature search was conducted using Medline (1966-2011), EMBASE (1986-2011) and the Cochrane Clinical Trial Register and fifty studies were identified. Thirty studies were included in the review, two studies were conducted in infants, 14 were simulated, one was an observational study and the 13 remaining used TPR without comparison. A number of primary and secondary endpoints were defined *a priori* including: mortality before discharge home, need for endotracheal intubation in the delivery room, incidence of bronchopulmonary dysplasia (primary determinants of efficacy), provision of predetermined positive inspiratory pressure (PIP), ability to provide predetermined PEEP, ability to alter both pressures during resuscitation, inspiratory time provided, ability to provide a prolonged inflation breath, ability to provide consistent targeted tidal volumes, mask leak and the effect of training on device use (secondary determinants of efficacy).

## Primary determinants of efficacy

Data from two studies were available. The first did not report any significant difference between TPR and SIB with respect to mortality, need for endotracheal intubation, need for respiratory support at 28 days and oxygen saturation at 5 minutes. The second study reported a 26% reduction in the incidence of chronic lung disease over a 3-year period following the introduction of Neopuff for delivery room management of infants with a birthweight of <1500g. However, the contribution of TPR to this decrease cannot be definitively determined because of the presence of too many confounding variables.

## Provision of predetermined PIP (15 studies)

Comparative collated data reported from 11 studies suggested

that Neopuff provided less variation in pressures than both SIB and FIB. In another comparative trial the percentage of pressures within the target range was substantially higher for Tom Thumb (89%) versus SIB (5%) and FIB (17%). At a target PIP of 20 cmH<sub>2</sub>O, percentage of breaths with a PIP <21 cmH<sub>2</sub>O and percentage of breaths with PIP >30 cmH<sub>2</sub>O were all significantly lower with Neopuff compared with SIB and FIB. PIP was shown to be flow dependent in a number of studies, while use of a commercially available gas flow restrictor (Flowtec Model HBD2) allowed the Neopuff to provide appropriate levels of PIP and PEEP without inadvertently delivering excessive pressures.

## Provision of predetermined PEEP (12 studies)

The comparison between Neopuff and both SIB (with and without a PEEP valve) and/or FIB in the 7 manikin studies was favorable. In the one study conducted in infants, PEEP was closer to the target with Neopuff than with SIB without a PEEP valve. PEEP was shown to increase as gas flow increased, although use of the PEEP valve could reduce the change in PEEP for the same increase in gas flow. In one study, the results suggested that the PEEP valve may be inadvertently turned during resuscitation. When the PEEP valve is fully occluded and the mask loosely at the infant's face, Neopuff can provide nearly 100% free flow oxygen.

## Ability to alter pressures during resuscitation (two studies)

The time taken to change pressure from 20 to 40 cmH<sub>2</sub>O during resuscitation was longer with Neopuff compared with SIB and FIB (5.7 sec vs. 2.2 and 1.8 sec, respectively). In a manikin study, Neopuff users did not respond to change in compliance during resuscitation whereas those using SIB increased PIP in response to reduced compliance.

## Inspiratory time (three studies)

Inspiratory time during Neopuff use has been reported to be decreased when the operator is distracted, to be significantly affected by operator experience, and to be slightly longer than that with SIB and FIB when the target was 60 inflations per minute.

## Prolonged inflation breaths (three studies)

The Neopuff provided more consistent prolonged inflation than SIB (in all three studies reporting this endpoint), and than FIB in two of the three studies. There was no difference reported between Neopuff and FIB in one study.

*Continued on page 28...*

# Volume Ventilation in the Neonatal Population

Edwin Coombs, MA RRT-NPS, ACCS, FAARC

Mechanical ventilation has improved to the point where few newborns die because of acute respiratory failure. Mortality now is predominantly from other complications of extreme prematurity, such as infection, necrotizing enterocolitis, and intracranial hemorrhage or congenital anomalies. As a result, much focus has shifted from reducing mortality to reducing the incidence of chronic lung disease. As a result of improved survival of extremely premature infants, chronic lung disease has increased in recent years. One focal point has been the improvements in neonatal respiratory support. Volume-targeted modalities of conventional ventilation allows for the effective control of delivered tidal volume for neonates.

Exceedingly high inspiratory pressures have been thought to be a chief contributing factor of lung injury. Pressure-limited, time-cycled, continuous flow ventilation has been the standard of care in neonatal ventilation for more than 30 years. One of the advantages cited for the preference for pressure-limited over volume-controlled ventilation has been the ability to directly control the inspiratory pressure. Over the past eight to ten years, a wealth of accumulating evidence shows that volume, rather than pressure, is the critical determinant of ventilator-induced lung injury.<sup>1</sup>

Dreyfuss and colleagues demonstrated as early as 1988 that severe acute lung injury occurred in animals ventilated with large tidal volume, regardless of whether that volume was generated by positive or negative inspiratory pressure. However, animals whose chest walls and diaphragmatic excursions were limited by external binding, but who were exposed to the same high inspiratory pressure, experienced much less lung damage. Results from this and other experiments clearly show that excessive tidal volume, not pressure per se, is chiefly responsible for lung injury.<sup>2,3</sup>

A second rationale for volume-targeted ventilation is the extensive body of evidence demonstrating hypocarbia as a potential contributor of neonatal brain injury. Despite clinician's awareness of the dangers of hypocarbia; inadvertent hyperventilation remains a common problem with pressure-

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limited ventilation, especially early in a patient's clinical course where lung compliance can be changing rapidly in response to clearing of lung fluid, surfactant administration, and optimization of lung volume.<sup>4,5,6</sup>

Volume Guarantee (VG) is a volume-targeted, time-cycled, pressure-limited form of ventilation that can be combined with any of the standard ventilator modes (assist control, synchronized intermittent mandatory ventilation, or pressure support ventilation). The operator chooses a target tidal volume and selects a pressure limit up to which the ventilator operating pressure (the working pressure) may be adjusted. The microprocessor compares the tidal volume of the previous breath, using exhaled tidal volume to minimize possible artifact due to air leak, and adjusts the working pressure up or down to try to achieve the set tidal volume. The algorithm limits the amount of pressure increase from one breath to the next to avoid overcorrection leading to excessive tidal volume.

This, and use of the exhaled tidal volume of the prior breath, means that very rapid changes in compliance or patient inspiratory effort requires several breaths to reach target tidal volume. To minimize the risk of excessively large tidal volume, the microprocessor opens the expiratory valve, terminating any additional pressure delivery if the delivered tidal volume exceeds 130% of the previous breath. By design, the Draeger algorithm is geared toward slower adjustment for low tidal volume and more rapid adjustment for excessive, potentially dangerous tidal volume.

As a result of the overwhelming evidence that excessive tidal volume, rather than high inspiratory pressure, is the primary determinant of lung injury, most clinicians now monitor the delivered tidal volume when using pressure-limited ventilation or volume-targeted ventilation. The critical importance of distributing the tidal volume evenly into an optimally aerated lung has not been as widely appreciated and requires attention at the bedside. If extensive atelectasis is allowed to persist, the normal physiologic tidal volume entering the small proportion of open alveoli inevitably leads to overexpansion of the relatively healthy portion of the lung, with subsequent volutrauma and/or biotrauma. The collapsed portion of the lung is also damaged known as atelectotrauma.<sup>7</sup>

The benefits of volume-targeted ventilation cannot be realized without ensuring that the tidal volume is distributed evenly throughout the lungs. In practical terms, optimization of lung

inflation, referred to as the “open lung concept,” is achieved by applying adequate positive end-expiratory pressure (PEEP). It is important to understand that there is no single “safe” PEEP level.<sup>8</sup>

Optimal end-expiratory pressure must be tailored to the degree of lung injury. For example, infants who have no lung disease and, thus, normal lung compliance, a PEEP of 3 cm H<sub>2</sub>O is probably appropriate, and a PEEP of 5 cm H<sub>2</sub>O may result in overexpansion of the lungs, with impairment of venous return, elevated cerebral venous and systemic venous pressures, and decreased cardiac output.<sup>8</sup>

Conversely, severely atelectatic, poorly compliant lungs may require PEEP levels as high as 8 to 10 cm H<sub>2</sub>O or more to achieve adequate lung volume and improve the ventilation/perfusion ratio.<sup>8</sup>

Volume Guarantee ventilation has led to more stable tidal volumes, with a lower incidence of hypocarbia and excessively large tidal volumes. When combined with other lung-protective strategies aimed at optimizing lung volume and ensuring even distribution of tidal volume, VG appears to offer a significant impact to minimize ventilator-induced lung injury. However, the development of chronic lung disease in extremely preterm infants is multi-factorial. The degree of prematurity and presence of intrauterine inflammation have a very significant effect that may minimize the impact of a protective ventilation strategy. Thus, it will be difficult to demonstrate substantial differences in various ventilation strategies specific to long-term outcomes.

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*Comparison of the T-piece...continued from page 26*

## Tidal volumes (eight studies)

The results of all eight comparative manikin studies reported that tidal volumes were lower and more stable during use of Neopuff versus SIB. In one infant study, TPR tended to provide a lower tidal volume than SIB in preterm infants born at <29 weeks' gestation. Delivery of tidal volume with Neopuff did not vary according to operator experience, but SIB inexperienced operators tended to provide a greater tidal volume than those who had more resuscitation experience.

## Mask leak (six studies)

Five studies comparing mask leak with TPR versus SIB reported lower mask leak during use of SIB; there was no difference between devices in one manikin study. During use of Neopuff, mask leak was greater with one operator than with two, availability of a manometer decreased mask leak, training in mask handling reduced mask leak, and mask leak increased at higher gas flow rates. One manikin study reported no difference in mouth leak between Neopuff, SIB and FIB.

## Training (six studies)

Data from three studies reported that operator experience had no effect on the PIP or tidal volume provided during Neopuff use. Operators who had used Neopuff infrequently had difficulty setting up the device, but could provide ventilation with an SIB without assistance. The level of operator experience had no effect on mean airway pressures or tidal volumes during Neopuff use, but inexperienced operators provided a longer inspiratory time whilst mean airway pressures and tidal volumes remained constant.

## Ongoing clinical trials (five studies)

Use of Neopuff in the delivery room is being investigated in three ongoing randomized controlled trials. Main outcome measures include the incidence of transient tachypnea of the newborn, need for mechanical ventilation and surfactant in very low birthweight infants, and establishment of functional residual capacity. Comparative studies are investigating Neopuff versus SIB, with and without a PEEP valve, in infants born at >26 weeks' gestation, and Neopuff then continuous positive airway pressure versus intermittent positive pressure ventilation in infants born at 27-33 weeks' gestation.

## Conclusion

Overall, there was insufficient data to allow accurate determination of the optimal manual resuscitation device for use in infants at birth. In general, though, TPR is good at providing PIPs close to the target with little variation and PEEP closer to predetermined targets compared with SIB and FIB. In addition, volutrauma appears to be less likely with TPR and inspiratory times are more consistent. However, it is more difficult for users to detect changes in compliance when using TPR for resuscitation, mask leak is higher for TPR versus SIB or FIB, and changes to gas flow during TPR have marked effects on PIP, PEEP and mask leak. In addition, the TPR is more difficult to set up and requires a higher level of operator training. The results of ongoing randomized clinical trials will help to determine whether TPR improves resuscitation outcomes and reduces morbidity compared with SIB, and whether TPR-associated sustained lung inflation is superior to SIB ventilation. Until these data become available it is recommended that healthcare providers are well trained to use the device of choice for their clinical practice, and have a good knowledge of its limitations.

# The Convergence of CPAP and Auto-CPAP Devices

Carlos Nanni, Product Manager, 3B Medical, Inc.

The migration from CPAP to Auto-CPAP devices is as expected as the migration from tube televisions to flat-panel televisions in consumer electronics. As technology evolved, flat-panel televisions with crisp resolution made the bulky sets with a fuzzy picture obsolete. The cost of flat-panel televisions steadily decreased from \$10,000 in the mid-1990s to \$5,000 in the 2000s. It was not until the FCC-mandated Digital Migration, the switch from analog to digital broadcasting, however, that the boom of flat-panel television sales happened. The reasons and arguments behind the FCC Digital Migration mandate aside, the end result has been the proliferation of flat-panel televisions in the consumer market. Today you can hardly walk into a home and not find a flat-panel digital television with screens 2 to 5 times the size of the old tube televisions at a fraction of the cost of the old technology. Prior to the FCC digital migration project, not only were flat-panel televisions pricy, the market had fewer vendors offering them. After FCC-mandated Digital Migration, the number of vendors offering flat-panel televisions exploded, and prices dropped to today's levels, making flat-panel televisions a staple in the average American home.

The HME/DME industry has been evolving since the first delivery to the first home patient was made possible by technology and the willingness of the patient or insurance program to pay for home medical equipment and services. Since the 1970s, leapfrog technology has advanced products and services being provided to patients in the home. Our reimbursement structure has also evolved from a needs-based, fee-for-service, freelance structure in the early years. IDC codes, HCPCS, LCDs, compliance and documentation requirements have been introduced. Today there are the additions of competitive bid programs and capitated and sole-source contract structures with both government and commercial insurance sectors.

Reimbursement pressures and ever-advancing technology combined with more aggressive intervention by healthcare professionals shifted costs from operating to capital costs based on utilization analysis. This shift might be called a reimbursement paradox. New capital-intensive technologies offer claims of lower operating costs or limited service needs to maintain profitability, but lower reimbursements have stifled implementation of capital-intensive solutions. In light of lower reimbursements, some technological advances have been made cost-prohibitive in areas, such as oxygen, where ambulation

costs make or break a respiratory DME operation. Patient population demographics and desired outcomes are driving technology solutions. The introduction of portable oxygen concentrators (POCs) and other Oxygen Generating Portable Equipment (OGPE) has offset the delivery costs of other modalities, such as Liquid Oxygen (LOX) and Compressed Gas Cylinders, but recent reimbursement cuts and the 36-month cap introduced during the 2005 Deficit Reduction Act (DRA) are an examples of the reimbursement paradox.

The market trends in oxygen offer a good example because all reimbursement changes impact the operational efficiencies and services offered by a respiratory DME and the outcomes of patients. To return to CPAP and Auto-Titration devices, it is undeniable that CPAP therapy is a life-changer for compliant patients. Several studies have documented the benefits of auto-adjusting CPAP devices over fixed-pressure devices: "During automatic therapy, patients reported more restful sleep, better quality sleep, less discomfort from pressure, and less trouble getting to sleep for both the first week of therapy and for the averaged scores for Weeks 2-6. Patients who require higher fixed CPAP use auto-titrating CPAP more and report greater benefit from this therapy."<sup>1</sup> It has also been shown that one reason for increased compliance with auto-adjusting versus fixed-pressure devices is a lower mean pressure.<sup>2</sup>

Increased compliance has important cost-saving potential. Several manufacturers and advocacy groups have sought special reimbursement codes. Auto-adjusting CPAPs and fixed-pressure CPAP devices continue to share the same coding, E0601, and are still reimbursed at the same rate, making the transition from fixed-pressure to auto-adjusting device difficult from an economic point of view. The reimbursement paradox disfavors the use of the auto-adjusting CPAP despite the long-term therapy and cost benefits.

It is an axiom in consumer electronics that each successive iteration of a new product results in improved performance and greater features at a lower price. That axiom has not held true, however, in the CPAP product space. While technology has progressed to the point where improvements in auto-adjusting technology exist, the industry continues to center on no-frills fixed-pressure devices in response to increasing economic challenges. From a production perspective, there is no cost savings in disabling available features in a CPAP device in order to market it at a lower price point. In other words, the industry artificially constructs product differentiation by increasing or

*Continued on page 39...*

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Juan "Carlos" Nanni is product manager at 3B Medical Inc. and has worked in the respiratory industry since 1996. He has also been a CPAP patient for the past 12 years.

# INOMax DS/DS<sub>IR</sub> Ventilator Validation List (US)

As of March 2012

The INOMax DS/DS<sub>IR</sub> is compatible with most types of ventilators by connecting into the inspired limb of a patient's breathing circuit. The system measures the gas flow in the breathing circuit and then injects NO/N<sub>2</sub> gas to produce the set NO concentration in ppm.

## Ventilator Compatibility.

	Measure	Specification
Inspiratory Flow Rate:	L/min	2-120
Respiratory Rate:	bpm	6-60
Airway Peak Pressure:	cmH <sub>2</sub> O	0-70
PEEP:	cmH <sub>2</sub> O	0-20

The INOMax DS/DS<sub>IR</sub> has been validated with the following ventilators.

Manufacturer	Model
<b>NEONATAL</b>	
Bear	750ps (Cub)
Bird	VIP
Dräger	Babylog 8000
Dräger	Evita
Dräger	Evita Babylog VN500
Dräger	Infinity V500
eVent Medical	Inspiration LS
GE Healthcare	Engström Carestation
Hamilton	C2
Hamilton	G5
Hamilton	Galileo
Infrasonics	Infant Star 500
Infrasonics	Infant Star 950 (not HFV mode)
Maquet (formerly Siemens)	Servo i
Newport	E360
Newport	Wave
Puritan Bennett	840
Respironics	Esprit
Sechrist	IV-100B
Viasys	Avea
Viasys	Vela
<b>Nasal Cannula Circuit*</b>	
Nasal Cannula	---
<b>Nasal CPAP</b>	
Cardinal Healthcare	AirLife nCPAP System
Fisher & Paykel	Bubble CPAP System
Hamilton	Arabella
Viasys	Infant Flow CPAP System
Viasys	Infant Flow SiPAP

Manufacturer	Model
<b>High Flow Nasal Cannula</b>	
Teleflex Medical	Comfort Flo Humidification System
VapoTherm	2000i
VapoTherm	Precision Flow
<b>High Frequency Ventilation</b>	
Bunnell	Life Pulse
Sensormedics	3100 A (standard and filtered circuits)
Sensormedics	3100B (standard and filtered circuits)
<b>ADULT/PEDIATRIC</b>	
Bird	VIP
Dräger	Evita
Dräger	Infinity V500
eVent Medical	Inspiration LS
GE Healthcare	Centiva/5
GE Healthcare	Engström Carestation
Hamilton	C2
Hamilton	G5
Hamilton	Galileo
Maquet (formerly Siemens)	Servo 300
Maquet (formerly Siemens)	Servo i
Newport	E360
Newport	HT50
Newport	Wave
Pulmonetic Systems	LTV 1000
Pulmonetic Systems	LTV 1200
Puritan Bennett	840
Puritan Bennett	7200
Respironics	Esprit
Viasys	Avea
Viasys	Vela
<b>TRANSPORT</b>	
Airon Corporation	pNeuton
BIO-MED Devices	Crossvent 2
BIO-MED Devices	Crossvent 4
BIO-MED Devices	MVP-10
Impact Instrumentation	EMV+
Impact Instrumentation	Uni-Vent
Infrasonics	Infant Star 100
Smiths Medical	babyPAC 100
Smiths Medical	paraPAC Medic 200D
Smiths Medical	ventiPAC 200D
<b>ANESTHESIA</b>	
Dräger	Narcomed 2B
GE Healthcare	Aespire 7100
GE Healthcare	Aespire 7900
GE Healthcare	Aestiva
GE Healthcare	Aisys
GE Healthcare	Avance
GE Healthcare	Excel SE 7800
GE Healthcare	Mod SE 7900

\*Instructions for use of the INOMax DS/DS<sub>IR</sub> with nasal cannula, masks, self-inflating bags and anesthesia bags, please see the instructions in the Patient Application Section of the Operation Manual.

# Patient-Experienced Effect of an Active Implementation of a Disease Management Program for COPD — a Randomized Trial

Margrethe Smidth, Frede Olesen, Morten Fenger-Grøn and Peter Vedsted

## Abstract

**Background:** People living with chronic disease currently account for the majority of the total healthcare costs. The Central Denmark Region implemented a disease management program (DMP) for chronic obstructive pulmonary disease (COPD) in 2008. This presented an opportunity to examine the effect of an evidence-based, planned and proactive implementation of a DMP compared to the usual implementation strategy.

**Methods:** We performed a block- and cluster-randomized controlled trial with two groups and an extra external control group. The primary outcome was patients' assessment of their care after using an active implementation model for a DMP for COPD measured with the Patient-Assessment-of-Chronic-Illness-Care (PACIC) instrument. At baseline, questionnaires were sent to 2,895 patients identified by an algorithm based on health registry data on lung-related contacts to the healthcare system. Patients were asked to confirm or refute their diagnosis of COPD. Of those who responded, 1,445 (72.8%) confirmed their diagnosis. PACIC data were collected at baseline and at a 12-month follow-up for 744 (51.1%) patients.

**Results:** Comparing the three groups after the implementation of the DMP, we found a statistically significantly higher change in the PACIC score in the intervention group than in the control groups. No statistically significant differences were found between the control and the external control groups in any of the dimensions.

**Conclusions:** Reinforcing the role of general practice as coordinator for care and self-management-support with an active implementation of a DMP for COPD made patients score higher on the PACIC instrument, which indicates a better experience of the received healthcare.

## Background

Shared decision-making in healthcare is becoming ever more important. Patients want healthcare professionals to include them in the decisions about their own health, and they want to be involved in the management of their own lives and diseases.<sup>1</sup>

The number of patients with chronic disease is growing as a result of inappropriate lifestyle, growing diagnostic activity, improved treatment options and increased life-expectancy.<sup>2</sup> Currently, about a quarter of the 5.6 million Danes<sup>3</sup> are living with one or more chronic diseases, and thus live with multimorbidity.

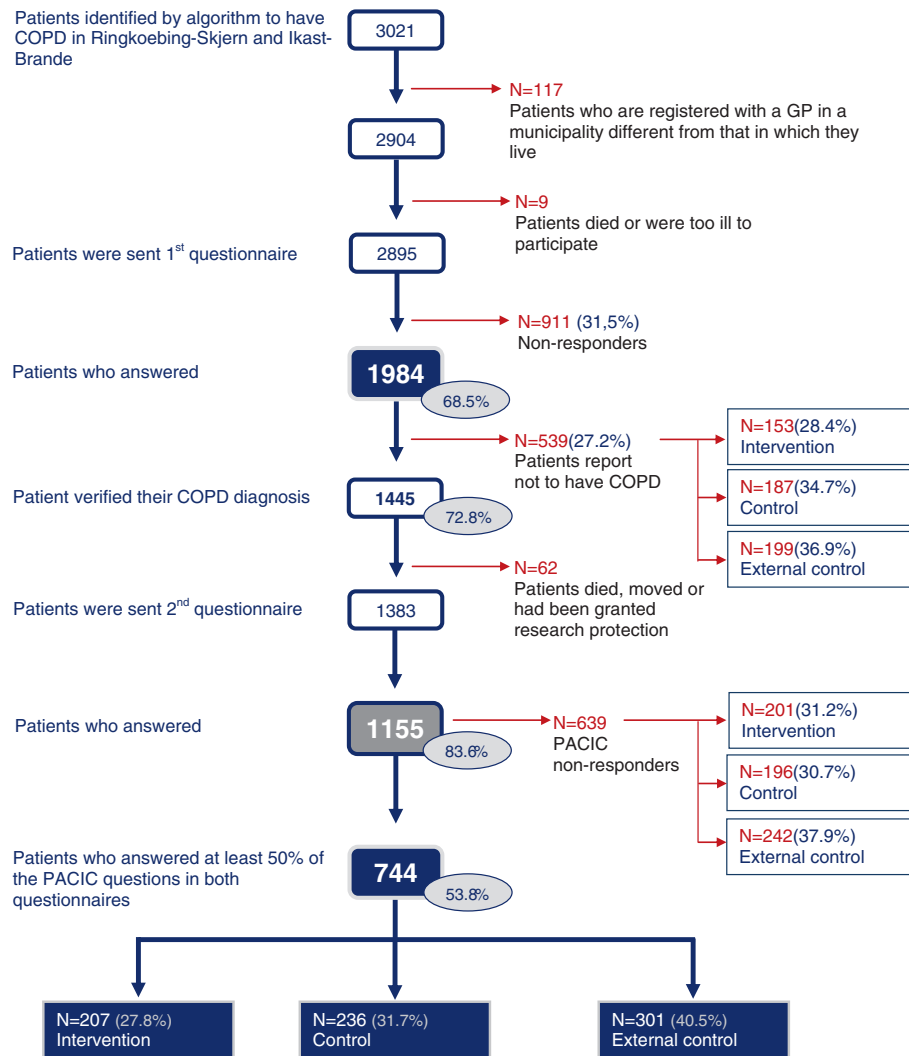
Patients with multimorbidity often spend much time and encounter many frustrations when they undergo specialized treatment as high-quality multidisciplinary care is often characterized by lack of communication and coordination between health professionals. Patients experience inadequate continuity of care and they face problems in accessing the health professionals they trust.<sup>4,6</sup> Health professionals often consider encounters with patients with multimorbidity demanding and they do not find it easy to delegate responsibility to other professions.<sup>7</sup> The recent rapid growth in technology and specialized treatment makes it feasible to centralize the settings for specialized treatment. Unfortunately, specialized treatment also paves the way for "silo thinking,"<sup>8-10</sup> and it is vital that care is tailored to the patients' needs and that treatment is professional, effective and non-fragmented.<sup>11</sup> People living with chronic diseases currently account for 70-80% of the total healthcare costs<sup>12</sup> and they are more frequently hospitalized than other patients, which is costly and may hamper patient-centred care. A framework for the concerted effort for the care for people living with multimorbidity is needed to give these patients an experience of a healthcare system that cooperates to provide the best possible care.

One such strategy is the Chronic Care Model (CCM), which has been successfully implemented in full or partly in different healthcare settings.<sup>13,14</sup> The CCM supports the provision of high-quality care where emphasis is placed on the continuity of care in a strong primary care sector<sup>15</sup> to ensure that patients are given the right care at the right place at the right time and with optimized use of resources;<sup>16</sup> such care should, moreover, be evidence-based, planned and proactive.<sup>13</sup>

It becomes important to ensure and support the implementation of such care. This was underpinned in a meta-analysis by Weingarten et al. who concluded that the studied interventions for disease management programs (DMPs) improved provider adherence and disease control and asked for future studies to directly compare different types of interventions and models for interventions.<sup>17</sup> Patient Assessment of Chronic Illness Care (PACIC) is a patient evaluation tool developed to measure

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**Figure 1 Flowchart.** Flowchart for inclusion of patients who scored at least 50% of the PACIC instrument in both the baseline and in the follow-up questionnaire a year after the active implementation of a disease management programme for COPD.

specific actions or qualities of care which patients report that they have experienced in the delivery system.<sup>18,19</sup> Glasgow et al. showed that greater exercise adherence and higher PACIC score<sup>19</sup> were linked for patients with diabetes and a cross-sectional study from the North American insurance company Kaiser Permanente where the CCM is fully implemented concluded that PACIC could be used as a tool for health systems to improve care for chronic diseases.<sup>20</sup>

Denmark (3.02 mill citizens who are 35 years old or older) is organized into five regions and 98 municipalities. Responsibility for rehabilitation and preventive services lie with the municipalities, and responsibility for the running of the hospitals and for the provision of service from general practice lies mainly with the regions.<sup>21</sup> Some of the key elements in the CCM model have come to Denmark in the sense that it has become mandatory to jointly plan care in cooperation between the regions and the municipalities healthcare.<sup>15,22</sup>

Chronic obstructive pulmonary disease (COPD) is an important chronic disease. Moreover, it is an under-diagnosed, irreversible and potentially life-threatening condition where secondary prevention, treatment and rehabilitation can help control the symptoms, increase the patient's quality of life and delay disease progression.<sup>23</sup> Newly published results indicate that 14.3% of

those who are 35 years or older have COPD;<sup>24</sup> and only approx. 28% of these have been diagnosed.<sup>25</sup>

A DMP for COPD was implemented in 2008 in the Central Denmark Region (720,000 citizens aged 35 years old or older) based on the CCM.<sup>23</sup> The program uses evidence-based clinical and organizational recommendations and is a manual on treatment, task distribution, communication and coordination between stakeholders,<sup>12</sup> which has been shown to improve care for chronic conditions.<sup>26</sup> The Central Denmark Region adopted the DMP as standard care for patients with COPD.

To be able to support the patients in assuming an active role in the management of their own illness, we need research-based information, and a recently published cross-sectional study from the Netherlands showed that patients with COPD became more satisfied with their care when a DMP had been implemented.<sup>27</sup> Therefore, we developed an active implementation model to test the active implementation compared to the usual implementation of DMPs.<sup>28</sup>

The aim of this paper is to present the effect of the previously developed active implementation model for a DMP for COPD on patients' assessment of their care.



**Table 1 Baseline data for patients as listed in the Danish health insurance service registry by 1 November 2008**

	Patients who confirmed that they had COPD			
	Intervention	Control	Ext. control	Total
<b>N (%)</b>	424 (29.3)	451 (31.2)	570 (39.4)	1445 (100)
<b>Men (%)</b>	206 (48.3)	217 (48.1)	284 (49.8)	707 (48.9)
<b>Female (%)</b>	218 (51.7)	234 (51.9)	286 (50.2)	738 (51.1)
<b>Mean age (min-max)</b>	68.3 (35–91)	66.5 (35–95)	67.2 (36–95)	67.3 (35–95)
	Patients who answered at least 50% of the PACIC questions in both questionnaires			
	Intervention	Control	Ext. control	Total
<b>n (%)</b>	207 (27.8)	236 (31.7)	301(40.5)	744 (100)
<b>Proportion of N (%)</b>	48.8	52.3	52.8	51.5
<b>Men (%)</b>	106 (51.2)	126 (53.4)	143 (47.8)	375 (46.6)
<b>Female (%)</b>	101 (48.8)	110 (46.6)	158 (52.2)	369 (53.4)
<b>Mean age (min-max)</b>	68.7 (39–91)	65.8 (35–89)	67.2 (36–90)	67.1 (35–91)

## Methods

### Study design

The study was a prospective, multicentre, block- and cluster-randomized controlled trial with intervention and control groups and an additional external control group to enable estimates of the extent of spillover effect of the intervention on the local control group.<sup>29,30</sup> The intervention group consisted of patients from a randomly selected half of the general practices in Ringkoebing-Skjern municipality in the Central Denmark Region. Patients from the other half of the practices formed the control group. Patients in a comparable neighboring municipality all formed the external control group.

A validated COPD algorithm<sup>31</sup> was used to identify the patients who were sent the baseline questionnaire at the start of the intervention. A year later responders to the baseline questionnaire who had confirmed their COPD diagnosis were sent a follow-up questionnaire. Both questionnaires included the PACIC instrument (see Figure 1).

The primary outcome was the patients' assessment of the care received after implementation of the DMP for COPD based on the CCM.<sup>23</sup> Patients' assessments were measured with the PACIC instrument,<sup>18</sup> which has been developed and validated in the United States to measure the quality of care experienced by the patients as far as the elements of the CCM were concerned; i.e. the community, the healthcare system, self-management support, delivery system design, decision support and clinical information systems. The instrument has been translated and validated within the Danish healthcare system.<sup>32</sup>

### Participants

The patient population comprised patients aged 35 years or older from the two municipalities; the patients had to be registered with a GP practice in their residing municipality and identified by the COPD algorithm<sup>31</sup> — where patients were identified from administrative data which indicated whether they had been hospitalized at least once with a lung-related diagnosis during the past five years and/or had redeemed a prescription for lung medication at least twice during the past year and/or had two spirometries performed on different days during the past year. Furthermore, the patients were the responders to the baseline questionnaire who had confirmed their COPD diagnosis and answered at least 50% of the questions in the PACIC instrument in both questionnaires. The patient population belonged to the

group to which their respective GP practices belonged.

The letter of invitation informed the patients about the consequences of their participation and their possibility to withdraw at any time without any consequences for their further treatment within the healthcare system. It was therefore considered equivalent to informed consent to participate in delivering data to the study when patients answered and returned the questionnaire.

### Setting

In Denmark, healthcare is free at the point of care and is tax-financed. The approx. 3,600 Danish GPs have an average of 1,600 patients on their list as approx. 99% of the population is registered with a GP. The GPs are independent contractors with the region and remunerated on a combination of fee-for-service and capitation basis (75/25). GPs act as gatekeepers, and the patients on the list must consult their GP in case of need for medical advice except for emergency room services and for some of the health-related services offered by the municipality.

Ringkoebing-Skjern municipality had approx. 58,000 inhabitants of whom approx. 35,000 were aged 35 or above, and the municipality had 38 GPs organized into 15 practices. The neighboring municipality (Ikast-Brande) had close to 40,000 inhabitants of whom approx. 24,000 were aged 35 or above, and this municipality had 25 GPs organized into 10 practices. All practices had staff that conducted parts of or the entire consultation on their own. The staff was employed by the GPs and was educated as nurses, laboratory technicians or secretaries.

### Intervention

The intervention practices undertook an active, structured implementation of a DMP for COPD.

The DMP from the Central Denmark Region<sup>23</sup> was based on the GOLD Guidelines<sup>12</sup> and the clinical guideline from The Danish Society for General Practice.<sup>33</sup> It uses evidence-based clinical and organizational recommendations and is a manual on treatment, task distribution, communication and coordination between stakeholders. The program includes i.a. smoking cessation, yearly follow-up, flu and bronchitis vaccination, advice on comorbidities, diet, exercise and end-of-life care.

**Table 2 PACIC scores**

<b>N = 744</b>	<b>Intervention N = 207</b>	<b>Control N = 236</b>	<b>External control N = 301</b>
<b>PACIC dimension 1 – Patient activation</b>	(203)	(230)	(298)
Baseline	2.39 [2.25;2.54]	2.31 [2.15;2.46]	2.27 [2.15;2.41]
Follow-up	2.48 [2.33;2.64]	2.22 [2.07;2.37]	2.11 [1.99;2.23]
Difference	0.09 [-0.06;0.23]	-0.07 [-0.22;0.08]	-0.16 [-0.28;-0.03]
Difference compared with Control	0.16 [0.05;0.37] p = 0.142	-	-
Difference compared with External control	0.25 [0.05;0.44] p = 0.013	0.09 [-0.10;0.28] p = 0.363	-
<b>PACIC dimension 2 – Delivery system design/decision support</b>	(206)	(233)	(299)
Baseline	2.78 [2.65;2.92]	2.76 [2.63;2.90]	2.67 [2.55;2.78]
Follow-up	2.86 [2.73;3.00]	2.63 [2.49;2.77]	2.53 [2.42;2.64]
Difference	0.07 [-0.05;0.19]	-0.12 [-0.25;0.02]	-0.13 [-0.24;-0.02]
Difference compared with Control	0.19 [0.00;0.37] p = 0.044	-	-
Difference compared with External control	0.20 [0.04;0.37] p = 0.018	0.01 [-0.16;0.19] p = 0.868	-
<b>PACIC dimension 3 – Goal setting</b>	(204)	(234)	(299)
Baseline	1.74 [1.62;1.89]	1.80 [1.69;1.92]	1.65 [1.55;1.75]
Follow-up	1.88 [1.76;2.00]	1.71 [1.60;1.81]	1.64 [1.55;1.73]
Difference	0.12 [0.01;0.23]	-0.08 [-0.19;0.02]	-0.01 [-0.09;0.08]
Difference compared with Control	0.20 [0.05;0.35] p = 0.009	-	-
Difference compared with External control	0.12 [-0.01;0.26] p = 0.071	-0.08 [-0.21;0.07] p = 0.260	-
<b>PACIC dimension 4 – Problem-solving/Contextual Counseling</b>	(204)	(231)	(296)
Baseline	2.26 [2.12;2.40]	2.22 [2.08;2.37]	2.05 [1.93;2.17]
Follow-up	2.33 [2.18;2.48]	2.13 [2.00;2.27]	2.00 [1.89;2.12]
Difference	0.06 [-0.07;0.18]	-0.05 [-0.18;0.08]	-0.06 [-0.16;0.05]
Difference compared with Control	0.11 [-0.08;0.29] p = 0.258	-	-
Difference compared with External control	0.11 [-0.05;0.28] p = 0.172	0.01 [-0.16;0.17] p = 0.929	-
<b>PACIC dimension 5 – Follow-up/Coordination</b>	(200)	(223)	(288)
Baseline	1.56 [1.45;1.66]	1.48 [1.40;1.56]	1.44 [1.36;1.51]
Follow-up	1.58 [1.48;1.67]	1.51 [1.42;1.60]	1.42 [1.35;1.49]
Difference	0.01 [-0.08;0.11]	0.03 [-0.05;0.12]	-0.05 [0.12;0.03]
Difference compared with Control	-0.02 [-0.15;-0.11] p = 0.760	-	-
Difference compared with External control	0.06 [-0.06;0.18] p = 0.343	0.08 [-0.04;0.20] p = 0.179	-
<b>PACIC Total – The overall score</b>	(207)	(236)	(301)
Baseline	2.05 [1.95;2.15]	2.02 [1.92;2.13]	1.92 [1.83;2.01]
Follow-up	2.14 [2.03;2.24]	1.97 [1.86;2.07]	1.87 [1.78;1.95]
Difference	0.08 [0.00;0.16]	-0.05 [-0.14;0.04]	-0.06 [-0.13;0.01]
Difference compared with Control	0.12 [0.00;0.25] p = 0.048	-	-
Difference compared with External control	0.14 [0.03;0.25] p = 0.014	0.01 [-0.10;0.13] p = 0.827	-

The mean PACIC scores for each dimension and the total score for each group recorded at baseline and at follow-up. The change in difference of means scores when comparing the control and external control group, respectively, with the intervention group is shown together with a comparison of change in mean scores between the control and external control groups.

The number of patients who have scored 50% of the dimension is shown for each group in brackets ().

The intervention is depicted in the Additional file 1; we have described the development of the intervention in detail elsewhere.<sup>25</sup> The intervention comprised components from the main areas of the CCM — Policies and Resources, Self-Management Support, Delivery System Design, Organization of Healthcare and Clinical Information System.<sup>34</sup> To stimulate the process, we asked a local, esteemed opinion leader to introduce and support the intervention<sup>35</sup> both to GPs and to the municipality.

Additional file 1. The PaTPlot depicting the timeline and the contents of the active implementation model. Squares illustrate fixed objects, e.g. printed materials like questionnaires. Circles illustrate that an activity was involved in the component, e.g. Continued Medical Education meetings.

The intervention practices were invited to participate in four two-and-a-half-hour sessions. The Breakthrough Series<sup>36</sup> was used as a framework for the implementation of planned and

targeted changes. All meetings were chaired by experts and experienced facilitators, who were all clinically educated and experienced in aiding change in practice. One facilitator (MS) visited each practice to explore and/or address challenges encountered in pursuing their goals.

We negotiated our implementation strategy with the municipality, which took active ownership by increasing the number of free COPD courses and smoking cessation courses. The region agreed on providing a special reimbursement to GPs for joint home visits together with the community nurse to newly discharged COPD patients.<sup>37</sup>

Targeted self-management support for patients to cope with exacerbations of the disease was an integral part of our strategy, and we developed an action card with advice to patients on management of sputum and exacerbations. The action card was based on the research by Robert Stockley.<sup>38</sup>

To provide family, friends and the patients themselves with more knowledge to improve their ability to cope with their disease, we designed a website with information about COPD including contact details to the municipality, patient support groups and the involved GPs.

The standard implementation of the DMP from the Central Denmark Region went ahead and thus also covered all the groups in our study.

## Randomisation and sample size

### *Randomisation and allocation concealment*

An independent researcher drew slips that were matched to an electronic record with all GP practices in the Ringkøbing-Skjern municipality. The allocation of both GPs and patients was open and known to GPs and researchers for the intervention and the control groups. The patients were not directly informed that their GP practice participated in the study. They simply received the questionnaires with a flyer, and posters were exhibited in the waiting area in the practice. The external control group was only known to the researchers. The practices were block-randomized using three blocks where the first block was solo-practices with two practices randomly allocated to the intervention group and three to the control group. The second block was practices with two GPs: two practices were in the intervention group and three in the control group. The third block was practices with three or more GPs: there were three practices in both the intervention and the control group. There were two solo-practices, three practices with two GPs and four with three or more GPs in the external control group.

Out of the nine invited intervention practices, seven accepted the invitation to participate. One practice with three GPs was allocated to the intervention group as one of the GPs was partly involved in the overall planning of the study. The two practices that declined the invitation were allocated to the control group as we wanted to examine the effectiveness of the intervention. In total, there were 17 GPs in the intervention group, 21 in the control group and 25 in the external control group.

### *Sample size*

The sample size calculations were based on the primary outcome for the expected changes and  $\alpha = 0.05$ ,  $\beta = 0.1$ , sampling 1:1 and a minimal, relevant difference of 10%. Approx. 10% of the patients with a chronic disease attended a yearly follow-up consultation;

and to ensure statistically power for a change to 20%, we needed to include 360 patients in each of the groups in the randomized controlled trial. For a minimal relevant difference of 10% from 50% to 60%, 1,400 patients needed to be included.

## Patients

The COPD algorithm<sup>31</sup> identified 3,021 patients for inclusion in the study. Of those, 2,895 were sent a baseline questionnaire (see Figure 1). Of the 1,445 patients (72.8% of the responders to the baseline questionnaire) who confirmed their diagnosis, 1,383 (69.7% of the baseline responders) were sent a follow-up questionnaire 12 months later. There were 228 (16.5%) non-responders to the follow-up questionnaire. PACIC scores were collected from the 744 (53.8%) patients who answered at least 50% of the PACIC questions in both the baseline and the follow-up questionnaire.

## Data collection

The PACIC tool includes 20 items in the following five scales: Dimension 1: Patient Activation (items 1-3). Dimension 2: Delivery System Design/Decision Support (items 4-6). Dimension 3: Goal Setting (items 7-11). Dimension 4: Problem-Solving/Contextual Counselling (items 12-15). Dimension 5: Follow-up/Coordination (items 16-20). Each scale is scored by averaging the items completed within that scale, and an overall PACIC score is scored by averaging scores across all 20 items. At least 50% of the items have to be answered to calculate a score. The PACIC was scored by summing participants' responses across all 20 items. Scores on the PACIC range from 1 to 5 with higher scores indicating a patient's perception of greater involvement in self-management and receipt of chronic care counselling in line with proactive care provided in line with the CCM.

In their paper on the process of translating and validating the PACIC into Danish, Maingal et al. found that it had good face validity and the internal validation endorsed the five proposed scales.<sup>32</sup> Scores were collected from the patients who had answered at least 50% of all the subscales in the PACIC instrument both at baseline and at follow-up.

## Analyses

To measure the effectiveness of the implementation, we used as-treated analysis, i.e. the practices actually participating in the intervention formed the intervention group. We also performed an intention-to-treat analysis as a sensibility analysis (i.e. the two practices that refused to be in the intervention group were analysed as intervention practices).

We compared the difference between the mean difference in change in scores for the corresponding pairwise comparisons between intervention, control and external control groups to eliminate any variation at baseline. Two-sample t-test was used to test the differences because the differences were normally distributed.

At baseline, responders and non-responders were compared in terms of gender and age. Responders with full follow-up and non-responders to the follow-up questionnaire were compared in terms of age and baseline PACIC scores for each scale and the total PACIC score using two-sample t-test. The distribution of gender was tested by Pearson's chi-square test.

We applied a significance level of 5%; and in connection with testing of the scales of PACIC, a Bonferroni level of 1% was

considered to account for multiple testing. Analyses were performed using STATA version 11.0. (StataCorp, College Station, Texas). The trial followed the consolidated standards of reporting trials guidelines.

## Ethics

The study was recommended by the Multi Practice Committee of the Danish Society of General Practitioners and the Association of Danish General Practitioners (MPU 17-2009) and approved by the Danish Data Protection Agency (J.nr. 2008-41-2855), the Danish National Board of Health (J. NR.: 7-604-04-2/71/EHE); and the RCT is indexed at <http://clinicaltrials.gov/show/NCT01228708>. According to the Scientific Ethics Committee for the Region of Central Jutland, the Biomedical Research Ethic Committee System Act did not apply to this project.

## Results

### Baseline characteristics

#### Patients

No gender differences between responders and non-responders were observed in the intervention group or in the external control group. The control group counted more men than women (59.7% men ( $p=0.007$ )). No statistically significant age difference between responders and non-responders was found in any of the groups. For the full study population, the responders' mean age was 67.1 years [95% CI: 66.4;67.9] vs. 66.6 years [95% CI: 65.7;67.6], ( $p=0.418$ ) for non-responders (see Table 1).

The difference in baseline score between the patients with follow-up and that of those with no follow-up was only statistically significantly different in the control group in regard to goal setting (dimension 3), where responders with follow-up had a baseline mean score of 1.79 [95% CI: 1.68;1.90] and non-responders one of 1.52 [95% CI: 1.34;1.70], ( $p=0.013$ ).

#### Outcome

Table 2 shows the baseline scores, the follow-up scores and the differences between the groups for PACIC. For all three groups, the mean scores for each of the scales and for the total PACIC score were all below 3, both at baseline and at follow-up (max. score is 5). The scores in the intervention group tended to be higher, though not statistically significantly so, than in both control groups at baseline (see Table 2).

In the intervention group, the total PACIC score rose from 2.06 to 2.14 (difference = 0.08 [95% CI: 0.00;0.16]), while a decrease of 0.05 [95% CI: -0.14;0.04] was seen in the control group. The implied intervention effect was 0.12 [95% CI: 0.00;0.25], ( $p=0.048$ ). The effect of the active implementation when comparing the intervention group and the external control group was 0.14 [95% CI: 0.03;0.25], ( $p=0.014$ ).

Comparison of the intervention group and the control group showed a change for the scales measuring delivery system design and decision support (dimension 2): 0.19 [95% CI: 0.00;0.37], ( $p=0.044$ ) and for the scale of goal setting (dimension 3): 0.20 [95% CI: 0.05;0.35], ( $p=0.009$ ).

No difference between the control and the external control group was observed for any of the scales. The only statistically significant difference between men and women was seen in the control group's goal setting scale (dimension 3), where men scored 1.83 [95% CI: 1.69;1.97] and women 1.60 [95% CI: 1.49;1.72], ( $p=0.016$ ).

Although these results were just significant according to the 1% Bonferroni level, together they point in the same direction just like the sensitivity analysis, where the intention-to-treat analysis showed approximately the same patterns as the as-treated analysis. A statistically significant difference in change was observed between the intervention group and the control group on the goal setting scale (dimension 3); the change in the total PACIC score between these two groups was 0.09 [95% CI: -0.03;0.21], ( $p=0.134$ ). The overall total PACIC score change between the intervention and the external control group was 0.11 [95% CI: 0.01;0.22], ( $p=0.038$ ) (data not shown but available).

## Discussion

In this randomized trial, we found a statistically significant change in the mean differences in the total PACIC score between the intervention group and on the one hand the control group, and the external control group on the other hand. The care received was thus given a higher score by patients in the intervention practices than by patients in the control groups.

The results show that the active intervention changed the way patients evaluated their overall care in general and patient activation, delivery system design and decision support and goal setting in particular. However, our results also showed no noteworthy changes for the two dimensions measuring problem-solving/contextual counselling and follow-up/coordination of care. This finding indicates that the implementation of the DMP did not affect the way health professionals support patients in dealing with the challenges of living with COPD and the way they interact with other healthcare providers involved in the patient's care. It is possible that it is simply too demanding for Danish health professionals to share care considerations both with other healthcare sites and with the patients themselves. This finding highlights a target area for future active implementation models designed to ensure further change in the care for patients living with COPD.

### Comparison with other studies

In a study from the Department of Veterans Affairs in the United States, patients evaluated their care higher if the care they received emphasised self-management, and this meant more for their evaluation than the severity of their disease.<sup>39</sup> In a Danish study where patients assessed the care in general practice using the DANPEP (Danish patients evaluate practice) instrument,<sup>40</sup> the patients were more likely to recommend their GP if the care they received was emphatic, patient-oriented, informative and coordinated than if it was easily accessible.<sup>41</sup> In these studies, the patients evaluated their care in one part of the healthcare system only, i.e. general practice. Several randomized controlled trials with complex interventions are being planned in different countries in which the PACIC will be used to measure the effect of the interventions on patients' assessment of their care from all sectors. One such example is the study by van Lieshout et al. who are planning to measure the effect of two strategies for patients with chronic heart failure using the PACIC.<sup>42</sup>

Other studies have used PACIC to illustrate how participation in a DMP affects patients' evaluation of their care compared to patients who are not in a program. In one such cluster-randomized study where the researchers administered the PACIC instrument over the telephone 18 months after having implemented a "Guided Care" program for multi-morbid older persons, the patients had twice as high odds for rating their chronic care highly if they had received the program than if

they had not.<sup>43</sup> The multi-morbid older persons scored higher on all PACIC scales, even when they were not receiving the “Guided Care”, than the intervention patients in our study did after the implementation. The same did patients with COPD in a Dutch study<sup>27</sup> which investigated whether patients enrolled in DMPs perceived the quality of care to be better than those who received the usual care. Compared to these two studies, the intervention patients in our study scored remarkably lower on the Follow-up/Coordination and the Goal setting dimensions, which may point in the direction where the active implementation model would benefit from a stronger focus in the future. Hence, no noteworthy change in these two dimensions was observed in our study.

In a different Dutch study conducted to assess if the care in primary care was congruent with the CCM, patients with cardiovascular disease and patients with COPD evaluated their care.<sup>44</sup> Again, their scores are higher than the scores for the intervention patients in the present study; and although the pattern for the scores is similar, the greatest difference is for the Follow-up/Coordination and the Goal setting dimensions.

### Strengths and limitations

The strength of our study is its randomized design and the inclusion of an external control group to assess the extent of Hawthorne bias and any spill-over effect. Hawthorne bias could arise if patients were happy that “something” was happening with their care and did not know what else the healthcare system could aspire to provide. This potential bias and any spill-over effect could explain why no statistically significant difference between the intervention group and the control group was found in the patient-activation scale, but the result from the external group makes this less probable.

The Danish version of the PACIC instrument was translated and validated in a population with diabetes and it was culturally adapted.<sup>32</sup> We chose to use the PACIC instrument among others because an Australian study concluded that it was a feasible instrument for comparing patients’ assessment of the quality of care in those situations where they interact with the healthcare system, especially where emphasis is given to self-management.<sup>45</sup> Furthermore, Vrijhoef concluded that the PACIC instrument is the most appropriate instrument among the existing generic instruments that measure patients’ experience of their integrated care for chronic conditions.<sup>46</sup>

A weakness of the present intervention, one that is present in most health services research, is that recruitment of patients for the courses covered the whole of Ringkoebing-Skjern municipality and not just the intervention practices. This is one of the obvious drawbacks of health services interventions and this bias would tend to underestimate the actual effect of the intervention.

We chose to only analyse those 53.8% of responders to the follow-up questionnaire who had answered at least 50% of all PACIC questions in both questionnaires. In no way can we reject that these 53.8% of the patients is a selected group who answered at least half instead of some or no PACIC questions at all, and they may not be representative of the full population. We were interested in making a comparison between groups, and the risk for selection connected to randomisation group — “double skewed drop-out” — is therefore considered to be minimal.

There were more men than women in the control group. This could introduce a bias as they might value specific parts of their care in other ways than women. Another bias could be that responders with follow-up scored higher than those without in the control group as far as goal setting was concerned; however, a lower score would only increase the size of the change; and since we compare the mean of the change, the difference would then become even more significant.

The trend towards higher baseline scores for the intervention group could imply that intervention practices already had increased their focus on the collaborative care for the patients with COPD. To assess the effect of the intervention, we used a difference-in-difference approach that captured the change in the mean of the difference between the baseline and the follow-up score whereby we eliminated differences at baseline by focusing only on the change between baseline and follow-up.

Despite our efforts to identify as many of the patients with COPD as possible, we were only able to identify those who had been in contact with the healthcare system where lung-related complaints had caused the healthcare system to take action. It would have been better if the International Coding System for Primary Care (ICPC-coding) had been implemented completely and validated in Danish general practice, which would have made it possible to include also milder degrees of COPD. However, that was not a possibility at the time of this study.

We chose to consider the two GP practices that declined to participate in the intervention as part of the control group because we wanted to examine the effectiveness of the active implementation and they would not be among the practices receiving any of the elements. These two practices were included in our sensibility analysis as intention-to-treat. The difference seen between the intervention group and the control group in the as-treated analysis and the absence of any difference in the intention-to-treat analysis suggests that a possible spill-over effect did not influence the patients’ evaluation.

We could have excluded the two practices that declined invitation. However, if the two practices were just two normal GP practices in Ringkoebing-Skjern, their exclusion would have decreased the statistical precision and this had weakened the conclusions of the randomized study.

### Conclusions

This study showed that patients gave a more positive evaluation of the care they received for their COPD after an active implementation of a DMP for COPD focusing on the GP’s role as a coordinator of the care and on self-management than after standard implementation of a DMP for COPD. Thus, the present study supports the idea of active implementation strategies when implementing new healthcare programs. The results of the PACIC assessment can also guide us in the direction of where the active implementation model could be improved, namely in the areas of problem solving and follow-up.

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*CPAP and Auto-CPAP...continued from page 29*

decreasing the feature/function sets of the devices at the expense of the patient.

Technology has advanced since the introduction of CPAP and Auto-CPAP technologies. Today's sleep therapy industry is on a similar path to that of flat-panel televisions and digital migration. Reimbursement has also decreased for diagnosis and therapy. CPAP therapy has fallen to new lows, not unlike portable oxygen devices. There are many advantages Auto-CPAP machines offer over traditional CPAP devices.<sup>3</sup> The monitoring, algorithms, and technology available in Auto-CPAPs offset the costs associated with traditional CPAP therapy devices.

Quality of life and operational efficiencies have to factor in the decisions healthcare professionals and insurance payers make in the diagnosis and therapy course for the population of OSA patients. Patient therapy pressure requirements can and often do change over time due to fluctuations in weight, age, and co-morbidities, just to name a few variables. Patient CPAP prescription pressure setting changes and compliance download requirements are two labor costs that are covered under the initial rental/purchase reimbursement period to the patient. These are costs all providers incur without additional reimbursement that could be mitigated by migrating to Auto-CPAP technology. With no additional reimbursement to DMEs for pressure setting changes, these costs are written off as cost of doing business. For example, the patient and machine need to be serviced for five years for Medicare providers and most commercial insurance payers. Compliance requirements must be met during the initial 90 days to receive continued coverage for services provided beyond initial set-up by most payers. It is a losing proposition for any provider not to have a compliant patient, since the first 90 days typically predict the success of patient compliance. Innovations like as easy breathing features, such as 3B/BMC's RESlex, have improved initial compliance, but improvement is needed for long-term therapy outcome.

Every home visit has an associated hidden cost. Auto-CPAP devices, like 3B/BMC's RESmart Auto-CPAP, can reduce the number of pressure corrections with an auto-titration algorithm. When combined with compliance connectivity software, like 3B/BMC's iCode and iCode Connect, Auto-CPAPs offer the best clinical outcomes at lowest cost for all parties involved.

It is inevitable that, as reimbursement pressures continue, the industry will move away from standard fixed-pressure CPAP devices towards auto-adjusting CPAP devices, which offer more features and functionality at lower prices.

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# General Practice Variation in Spirometry Testing Among Patients Receiving First-Time Prescriptions for Medication Targeting Obstructive Lung Disease in Denmark: A Population-Based Observational Study

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## Abstract

**Background:** Spirometry testing is essential to confirm an obstructive lung disease, but studies have reported that a large proportion of patients diagnosed with COPD or asthma have no history of spirometry testing. Also, it has been shown that many patients are prescribed medication for obstructive lung disease without a relevant diagnosis or spirometry test registered. General practice characteristics have been reported to influence diagnosis and management of several chronic diseases. However, these findings are inconsistent, and it is uncertain whether practice characteristics influence spirometry testing among patients receiving medication for obstructive lung disease. The aim of this study was therefore to examine if practice characteristics are associated with spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease.

**Methods:** A national register-based cohort study was performed. All patients over 18 years receiving first-time prescriptions for medication targeting obstructive lung disease in 2008 were identified and detailed patient-specific data on sociodemographic status and spirometry tests were extracted. Information on practice characteristics like number of doctors, number of patients per doctor, training practice status, as well as age and gender of the general practitioners was linked to each medication user.

**Results:** Partnership practices had a higher odds ratio (OR) of performing spirometry compared with single-handed practices (OR 1.24, CI 1.09-1.40). We found a significant association between increasing general practitioner age and decreasing spirometry testing. This tendency was most pronounced among partnership practices, where doctors over 65 years had the lowest odds of spirometry testing (OR 0.25, CI 0.10-0.61). Training practice status was significantly associated with spirometry testing among single-handed practices (OR 1.40, CI 1.10-1.79).

**Conclusion:** Some of the variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease was associated with practice

characteristics. This variation in performance may indicate a potential for quality improvement.

## Background

Spirometry is recommended for diagnosis and management of obstructive lung diseases like asthma and chronic obstructive pulmonary disease (COPD).<sup>1-3</sup> Spirometry testing is not only essential to confirm a diagnosis of obstructive lung disease, it also enables the general practitioner (GP) to rule out airway obstruction in patients with respiratory symptoms caused by other illnesses, such as heart failure or lung cancer.

Despite international guidelines recommendations, we confirmed that a large proportion of patients prescribed medication targeting obstructive lung diseases do not undergo spirometry testing.<sup>4</sup> Hence, these patients may be medicated without having airway obstruction and exposed to unnecessary economic costs and medication risks.<sup>5,6</sup> More important, when spirometry is not performed, patients may experience an unnecessary delay in the diagnostic process. In Denmark, the majority of patients with respiratory symptoms are diagnosed and managed in general practice. Spirometry has been shown to be both feasible and reliable in general practice,<sup>7</sup> but if preferred, GPs can also refer patients to spirometry testing at hospitals or outpatient clinics. Underutilization of spirometry when diagnosing obstructive lung disease is well known.<sup>8-11</sup> Patient characteristics like age and gender have been shown to influence spirometry testing<sup>4,11,12</sup> and accuracy of diagnosis.<sup>13</sup> Also, some doctor and practice characteristics have been shown to influence spirometry testing; unfamiliarity with conducting or interpreting spirometry tests and spirometry being too time-consuming are reported as barriers,<sup>14-17</sup> and practice characteristics like presence of a practice nurse and use of protocols have been reported to enhance spirometry testing.<sup>15</sup> Rural differences in spirometry testing have also been reported.<sup>18</sup>

Studies have reported practice characteristics such as practice size, organization in partnership or single-handed practices and having training practice status to influence diagnosis and management of other illnesses.<sup>19-21</sup> Doctor characteristics like age and gender have also been associated with different practice patterns.<sup>22,23</sup> However, we have not found studies assessing these factors association with spirometry testing. Identifying practice characteristics may have important implications for future organization of primary care services<sup>24</sup> and can help target interventions aiming to improve spirometry testing. The aim of

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MMK, RC, JS and DJ all participated in the design of the study. MMK and RC performed the statistical analysis. MMK drafted the first manuscript and all authors helped extensively revising the manuscript. All authors read and approved the final manuscript.



this study was therefore to examine if variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease is associated with specific practice characteristics.

## Methods

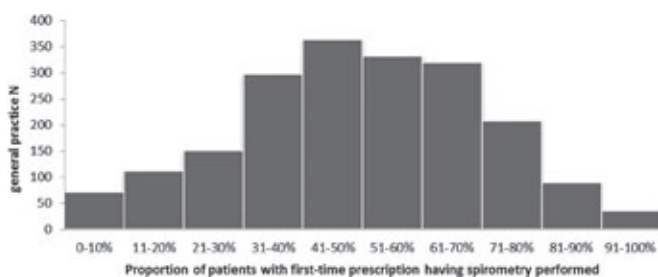
A register-based cohort study covering the entire population of 5.5 mill people and all general practices in Denmark (approx. 2400) was carried out. More than 98% of the population in Denmark is registered with a general practitioner, who provides primary care services, acts as a gatekeeper and refers patients to specialist care when needed. The health care system in Denmark is tax funded and patients have free access to all services related to general practice and hospital care, including spirometry.<sup>25</sup> All general practices have direct access to spirometry testing; either in their practice where the doctors can conduct these tests themselves or have practice staff conduct spirometry testing or the doctors can refer patients to spirometry testing at hospitals or outpatient clinics. From an earlier study we know that the majority of spirometry tests conducted among new medication users were performed in general practice.<sup>4</sup>

All Danish citizens are registered in the Danish Civil Registration System and assigned a unique personal identification number. Likewise, each general practice is also assigned a unique identification number and these identification numbers are used in all national registers, enabling accurate linkage between patients, health care services and general practice.<sup>26</sup>

This study links several national registers all maintained in Statistics Denmark, where researchers can apply for access.

## Study subjects

Patients were identified in the National Prescription Register. We identified all adults who were first-time users of medication targeting obstructive lung disease in 2008. Firstly, all patients who redeemed medication targeting obstructive lung disease, defined as the anatomical therapeutic chemical (ATC) code R03 in 2008, were identified. We then excluded patients who were either under 18 years of age on 1 January 2008 or who had previous records of prescriptions with ATC code R03 in the register (1995- 2007). All medication with ATC code R03 requires a prescription and registration is therefore complete. For each patient we identified whether they had redeemed R03 medication repeatedly within the first year and how many types of R03 medication they initiated within this first year. These two variables, “redeemed repeatedly” and “number of therapies”, were used as proxies for severity. Additionally, for each patient we retrieved 2008 data on socioeconomic and demographic status such as age, gender, income, highest attained education, labor market affiliation and cohabitation status.



**Figure 1.** Distribution of the spirometry proportion among general practice in total numbers (N=1980).

## Outcome — spirometry within the first year when initiating medication

All spirometry measurements registered in the time period 2007-2009 were extracted from the National Health Service Register, which covers primary care, and from the National Patient Register, which covers hospitals and outpatient clinics. These registers are administrative databases used for reimbursement and a prerequisite for reimbursement is that all services conducted, including spirometry testing, must be recorded in these registers. For each patient we assessed if spirometry was registered in an 18-month period counting from 6 months before to 12 months after the date of the first redemption of obstructive lung medication. All spirometric procedures were included, irrespective of whether they were performed in general practice, in an outpatient clinic, or in a hospital. The results from the spirometry tests were not available in the register.

## General practice

All data on general practice were extracted from the Danish National Health Service Provider Register. We extracted data covering the period July 2007-December 2009, corresponding to the absolute observation time of the cohort. A total of 428 practices were omitted due to missing data at the beginning or end of the time period, indicating that these practices were established or closed in this time period. A further 11 practices were omitted due to a small list size (<500 patients), because these practices are probably atypical and are not representative of general practice. For each general practice we identified the number of established doctors registered at each practice. Doctors not registered in the entire period were defined temporary doctors and were not considered to be in the established doctor group. Practices were defined single-handed practices if only one established doctor was registered, and partnership practices if two or more established doctors were registered. The majority of the temporary doctors in general practice were junior doctors having six months' residency in practice, and practices with these doctors listed in the time period were defined training practices. The number of patients per doctor was defined as the practice's patient list size divided by the number of established doctors. In single-handed practices the doctor's age and gender were extracted, in partnership practices we calculated the mean age of the established doctor group and assessed whether their gender was exclusively male or female, predominantly male or female or equally mixed. For each practice we calculated a “spirometry proportion” defined as the proportion of adult patients within the practice receiving first-time prescriptions for medication targeting obstructive lung disease who had spirometry performed in the 18-month interval.

## Statistical analysis

Practice characteristics are reported as categorical variables. For each practice characteristic we report the mean and standard deviation of the “spirometry proportion”.

We used mixed effects logistic regression models with patients nested within practice to calculate odds ratios (ORs) with 95% confidence intervals (CI) for the associations between practice characteristics and having spirometry performed. We used two models. Model one estimated the crude OR for each practice characteristic's association with spirometry testing, model two estimated the OR for each practice characteristic, adjusted for both patient characteristics and the other practice characteristics included in the analysis. Our primary analysis was model 2. Analyses comprised the entire cohort of general

**Table 1 Distribution of practice characteristics within the entire general practice cohort in absolute numbers (N); the mean and standard deviation of the variable “spirometry proportion”<sup>\*\*</sup> is reported for each practice characteristic**

		All general practices		Single-handed practices		Partnership practices	
		N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Partnership practice	Yes	773	54.4 (16.8)	-	-	773	54.4 (16.8)
	No	1207	48.6 (22.7)	1207	48.6 (22.7)	-	-
Training practice	Yes	566	53.7 (18.0)	239	53.8 (20.2)	327	53.7 (16.1)
	No	1414	49.7 (21.8)	968	47.3 (23.2)	446	54.8 (17.3)
No of doctors	1	1207	48.6 (22.8)	1207	48.6 (22.8)	-	-
	2	388	54.2 (18.7)	-	-	388	54.2 (18.7)
	3	213	53.4 (15.6)	-	-	213	53.4 (15.6)
	4	94	57.2 (13.2)	-	-	94	57.2 (13.2)
	5	52	54.5 (14.2)	-	-	52	54.5 (14.2)
	>5	23	55.0 (11.3)	-	-	23	55.0 (11.3)
Age (mean for partnership practices)	<45	106	56.0 (19.1)	67	52.2 (18.8)	39	62.5 (18.1)
	45–49	238	55.8 (18.1)	122	54.5 (20.0)	116	57.2 (15.8)
	50–54	516	54.2 (18.8)	228	52.4 (21.4)	288	55.7 (16.3)
	55–59	609	49.7 (20.9)	366	48.3 (23.3)	243	51.7 (16.4)
	60–64	390	46.4 (22.4)	314	45.9 (23.3)	76	50.4 (17.8)
	>65	121	41.2 (23.9)	110	40.7 (24.3)	11	46.6 (-)
Gender	Male	1017	49.4 (22.1)	873	48.7 (22.7)	144	53.4 (17.5)
	Predominantly male	189	54.4 (15.0)	-	-	189	54.4 (15.0)
	Equal male/female	283	54.9 (18.6)	-	-	283	54.9 (18.6)
	Predominantly female	98	54.3 (13.6)	-	-	98	54.3 (13.6)
	Female	393	49.2 (22.3)	334	48.3 (23.0)	59	54.0 (17.1)
Patients per doctor	<1347	513	49.8 (22.8)	227	43.9 (21.8)	286	54.4 (18.2)
	1347–1575	489	51.0 (19.8)	277	49.1 (21.8)	212	53.5 (16.4)
	1576–1756	489	52.3 (20.8)	307	49.9 (23.4)	182	56.5 (14.6)
	>1756	489	50.3 (19.7)	396	49.9 (20.3)	93	51.9 (17.0)

\*The “spirometry proportion” is defined as the proportion of adult patients within the practice receiving first-time prescriptions for medication targeting obstructive lung disease who had spirometry performed in the 18-month interval.

practices and were subsequently stratified into single-handed and partnership practices. This stratification was done for two reasons: firstly, we hypothesized that this important organizational factor could interact with other practice characteristics, and secondly, some of the variables like age and gender were average values in partnership practices, but precise values in single-handed practices, and separate analyses were needed. Patient characteristics adjusted for were age, gender, income, highest attained education, labor market affiliation, cohabitation status, number of therapies initiated in the first years and repeat prescription redemption. P-values < 0.05 were considered statistically significant associations. Finally, we conducted subgroup analyses of the association between practice characteristics and spirometry testing among two different subgroups of patients 1) patients over 45 years of age initiating at least two types of medication and redeeming medication repeatedly and 2) patients less than 45 years of age initiating only one type of medication. This was done to assess if the associations shown among practice characteristics in the overall group of patients receiving first-time prescription for medication targeting obstructive lung disease were also present in 1) a subgroup of patients where COPD is more common and 2) among younger patients with mono therapy. We also repeated all analyses including peak flow measurements conducted in the time period as peak flow measurements might have been used in asthma patients and this might influence some of associations seen.

All statistical analyses were carried out using STATA 11 (STATA Corp, College Station, TX, USA).

## Ethics

This project is register-based and according to “The Act on Research Ethics Review of Health Research Projects in Denmark” only questionnaire surveys and medical data-base research projects involving human biological material are required to be notified to the research ethics committee. The research ethics committee has, therefore, not been contacted. The study was approved by the Danish Data Protection Agency, J.nr. 2011-41-5798.

## Results

A total of 1980 practices and 35 677 patients were included in our analysis. Just about half of the patients had spirometry performed in the time period corresponding to 51.2% (18 263/35 677). Among general practices, the mean “spirometry proportion” was 50.8%. The distribution of the

“spirometry proportion” among general practice is illustrated in Figure 1 and it demonstrates quite a large variation between practices. An overview of practice characteristics and their mean “spirometry proportion” is shown in Table 1.

When comparing all general practices, partnership practices had a higher OR of performing spirometry compared with single-handed practices (OR 1.24, CI 1.09-1.40), Table 2. In all analyses we saw that increasing age among the group of established doctors decreased the odds of spirometry testing; in the analysis comparing all practices, the smallest OR was seen among doctors over 65 years (OR 0.33, CI 0.22-0.50). The most pronounced effect of doctors’ increasing age on spirometry was seen among partnership practices (OR 0.25, CI 0.10-0.61), Table 3. A test for trend showed a significant association between increasing GP age and decreasing spirometry testing. Being a training practice was significantly associated with spirometry testing among single-handed practices (OR 1.40, CI 1.10-1.79), Table 4. There was no significant association between the doctors’ gender or number of patients per doctor and having spirometry performed. Further, there was no significant association between number of doctors in a partnership practice and having spirometry performed. Both subgroup analyses demonstrated the same tendency in associations: an increased OR for spirometry testing was seen among partnership practices, practices with younger doctors and among single-handed practices with training practice status (data not shown). These associations were however, only statistically significant among patients over 45 years of age initiating at least two types of medication and redeeming medication repeatedly. Adding

**Table 2 Association between practice characteristics and spirometry testing among all practices**

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	1.20 (1.06–1.36)*	1.10 (0.97–1.25)
Single-handed practice		
Yes	1	1
No	1.34 (1.16–1.55)*	1.24 (1.09–1.40)*
Mean age of doctors (years)		
≤ 45	1	1
45–49	0.94 (0.74–1.19)	0.87 (0.66–1.14)
50–54	0.88 (0.70–1.09)	0.78 (0.60–1.00)
55–59	0.68 (0.53–0.87)*	0.58 (0.44–0.76)*
60–64	0.58 (0.43–0.79)*	0.52 (0.39–0.70)*
≥65	0.41 (0.27–0.64)*	0.33 (0.22–0.50)*

\*P-value < 0.05 \*\*Adjusted for patient factors and practice characteristics.

peak flow measurements to the analyses did not influence the associations significantly.

## Discussion

### Main findings

This study demonstrated that patients receiving first-time prescriptions for medication targeting obstructive lung disease had higher odds of having spirometry performed if their general practice was a partnership practice. All analysis confirmed decreasing spirometry testing with increasing age of doctors. Among single-handed practices, training practice status was associated with increased spirometry testing. These associations all had an OR above 1.23 or below 0.67 and were considered relevant associations.

### Strengths and limitations of this study

The register-based design has the major strength that it allows us to include the entire population and all established general practices in Denmark. The validity of the data in these national registries is considered high, as they are based on administrative data used for reimbursement in the health care system.<sup>27</sup> Due to this economic incentive, spirometry recording is quite complete, although a slight under- or over-recording cannot be entirely excluded. The low rate of spirometry testing is therefore mainly due to non-use and not to inconsistent recording. The registers do, however, not contain data on how the spirometry was conducted, and we cannot exclude some variation in the quality of these measurements.

The registries enable accurate linkage of detailed information on each practice and patient and make it possible to adjust for numerous patient factors, enhancing the possibility of isolating and assessing practice characteristics' influence on spirometry testing in our cohort. Nonetheless, it is important to remember that influence of patient characteristics cannot be entirely excluded; the registers cannot provide complete information on all sociodemographic patient characteristics.

Another challenge was that patient data could only be linked on the level of general practice, preventing us from identifying the doctor within the practice who is primarily responsible for each patient. This complicates the assessment of the influence of doctors' age and gender on spirometry testing when dealing

**Table 3 Association between practice characteristics and spirometry testing in partnership practices**

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	0.95 (0.84–1.08)	0.91 (0.79–1.04)
Mean age of doctors (years)		
≤ 45	1	1
45–49	0.72 (0.50–1.03)	0.66 (0.45–0.97)*
50–54	0.68 (0.47–0.98)*	0.61 (0.42–0.89)*
55–59	0.54 (0.34–0.86)*	0.45 (0.29–0.71)*
60–64	0.52 (0.31–0.86)*	0.43 (0.26–0.72)*
≥65	0.39 (0.17–0.90)*	0.25 (0.10–0.61)*
Number of doctors		
2	1	1
3	0.97 (0.84–1.13)	0.99 (0.77–1.27)
4	1.17 (0.95–1.45)	1.15 (0.90–1.45)
5	1.03 (0.82–1.30)	1.08 (0.77–1.51)
>5	1.05 (0.76–1.37)	1.03 (0.69–1.53)
Number of patients per doctor		
<1347	1	1
1347–1575	0.96 (0.82–1.12)	0.97 (0.82–1.15)
1576–1756	1.12 (0.94–1.34)	1.16 (0.96–1.34)
>1756	0.86 (0.69–1.07)	0.88 (0.70–1.11)
Gender of doctors		
Male	1	1
Predominantly male	1.05 (0.87–1.27)	0.99 (0.77–1.27)
Equal male/female	1.07 (0.89–1.29)	1.04 (0.85–1.28)
Predominantly female	1.05 (0.84–1.32)	0.94 (0.73–1.26)
Female	1.07 (0.81–1.42)	1.04 (0.76–1.42)

\*P-value < 0.05 \*\*Adjusted for patient factors and practice characteristics.

with partnership practices. Mean age of established doctors is a compromise and is not as informative as an individual doctor's age. Also, "patients per doctor", a proxy for workload, may be inaccurate, as doctors in Denmark can schedule their own work. General practitioners with few listed patients may work part-time and still have a high workload in practice.

Newly established and closing practices were excluded in these analyses, and it is important to remember that our data underrepresent these practices, but this was done deliberately. Firstly, forming and closing practices were quite unstable in the time period with regard to both number of doctors and number of patients, making categorisation quite difficult, and secondly, we hypothesized that forming and closing practices could confound our results in favor of larger practices.

Other potential influential variables could have been interesting to include in our study if they were available in our databases. The presence of a practice nurse and the practice's location (rural or urban area, distance to outpatient clinics) could influence spirometry testing and were very relevant to include in our study. However, the registers contain no data on employed staff in general practice, and the limited data on practice location were not adequate for assessing either rural or urban location or distance to relevant outpatient clinics.

Interpretation of findings in relation to previously published work Two studies tested if quality of care scores in asthma

**Table 4 Association between practice characteristics and spirometry testing in single-handed practices**

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	1.40 (1.06–1.87)*	1.40 (1.10–1.79)*
Age of doctor (years)		
≤ 45	1	1
45–49	1.11 (0.78–1.58)	1.09 (0.73–1.61)
50–54	0.99 (0.78–1.58)	0.96 (0.67–1.38)
55–59	0.79 (0.73–1.35)	0.71 (0.49–1.03)
60–64	0.69 (0.56–1.10)	0.64 (0.43–0.95)*
≥65	0.50 (0.28–0.89)*	0.44 (0.28–0.76)*
Number of patients		
<1347	1	1
1347–1575	1.29 (0.97–1.71)	1.26 (0.95–1.67)
1576–1756	1.30 (0.99–1.72)	1.21 (0.92–1.59)
>1756	1.35 (1.02–1.79)*	1.17 (0.90–1.51)
Gender of doctor		
Male	1	1
Female	0.98 (0.84–1.15)	0.93 (0.77–1.12)

\*P-value < 0.05 \*\*Adjusted for patient factors and practice characteristics.

patients were influenced by practice size, but found no association.<sup>28,29</sup> Other studies have found single-handed practices and small practice size to be associated with increased acute admission rates to hospitals for asthma, but not for COPD.<sup>30,31</sup> Our measure for practice size was divided into two variables: number of doctors and number of patients per doctor. When looking solely at the number of doctors, we found that single-handed practices had lower odds of performing spirometry compared to partnership practices in concordance with the above mentioned studies. Among partnership practices, however, there was no association between number of doctors and odds of spirometry testing, indicating that size of partnership practices was not associated with spirometry testing. Further, we found no association between number of patients per doctor and spirometry testing. Although partnership practices and larger practices have been associated with higher scores for quality of care in several chronic diseases,<sup>19,20</sup> studies are not consistent with regard to this issue, as the opposite has also been shown,<sup>32</sup> and it is interesting that patient satisfaction has been reported to be in favor of single-handed practices.<sup>33,34</sup>

Increasing age among doctors has been reported to be associated with decreasing quality of care scores in studies<sup>35,36</sup> and these findings are in concordance with our study, where we found a clear tendency between increasing age and decreasing OR for spirometry testing. Our study does not clarify why older doctors perform fewer spirometry tests in patients initiating medication, but general practitioners' age has been shown to influence clinical practice patterns, with older GPs providing more home visits, doing fewer procedures and having higher prescribing rates.<sup>22</sup> We found no association between GP gender and spirometry testing. Other studies have reported that when assessing quality scores, female physicians are more often

among high scorers and the majority of the lowest scoring physicians are men.<sup>35,37</sup> Specifically, female GPs have been reported to attain higher scores in evaluation of antenatal care and more often refer to bone mineral density testing.<sup>23,38</sup> We therefore hypothesized that female GPs performed more tests as shown by Ioannidis et al.,<sup>23</sup> but our data showed no indication of this pattern.

Training practices have also been shown to influence quality of care<sup>19,35</sup> and in our study we also saw this tendency, but only among single-handed practices. Why training practice status influences single-handed practices, but not partnership practices, is unknown, but we suggest that this difference in effect is due to a greater interaction between the single-handed practitioner and the resident doctor compared to the interaction seen in a partnership practice with several doctors.

Overall, we conclude that the variation in spirometry testing between practices was quite large and some of this variation can be associated with practice characteristics. Concluding whether the variation shown in spirometry testing is due to a variation in quality of care is more challenging. Although spirometry is essential for diagnosing obstructive lung disease and could therefore be used as a marker of good quality, it may not be relevant for all patients receiving first-time prescriptions for medication targeting obstructive lung disease to have spirometry performed. Among some patients it may be clinically meaningful not to conduct spirometry testing, for example among patients who are unable to cooperate sufficiently. However, the variations shown could indicate a potential room for quality improvement and further studies should be conducted to clarify this issue. Also, assessing changes in spirometry testing over time in general practice would be relevant, as improvements have been seen in outpatient clinics in recent years.<sup>39</sup>

## Conclusions

Some of the variations in the frequency of spirometry testing are associated with practice characteristics. Young age among doctors, being a partnership practice, or if a single-handed practice, being a training practice, were all factors associated with increased odds of performing spirometry when patients receive first-time prescriptions for medication targeting obstructive lung disease.

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# Hypersensitivity Pneumonitis: Lessons for Diagnosis and Treatment of a Rare Entity in Children

Matthias Griese, Melanie Haug, Dominik Hartl, Veronika Teusch, Judith Glöckner-Pagel, Frank Brasch and the National EAA Study Group

## Abstract

Hypersensitivity pneumonitis (HP) also called exogenous allergic alveolitis = extrinsic allergic alveolitis in children is an uncommon condition and may not be recognized and treated appropriately. To assess current means of diagnosis and therapy and compare this to recommendations, we used the Surveillance Unit for Rare Paediatric Disorders (ESPED) to identify incident cases of HP in Germany during 2005/6. In addition, cases of HP reported for reference from all over Germany to our center in the consecutive year were included. Twenty-three children with confirmed pediatric HP were identified. All (age 9.4 y (4.4-15.1) presented with dyspnoea at rest or with exercise, mean FVC was 39% of predicted, seven of the 23 children already had a chronic disease state at presentation. IgG against bird was elevated in 20, and against fungi in 15. Bronchoalveolar lavage was done in 18 subjects (41% lymphocytes, CD4/CD8 1.99), and lung biopsy in 6. Except 2, all children were treated with prolonged courses of systemic steroids. Outcome was not favorable in all cases.

Late diagnosis in up to a quarter of the children with HP and inappropriate steroid treatment must be overcome to improve management of HP. Inclusion of children with HP into international, web-based registry studies will help to study and follow up such rare lung diseases.

Keywords: Biopsy, Bronchoalveolar lavage, Children, Diffuse parenchymal lung diseases, Exogenous allergic alveolitis = extrinsic allergic alveolitis, Precipitins, Steroid treatment

## Introduction

Hypersensitivity pneumonitis (HP) — in Europe called extrinsic or exogenous allergic alveolitis (EAA) — is a complex syndrome incited by numerous inhaled agents including agricultural dusts, bio-aerosols, fungal-, bacterial- or protozoan microorganisms, and certain reactive chemicals. In children it is a relatively uncommon condition and the two major inciting allergens are bird (avian) allergens including down and inhaled particles derived from fungi, like thermophilic actinomycetes, or rarely fusarium,<sup>1</sup> aureo-basidium<sup>2,3</sup> and epicoccum.<sup>4</sup>

A previous NHLBI/ORD Workshop has summarized state of the

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The authors are with University of Munich, Member of the German Center for Lung Research, & the Department of Pediatrics. Reprinted from BioMedCentral, Multidisciplinary Respiratory Medicine 2013. This is an Open Access article distributed under the terms of the Creative Commons Attribution License.

art and the needs and opportunities for research in HP.<sup>5</sup> It was stated that because pediatric cases of HP are rarely recognized or reported, knowledge is limited and is based mostly on case reports and small series of patients. Between 1960 and 2005, 95 cases of HP in children have been reported in the literature.<sup>6,8</sup> In contrast to the data from adults, 95% of the cases were males and 25% had a family history of HP.<sup>5</sup> This hints to some reporting bias. The finding of clubbing in 31% (10/32) of the children, suggested that in the past the disease was recognized late in its clinical course. Importantly, as deaths from HP have been reported in children as well as adults,<sup>5,6</sup> treatment may be more difficult than anticipated. This is highlighted by the fact that 3% of the children were not treated with removal from the exposure. Also, treatment with corticosteroids is very controversial. In addition to oral long term therapy most frequently done (about 66%),<sup>5</sup> methylprednisolone pulse therapy<sup>9,10</sup> or inhaled budesonide<sup>11</sup> were suggested. Current recommendations in adults, as well as our personal practice in children, clearly suggest no steroid treatment at all, if possible.<sup>12</sup>

Due to its rarity, many pediatricians and general practitioners are likely not to be very familiar with the clinical presentation and diagnosis of HP, and many pediatric pulmonologists may not use up-to-date treatment. All these issues, including an unknown proportion of cases of interstitial lung disease in children which may represent undiagnosed HP, suggested that current information on the diagnosis and treatment of HP is warranted. We used a survey that we performed to determine the incidence of pediatric diffuse parenchymal lung diseases in Germany, to learn more about the current status of HP in children in Germany.<sup>13</sup> The goal of this study was to assess current means of diagnosis and therapy of HP, to compare this to the recommendations and to propose ways to improve future management with the help innovative strategies for rare lung diseases.

## Methods

### Study subjects and study design

The German Surveillance Unit for Rare Paediatric Disorders [Erhebungseinheit für seltene pädiatrische Erkrankungen in Deutschland (ESPED)] sends out monthly inquiries to all pediatric hospitals, to report specific conditions investigated prospectively. We used this system from 2005 to 2006 to monitor interstitial lung diseases;<sup>13</sup> the number of children under 17 years of age under surveillance was 14 393 400. The overall return rate was 97%, in case of a positive reply, a detailed questionnaire was sent to the reporting institution. We identified 11 children with

HP during this 2-year period. 12 additional children who were reported to us for reference in the following year 2007 from all over Germany were also included. Only newly diagnosed cases of pediatric HP were eligible for the study. The main study objective was to describe current diagnosis and treatment of HP and to compare this practice to recommendations.<sup>12</sup> The surveillance study and the retrospective analysis of the children with HP were approved by the local ethical committee (EK 355/04 and letter 2010-3-5) and written informed consent of the subjects and parents or legal guardians was obtained.

The surveillance study was prospective; retrieval of detailed information on verified cases was retrospective. Clinical information at diagnosis and from follow-up was collected from all subjects. Of the 23, 22 were old enough for lung function measurements, 17 underwent bronchoscopy including BAL with cytology, and 13 chest CTs were done. Diagnostic open lung biopsies were done in 6 of the patients. None of the patients were treated with systemic corticosteroids therapy at the time of the diagnosis. All children had definite diagnosis of HP, based on the criteria proposed by Schuyler et al. 1997.<sup>14</sup>

### Serum and bronchoalveolar lavage fluid analysis

In all children serum IgG level for fungal and bird allergens and in 17 children mycoplasma serology were determined and the results judged as normal or increased according to the appropriate lab reference values. BAL was performed during flexible bronchoscopy. Lavage sites were middle or lower lobes with no preference for radiological more affected areas. Four times 1 ml per kg body weight of sterile 0.9% saline solution were instilled and then aspirated.<sup>15</sup> The pooled fluid from 2<sup>nd</sup> to 4<sup>th</sup> aspirations were processed for differential cell counts, and stained according to May-Grünwald. In 7 children CD4+ and CD8+ lymphocytes were determined by flow cytometric investigation.

### Chest x-ray and CT scoring

We evaluated the radiographs and computed topographies (CT) of the chest from each patient independently and blinded, knowing nothing about the patients, the severity of their diseases, and the chronological sequences of the images. First we assessed the quality of the scans and differentiated between high-resolution and multi-slice CT examinations with or without contrast medium. Afterwards we evaluated on both modalities, if the hilar lymph nodes were enlarged (yes/no). Then we divided each lung into three parts. The apical zone was defined as the area from the apex of the lung to the tracheal bifurcation, the middle zone from the tracheal bifurcation to the lower pulmonary vein, and the inferior zone from the lower pulmonary vein to the diaphragm. For each zone on both sides we evaluated on every plain film as well as on each CT scan different pathologies with a scoring system. "0" meant, the pathology was absent, "1" represented mild changes, "2" stood for medium abnormalities, and "3" for massive findings. We scored presence and extent of linear, reticular, or nodular patterns, cysts, bronchiectasis, ground glass opacities, emphysema, and consolidations. The pathologies were defined according to the Fleischner society.<sup>16</sup>

### Lung biopsy

Individual slides of all surgical lung biopsy specimens were stained with hematoxylin and eosin, Prussian blue (iron stain), Periodic acid-Schiff reaction (PAS) stain (Glycogen, neutral mucopolysaccharides), and van Gieson's Stain

**Table 1 Baseline data of the 23 children with hypersensitivity pneumonitis included into the study**

Sex	9 male of 23 total
Age at 1 <sup>st</sup> visit (y)	9.8 ± 3
Time to diagnosis (mon)	1.3 ± 1
Initial presentation	
Chronic cough, dyspnoea at rest, cyanosis, clubbing	15, 13, 11, 3 of 23
Loss of weight per week until diagnosis (kg)	- 0.73 ± 0.49
Non-pulmonary diagnoses	Atopic eczema (2), Diabetes mellitus Type I (1), hyperthyroiditis, adipositas (4), house dust mite allergy (2), bronchial asthma (1), celiac disease (2), small stature (1), hypothyroidism (1), alopecia areata (1), enuresis nocturna (1), vitiligo (1), GERD and nissen fundoplication (1)
Serum measurements	
Elevated fungus IgG	17 of 23
Elevated bird IgG	21 of 23
Total IgG (fold upper limit)	1.2 ± 0.6
LDH i. S. (U/l)	352 ± 189
ACE i. S.(U/l)	53 ± 31
Positive serology for mycoplasma	9 of 17 assessed
Bronchoalveolar lavage measurements	Done in 17 children
Total cell count (/µl)	8800 ± 11017
Macrophages (%)	41 ± 25
Lymphocytes (%)	46 ± 26
Neutrophils (%)	13 ± 13
Eosinophils (%)	2.6 ± 2.1
CD4+/CD8+ (% Lymph)	36 ± 16/48 ± 25
CD4/CD8 Ratio	2.0 ± 2.8
Cultured bacteria	None
Mycoplasma/Chlamydia	7 negative of 7 assessed for PCR in BAL
Lung function measurement	Done in 22 children
FEV1 (% pred)	44 ± 21
FVC (% pred)	38 ± 15
MEF25 (% pred)	62 ± 45
DLC0cHb (% pred)	52 ± 28
SaO2 (%) Rest/exercise	93 ± 27/83 ± 40
pO2 (mmHg) Rest/exercise	64 ± 34/57 ± 20
pCO2 (mmHg) Rest/exercise	38 ± 20/34 ± 12
Lung biopsy	Done in 6 children

Data are given as absolute numbers or mean ± SD.

(which demonstrates differential staining of collagenized connective tissue, smooth muscle and elastic tissue) and were assessed in a blinded manner by a pediatric pathologist (FB). Furthermore, immunohistochemical stains for T-lymphocytes (CD3), B-lymphocytes (CD20), and macrophages (CD68) were performed.

## Diagnosis of HP

The diagnostic criteria for HP included a known exposure to an offending antigen, the presence of specific IgG antibodies in serum against the identified antigen, compatible clinical, radiographic, or physiologic findings, a bronchoalveolar lavage (BAL) with lymphocytosis and in some cases a histopathology showing poorly formed, non-caseating granulomas or mononuclear cell infiltrates.

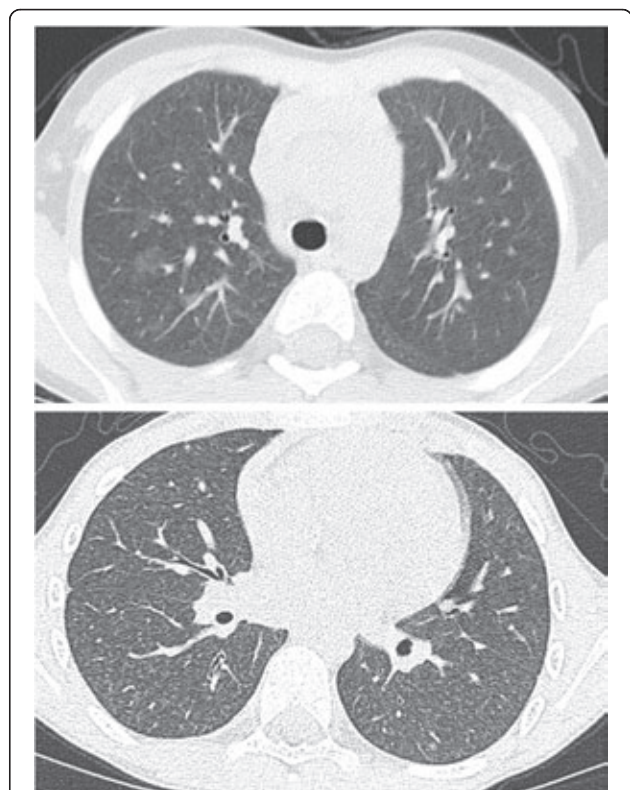
## Statistical analysis

The results are reported as mean  $\pm$  standard deviation (SD) or frequencies of patients expressing a particular feature or not. For comparison of the frequencies the Fisher exact test was used. A two sided p-value of  $< 0.05$  was considered significant. All individual data are available in the Additional file 1.

## Results

### Clinical presentation

During a period of 3 years 23 cases in children with the confirmed diagnosis of HP were collected from all over Germany. Mean age at diagnosis was 10 y. The children presented with acute (a, n=6; symptoms prompted assessments within days to one week), subacute (s, n=8; symptoms for at least one week, but less than 4 weeks duration), and chronic (c, n=9, symptoms for longer than 1 month) disease expression. The time to diagnosis after presentation to a physician was brief, however 3 of 23 children already had clubbing, suggesting that in some cases it may have taken more time to see a physician. The children were generally sick, with chronic cough, dyspnoea at rest, cyanosis, and a significant weight loss of up to 3 to 4 kg of body weight. The responsible antigen by history were bird



**Figure 1** HRCT findings of HP. Upper panel shows acute HP with ground-glass opacification more prominent on the right side, the lower panel shows diffuse micronodules and ground-glass attenuation in subacute HP.

or downy feathers alone in 16 of 23 cases, fungus alone in 3 of the 23 cases, both in 3 cases and in one the antigen could not be suggested from history (Table 1 and Additional file 1: Table S1).

### Laboratory results

In contrast to the type of exposure obtained from history, 15 children had elevated IgG antibodies against both, fungus and birds or downy feathers. Only 5 of the 15 children with a history suggestive of a reaction against birds or downy feathers had only these antibodies, and only 1 of the 3 with a history suggestive of fungus, had solely antibodies against fungus. Thus the specificity of elevated IgG antibodies is very low (Table 1 and Additional file 1: Table S2). Total serum IgG was not significantly elevated (expected mean 1.0, actual mean 1.18; discrepancy  $-0.18$ , 95% CI of discrepancy  $-0.026$  to  $0.38$ ,  $P=0.08$ , one sample t test). Of interest, in 16 of 23 children an atypical pneumonia was suspected and treated with macrolides or tetracycline, serology was positive for mycoplasma in 9 of 17 children tested, whereas PCR in BAL was negative in all tested cases.

### BAL results

Total cell count was elevated in some, but not all cases, whereas the cell differential showed a lymphocytosis in 91% (21 of 23). In 2 children neutrophilia was dominant, indicating the acute phase; in one of these lung biopsy confirmed the diagnosis of HP (Additional file 1: Table S3). The ratio of CD4/CD8 positive lymphocytes was elevated on average, however associated with a relatively large, well known scatter.<sup>8</sup>

### Lung function

All children had a severely restricted lung function at diagnosis (average FVC 38% of predicted), a reduced diffusion capacity for CO and a marked desaturation on exercise, however were normocapnic (Additional file 1: Table S4).

### Radiology

96% of the CT scans showed characteristic nodular opacities, 75% linear opacities, and 73% a ground glass pattern with increased attenuation (Figure 1). Except for reticular opacities, which were present in 63% of all cases, other abnormalities were much less frequent (Table 2). The chest x-rays were scored first and in a blinded manner. Unexpected the frequency of the abnormalities were comparable to those scored on the CT scans.

### Histology

In 6 of 23 children an open lung biopsy was done, as the diagnosis was not made on clinical and radiological grounds. Average age of diagnosis was not significantly lower than in the other children (Additional file 1: Table S3). In all patients, a mild to strong inflammation was found. Alveolar septal spaces were thickened by increased amounts of lymphocytes (Figure 2A) mainly T-lymphocytes (Figure 2C). Alveoli were variably filled with lymphocytes (Figure 2A), which were mainly T-lymphocytes (Figure 2E) and macrophages (Figure 2D). In three out of six cases loosely formed non-caseating histiocytic granulomas with multinucleated histiocytic giant cells (Figure 2B) were found. Furthermore a mild to strong bronchiolitis (Figure 2A) with many lymphocytes (mainly T-lymphocytes (Figure 2E)) and lymph follicles (mainly B-lymphocytes (Figure 2F)) in the bronchiolar wall as well as many intraepithelial lymphocytes (mainly T-lymphocytes (Figure 2E)) was found.

### Treatment and outcome

All children but one were hospitalized for prolonged times, the



**Table 2 Results of blinded, independent scoring by two specialized radiologists of 30 chest x rays films taken in 16 children and 13 CT scans taken in 13 different children**

Abnormality present	Chest x-ray (p.a.)		Chest CT	
	Yes/total scored	% positive (mean (range))	Yes/total scored	% positive (mean (range))
Hilar lymph nodes	6/30	20 (0–23)	2/13	12 (8–15)
Linear opacities	29/30	75 (53–97)	11/13	75 (65–85)
Reticular opacities	29/30	91 (85–97)	10/13	63 (50–77)
Nodular opacities	28/30	83 (73–93)	13/13	96 (92–100)
Cystic opacities	1/30	3 (2–3)	0/13	0 (0)
Bronchiectasis	5/30	10 (3–17)	1/13	8 (8–15)
Ground glass pattern, increased attenuation	24/30	72 (63–80)	10/13	73 (69–77)
Emphysema, reduced attenuation	0/30	0 (0)	0/13	0 (0)
Consolidation	4/30	12 (10–13)	0/13	10 (0–19)

The quality of the CT scans was judged as good in 9 cases, moderate in 3 and poor in 1. All were inspiratory scans, in four contrast medium was used, in six high resolution scans were available.

average stay being 16 days. During this time all except 3 of the 23 children, were treated with systemic steroids. Only two centers did not use steroids (Table 3 and Additional file 1: Table S5). The systemic steroids were tapered over prolonged periods, on average given for almost 4 months. About 50% of the children in addition received inhaled corticosteroids. Of interest, even initial allergen avoidance was not strict in all children. In these, as well as in those children with allergen re-exposure, a prolonged

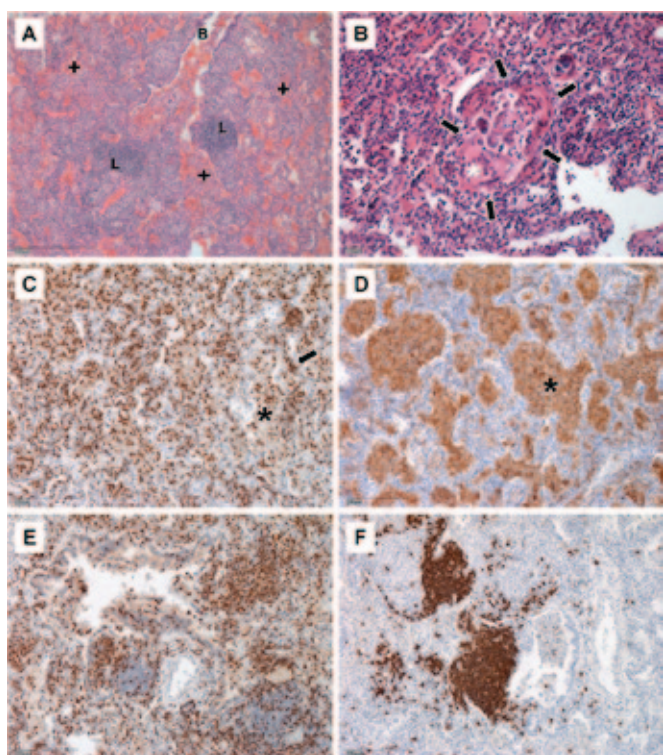
course was observed and in one child the course worsened during the follow up of about 1 year after the initial diagnosis.

## Discussion

From this work 3 main conclusions can be derived; (1) diagnosis of pediatric HP is frequently late, despite characteristic symptoms at presentation, (2) allergen avoidance as the principal treatment is not always followed very strictly, and (3) prolonged and high dose steroid treatment is often used.

Although HP is the most frequent chronic interstitial lung disease in children,<sup>13</sup> a quarter of the children with HP presented here and incident during a 3 y period in Germany, were diagnosed in chronic disease state. This together with the fact that lung biopsies were done at a relatively high frequency, suggests that some difficulties have to be overcome to diagnose this condition in childhood. All children, except one who was not measured, but was hypoxemic at rest (O<sub>2</sub>-saturation 80%), presented with a severely ( $\leq 65\%$  pred.) restricted lung function and almost all had reduced oxygen saturation at rest or with exercise (Additional file 1: Table S3). These findings are very characteristic for presenting HP,<sup>17</sup> nevertheless in 70% of the children an atypical pneumonia was diagnosed and empiric antibiotic treatment was started. Lung biopsy helped in all 6 instances when performed to substantiate the diagnosis and showed in all cases variable mural and luminal lymphocytic alveolitis as well as bronchiolitis, whereas loosely formed non-caseating histiocytic granulomata with multinucleated giant cells were found only in three cases; although in retrospect, diagnosis might have been possible from the combination of characteristic clinical features including the presence of serum precipitins, BAL lymphocytosis (except for 1 case), and FVC below 50% pred.

CT scans have recently been demonstrated to significantly contribute to the initial diagnosis of HP in adults, with specificity of 81%.<sup>5</sup> Their value in children has not yet been demonstrated. In this series in only 13 of 23 children CT's were done, i.e. a diagnosis was reached in more than 40% without a CT scan. In addition, a review of the CT scans obtained demonstrated studies of variable quality. Only 9 of 13 cases with CT had a quality judged as good, and the quality was moderate in 3 and poor in 1. Major reasons for the failure were artifacts from respiratory motion. As already proposed for adults, these results highlight the need for and compliance with standardized protocols.<sup>18</sup> The characteristic radiologic features known from



**Figure 2** The 3 typical findings of HP are 1. bronchiolitis, 2. alveolitis and 3. loosely formed non-caseating histiocytic granulomas. (A) shows bronchiolitis (B) with lymph follicles (L) and increased amounts of lymphocytes in the walls of the bronchiole and alveolitis (+). Figure 2(B) depicts a typical granuloma (arrows) with multinucleated histiocytic giant cells (\*). Immune histochemical stains for CD 3 confirm the presence of increased amounts of T cells in the alveoli (asterisk) and septi (arrow) (C), and stains CD68 the presence of macrophages in the alveoli (asterisk) (D). (E) demonstrates intraepithelial T lymphocytes in the bronchial epithelium and (F) aggregates of B lymphocytes (lymph follicles). Single scattered B lymphocytes were also found in alveolar septa and alveoli. Magnification is indicated by bar in each figure.

**Table 3 Treatment and follow up of the 23 children with hypersensitivity pneumonitis included into the study**

Empiric antibiotic therapy for suspected atypical pneumonia, response to this therapy	16 of 23 and 3 of 16
Allergen avoidance recommended and definitely eliminated	18 of 23
Initial stay in hospital (days)	16 ± 12
Systemic steroids	20 of 23
Dose of Prednisolone (mg/kg KG)	2 ± 0.5
Duration of taper (d)	119 ± 85
Inhaled steroids	11 of 23
Dose of budesonide equivalents (µg/d)	427 ± 271
Duration (weeks)	34 ± 22
Outcome	17 healthy 5 improved 1 worse
Follow up time (years)	1.1 ± 1.0

Data are given as absolute numbers or mean ± SD.

adult cases of HP were seen in these pediatric patients to similar extents.<sup>19</sup> Of interest was the high degree of concordance in the frequency of abnormal chest radiograph and CT findings. However it must be cautioned as only the chest CT findings “are characteristic” of HP.

The overwhelming majority of HP in the pediatric population is due to bird and fungus allergens; one of the challenges may be to identify alternative sources of these allergens, like fungus contaminated indoor hydroponics,<sup>3</sup> misting fountains,<sup>20</sup> basement showers<sup>4</sup> or possibly even wild city pigeons.<sup>21</sup> Up to 25% of the cases reported previously in the pediatric literature<sup>5</sup> and few additional case reports<sup>2,3,22</sup> were “familial” cases. Reasons may include (1) publication bias from preferring familial cases; (2) insensitivity of history to detect alone standing early disease, or (3) a higher likelihood for serologic testing in families with affected other members. Although common genetic predisposing factors may also be involved, they have not been demonstrated by now. Familiarity in the context of HP is most likely due to a common exposition to the antigens.

Identification of the responsible allergen is critical for avoidance and the causal and principal treatment.<sup>12</sup> Of interest, almost all children identified here were treated with systemic steroids. The advantage of such an approach is a more rapid therapeutic response with steroid treatment; however this introduces the impossibility to monitor the completeness of allergen avoidance measures. Lack of antigen avoidance and non-effectiveness of corticosteroid therapy results in pulmonary fibrosis and end-stage lung disease with death<sup>23</sup> or the need of lung transplant at young age.<sup>24</sup> Thus for treatment primarily careful allergen avoidance with associated clinical improvement is warranted. This proposition needs to be tested in a randomized controlled trial using steroids or placebo.

A weakness of the study may be that we recovered most, but not all incident cases, as one, published as a single case, and came to our attention during manuscript preparation.<sup>3</sup> Secondly, it is possible that some chronic forms might have been misdiagnosed as severe, steroid-resistant asthma.<sup>21</sup> Although there was a very high preponderance of male children (95%) in the pediatric cases

reported until 2005,<sup>5</sup> evened out sex ratios were demonstrated recently in a population based study.<sup>25</sup> Therefore the male to female ratio of 9/14 found in the present study, suggests an almost homogenous sampling. Lastly, long-term follow up was not possible with the design of the study, based on the German Surveillance Unit which is not prepared for longitudinal follow up. This can be achieved with register studies.

Among the strengths of the study is the relatively large cohort of contemporary and newly detected pediatric HP cases collected over a brief period of time. The observed current approach to diagnosis and therapy clearly demonstrates that the index of suspicion for HP needs to be increased substantially and that an early diagnosis must be established by much more quality controlled assessment of the clinical, radiological and laboratory findings. In particular, allergen avoidance is key for management. The role of corticoids which are generally used needs to be defined in prospective clinical trials.

These issues are surpassingly suited to be assessed in an international study of this rare entity. Capture and long-term follow up of the widely scattered cases of HP in children occurring in remote places can be easily overcome by web-based studies within rare disease registries ([www.kids-lung-register.eu](http://www.kids-lung-register.eu)). As such, the recently funded proposal “Orphans Unite: chILD better together — European Management Platform for Childhood Interstitial Lung Diseases” ([www.childeu.net](http://www.childeu.net)) under the FP7 program will provide an excellent base for this important task.

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*Continued on page 58...*

# Airway Pressure Release Ventilation (APRV)

## Part I of II: Building a Better (Safer) Mechanical Breath

A foundation of medical care is to have evidence regarding the therapies we apply; the patient outcome is always the gold standard benefit supporting any given intervention.

Mechanical ventilation is a life-saving intervention and has become the cornerstone of the practice of critical care medicine. Studies have shown that clinicians tend to select the mode of mechanical ventilation based on tradition or habit, rather than on evidence-based thinking. Many intensive care units seem to have arrived at the unfortunate conclusion of “one mode fits all.” Nothing could be further from the truth.

A mechanical ventilation mode describes the predetermined pattern of patient ventilator interaction. Because there are several mechanical ventilatory modes to choose from, we must have a rational evidence-based framework for selecting the best mode of mechanical ventilation for each patient care scenario.

A well-educated respiratory therapist can provide enormous clinical value when assisting the physician in developing a rational evidence-based framework for selecting the best mode of mechanical ventilation.

### Three Goals of Mechanical Ventilation

The clinical goals of mechanical ventilation may be simplified into 3 broad categories:

- provision of patient comfort
- promotion of liberation from mechanical ventilation
- safely promoting alveolar gas exchange and alveolar ventilation

Patient comfort is provided by fostering patient-ventilator synchrony. Liberation is promoted by the optimization of the weaning experience. Safety is achieved by optimizing alveolar gas volume and the matching of ventilation and perfusion while remaining in the safe airway pressure zone. This optimization is accomplished by matching the technological capacity and advantages of a particular mode to achieving these specific goals. To optimize gas exchange means not only to ensure adequate alveolar volume and ventilation-perfusion matching, but to

achieve the greatest alveolar volume (ventilation) for the least cost in terms of increasing intrathoracic pressure. The cost of this increased intrathoracic pressure would include decreasing local pulmonary perfusion and decreasing overall cardiac output. We now understand that unsafe ventilatory strategies may lead to ventilator-induced lung injury (VILI) and may adversely affect morbidity and mortality. Therefore, this paper will have two purposes; first will be assisting the respiratory therapist when selecting the best mode to safely optimize alveolar gas volume and alveolar ventilation. Secondly, the information presented is designed to assist the respiratory therapist in understanding the vital role the APRV mode can play in the treatment of hypoxemic respiratory failure (HRF) due to ARDS and ALI.

### Do No Harm

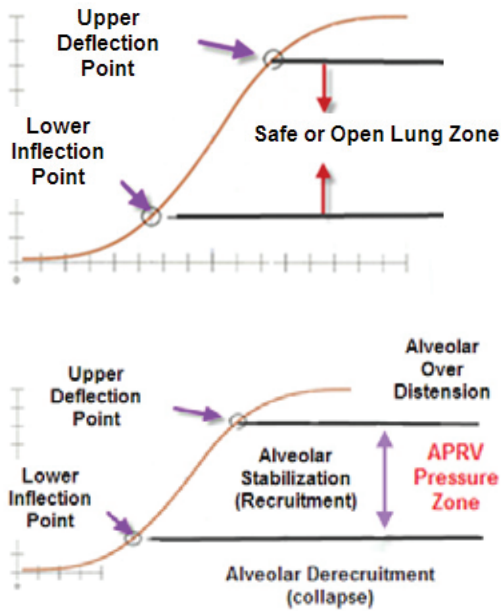
The first and most important rule of mechanical ventilation should always be to do no harm. When treating hypoxemic respiratory failure, ARDS / ALI the ventilator strategies we choose may impact patient survival. This is best illustrated by the ARDS net studies which showed significantly lower mortality and less ventilator days when using lower tidal volumes.

### Protective Lung Strategies

We now know that ventilating patients with lower tidal volumes dramatically reduces the incidence of ventilator-induced lung injury (VILI). Today, the goal is to employ protective lung strategies where the patient is ventilated in the safe lung zone (also referred to as open lung strategy). The safe zone is the pressure between the lower inflection (LIP) which represents the point of alveolar recruitment and the upper deflection point (UDP), any applied airway pressure above this UDP point may result in alveolar over distension. See the illustration below.

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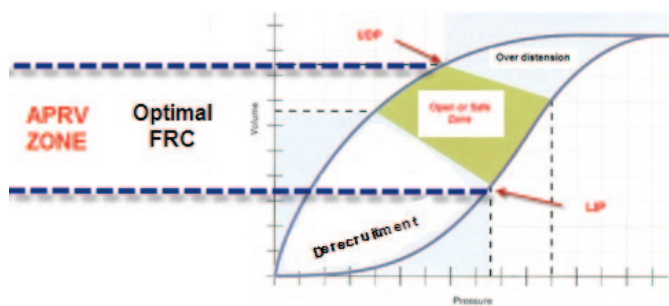
This was written by Kennard Chandler, who is solely responsible for its content. This project would not have been possible without the suggestions of many of the respiratory therapy staff at Manatee Memorial. The author is indebted to ICON for their unwavering support and guidance. ICON also supplied and/or suggested many of the graphic ideas used in this paper.



The above pressure-volume curves are identical. The vertical axis represents pressure and the horizontal axis represents volume. The uppermost pressure-volume curve shows the upper and lower pressure limits of the “Safe Lung Zone.” The volume-pressure curve underneath demonstrates the alveolar collapse, recruitment and over distension models seen in ARDS. Note that the APRV operating pressure remains in the safe pressure zone at all times.

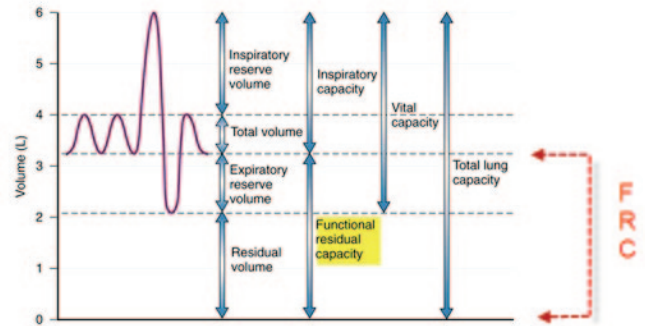
Looking at the volume-pressure illustrations above, you can see one purple arrow pointing to the lower inflection point (LIP). This is the alveolar critical opening pressure where alveolar recruitment is accomplished. When treating HRF due to ARDS / ALI allowing the airway pressure to fall below the LIP may result in alveolar collapse and loss of end-expiratory volume or FRC. In conventional modes such as SIMV and CMV, maintaining end-expiratory alveolar stability and volume is the function of the amount of the positive-end expiratory pressure (PEEP) that is applied. Maintaining alveolar stability using a conventional mode and PEEP in the face of HRF / ARDS / ALI may be impractical or impossible because of the very high PEEP levels required to prevent end-expiratory alveolar collapse.

The other purple arrow is pointing to the upper deflection point (UDP). Exceeding this point may result in alveolar over distension.



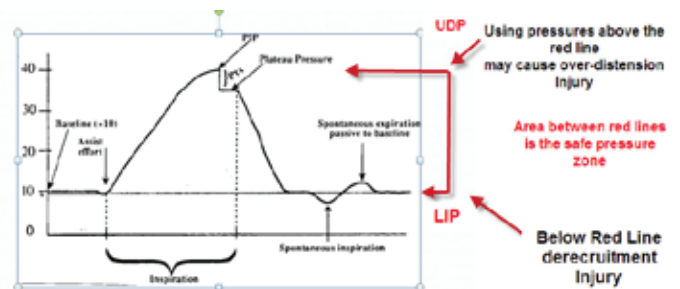
The above volume-pressure loop above gives the reader another look at the same concept; take a moment to identify LIP, UDP and the open or safe lung zone. If you think back to

basic spirometry, the expiratory reserve volume (ERV) and the residual volume (RV) equal the functional residual capacity (FRC). (See the illustration below). Why is FRC important? The FRC is the amount of volume in your lung following a normal expiration. The FRC is where gas exchange takes place. It is where we accomplish or lose alveolar stability. Optimizing FRC provides the alveolar stability and recruitment needed to treat patients with ARDS / ALI.



The illustration above identifies the various lung volumes and capacities on a spirometry tracing. The functional residual capacity (FRC) is where gas exchange takes place. It is also responsible for maintaining alveolar stability. During certain disease states such as ARDS, the FRC decreases and alveolar stability is threatened and/or lost.

When mechanical ventilation is instituted in a patient who has normal or near normal lung mechanics, conventional ventilatory modes such as SIMV or CMV are excellent choices. You will find these patients in the PACU, CVSI, ECC and elsewhere in the hospital. Because these patients have normal or near normal resistance, compliance, and alveolar time constants, conventional modes can be used very successfully. The PEEP levels that are needed to maintain alveolar volume and stability are reasonable (5-8 cms of water pressure). The peak inspiratory pressure remains within the safe zone because the alveolar structures are easily recruited at much lower inspiratory peak and mean pressures.



The illustration above represents a conventional CMV or SIMV mechanical breath being delivered to a patient with normal or near normal lung mechanics. You can see the pressure tracing remains in the “safe zone,” between the LIP and the UDP.

### Compliance / Resistance / Time Constants / Inspiratory Time

The variation of lung volume depends on the compliance of the alveolar structures and the amount of pressure used to produce that change. The normal lung does not present pure elastic behavior across the vital capacity range. Even in the normal lung

there are regional and postural variations in how fast or slow lung units will fill or empty along the vital capacity range.

When the lung is subjected to a pressure change, time is needed until a volume change will occur. The time necessary to inflate an alveolar structure to 63% of its volume is called a “time constant.” This concept is extremely important when trying to understand the consequences of different disease states such as ARDS and ALI on pulmonary mechanics, and the regional differences that may occur across the lung. Time constants refer to the speed at which the alveoli will fill or empty. In the normal or near normal lung the alveolar time constants will vary based on the resistance and compliance of the lung structures. Some alveoli will fill or empty faster while others are slower to fill or empty. During severe disease states such as ARDS and ALI your understanding of these regional differences in time constants will assist you in selecting the best and safest ventilator strategy to promote alveolar stability and enhance alveolar recruitment.

To illustrate the impact ARDS and ALI may have on alveolar time



constants, refer to the photo the bottom of page 6. These two balloons are identical and they represent two different alveolar structures. Imagine altering the right balloon by stuffing the gauze into the tubing (red arrow) and placing a rubber band around the balloon. Now apply the same inspiratory pressure to these two balloons. Obviously the balloon on the left would accept more volume, given the same inspiratory time.

Frequently, patients present in acute hypoxemic respiratory

failure due to adult respiratory distress syndrome (ARDS) and acute lung injury (ALI). These patients have dramatically different lung mechanics. The resistance, compliance and resulting alveolar time constants are unfavorably altered making it very difficult or impossible for the ventilator to recruit or open an adequate number of alveoli to support alveolar volume and gas exchange. Some of these alveolar structures will collapse at end-expiratory lung volumes.

The challenge in these patients is to achieve and maintain alveolar stability thereby improving alveolar recruitment. Achieving alveolar stability means that the mechanical breath must be able to open or recruit as much of the available alveoli as possible. Maintaining alveolar stability also means that the mechanical breath must keep recruited alveoli from collapsing at end expiratory lung volumes.

Traditional modes such as SIMV and CMV allow the end expiratory airway pressure to return to the preset PEEP level, usually 5 cms of water pressure at the end of each mechanical breath. Patients suffering from HRF secondary to ARDS or ALI have unusually high critical opening pressure or LIPs and these alveolar structures have much longer time constants. Often times the PEEP setting is lower than the LIP, allowing alveolar collapse at the end of each breath. These collapsed alveoli must be re-opened with each breath. As the disease process progresses,

more and more alveoli remain collapsed, worsening the HRF.

APRV is able to achieve and maintain alveolar stability because the airway pressure never falls below LIP, preventing alveolar collapse. Keeping these alveoli inflated and continuously participating in gas exchange is the unique secret of APRV.

In the perfect world the preset mechanical inspiratory time for each alveolar structure should be equal to its time constant or filling time. Unfortunately, this is not possible as there may be millions of different time constants across the lung depending on the severity of the disease process. To meet the challenge of attempting to fill alveolar structures with different filling times, the clinician might try to optimize the inspiratory time by increasing the inspiratory time to be equal to the longest alveolar time constant. Using this approach the ventilator should be able to fill or recruit a very large percentage of these alveolar structures. Unfortunately, the severe restrictive disease process of ARDS and ALI, may create alveolar time constants as long as 4.0 seconds.

Imagine trying to mechanically ventilate a patient with ARDS and ALI with the following ventilator settings:

Mode	CMV
Mechanical Breathing Rate	16/min
Tidal Volume	500 ml
Inspiratory Time	4 seconds
Peep	+ 8 cm of water pressure
FIO2	1.0

This extreme inspiratory time would be considered dangerous and contraindicated. The cardio-vascular and auto-PEEP consequences of a 4-second inspiratory time are well documented and understood. In the past there was a strategy called “inverse ratio ventilation (IRV) where the inspiratory time is prolonged beyond the physiologic range of 1:2. During IRV some inspired gas is not allowed to be exhaled, creating auto-PEEP and dynamically increasing the FRC. Unfortunately IRV has never been shown to improve important clinical outcomes when treating patients with HRF due to ARDS / ALI. In addition there are multiple complications and consequences of IRV including;

- Greatly increases the risk of developing or worsening ALI
- The patient must be paralyzed to undergo IRV. This strategy alone has several undesirable consequences
- The enormous cardio-vascular consequences
- The many consequences of auto-PEEP

IRV is no longer used to treat HRF due to ARSD / ALI. So what do we do when we see patients who present with worsening HRF due to ARDS /ALI in spite of aggressive conventional mechanical ventilation? These patients often require higher mechanical breathing rates and the longest safe inspiratory time would be 0.90 to 1.2 seconds. These inspiratory times are not long enough to fill alveolar structures with time constants of 3-4 seconds.

So what do you do when you have a patient in ARDS / ALI with severe HRF who is on the following conventional mechanical ventilator settings?

Mode	CMV
Mechanical Breathing Rate	16/min
Tidal Volume	500 ml
Inspiratory Time	1.0 seconds
Peep	+ 8 cm of water pressure
FIO2	1.0

The ABG reveals; pH 7.31 / PaCO2 56 mmHg / PaO2 43 mmHg

Where do we go from here? Fortunately, there is a ventilatory mode that will allow the practitioner to safely increase the inspiratory time to a value that is greater than that of these prolonged time constants, that is APRV.

### Airway Pressure Release Ventilation (APRV)

APRV provides a near continuous inspiratory time, at the lowest airway pressure possible. This near continuous inspiratory time will recruit or open the more severely affected alveoli that have longer time constants. Recruiting (opening) a greater percentage of the available alveoli and keeping them open will improve the matching of ventilation and perfusion and therefore arterial oxygenation. This alveolar recruitment is accomplished at lower mean airway pressures that will not over distend the alveoli with the normal or near normal time constants. As more and more alveoli are recruited the total alveolar gas volume is dynamically increased which produces a hyper-inflated FRC. The sum benefit of dynamically restoring the FRC is improvement in alveolar gas exchange.

We are now going to transition from the CMV mode to APRV. Below you will see the initial APRV settings.

Mode	APRV
T High	5.0 seconds
P High	26 cm of water
T Low	0.5 seconds
P Low	0 cm of water

ATC is always on — Slope is always set at zero

The ventilator is going to deliver and hold an inspiratory pressure or CPAP pressure of 26 cm of water pressure for a full 5.0 seconds. This inspiratory hold is followed by a brief drop in pressure towards 0 cm of water pressure causing a forceful exhalation. This brief exhalation lasts for a fraction of a second, after which the pressure is immediately restored to 26 cm of water pressure for another 5.0 seconds. This patient will be breathing spontaneously at a CPAP pressure of 26 cm of water pressure for 55 seconds out of every minute.

Unlike IRV ventilation, APRV patients are not paralyzed and may breathe spontaneously at whatever respiratory rate and tidal volume they choose, greatly enhancing patient comfort. This spontaneous breathing during APRV also contributes to the elimination of CO2.

The brief releases in the CPAP pressure are carefully timed and terminated when the expiratory flow rate (EFR) reaches 75% of the peak expiratory flow rate (PEFR). Setting this termination point on the expiratory flow curve is accomplished by observing the expiratory flow curve (EFC) and remains one of the most challenging aspects of managing the APRV mode. The ideal

TP-EFC is 75% of the PEFR. Having the TP-EFC at 75% of the PEFR maintains adequate end- expiratory alveolar lung volume or FRC, preventing the loss of alveolar stability and alveolar derecruitment.

These forceful exhalations account for most of the elimination of CO2. These “release volumes” are called “bulk ventilation” and may average 500-800ml of exhaled volume per release. Each presentation will vary in terms of the release volume. Referring to the APRV settings listed above, a simple calculation reveals that there will be 10.91 releases each minute. To make the math easier I am using a release volume of a liter, this would provide the patient with an exhaled minute volume of 10.91 liters just from the releases.

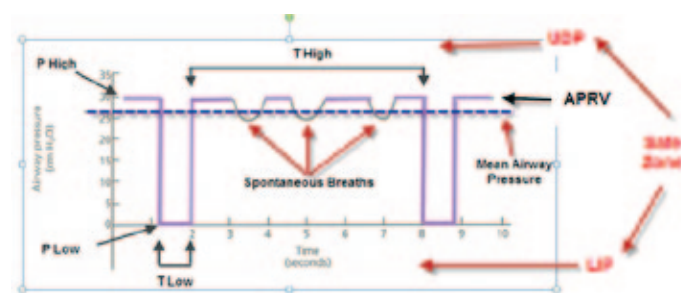
The high CPAP pressure of 26 cm of water pressure will over time, open more and more alveoli that were previously collapsed or partially collapsed. We call this process “de-wrinkling” the lung. The mean airway pressure remains low enough as to not have the typical consequences of reverse I:E ratio ventilation. As a matter of fact, reverse I:E ratio mechanical ventilation is no longer recommended to treat hypoxemic respiratory failure.

### Hypoxemic Respiratory Failure (HRF)

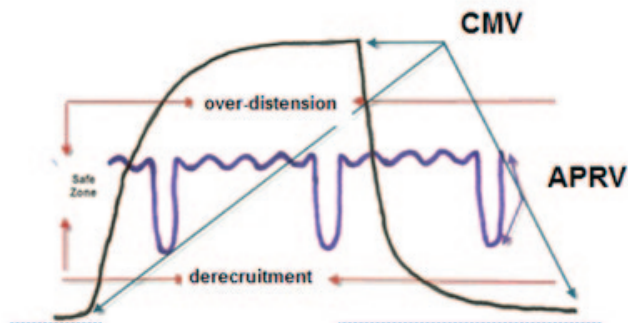
In this article, we are focusing on patients who have presented with hypoxemic respiratory failure, ARDS, ALI. These patients present with a restrictive disease process that may be severe. This restrictive process presents the respiratory care practitioner with several challenges.

### Alveolar Recruitment / Alveolar Stability

First, the restrictive component to this disease process makes it very difficult to maintain enough end-expiratory alveolar volume to provide alveolar stability using a conventional mode with PEEP.



The above pressure-time tracing represents a patient receiving APRV therapy who is suffering from severe hypoxemic respiratory failure as a result of ARDS / ALI. The purple line represents the airway pressure during APRV. Notice how the airway pressure stays within the safe zone throughout the ventilatory cycle in spite of the severity of the disease process.



In the illustration above, I have superimposed an airway pressure tracing from a CMV breath (black line) over an airway pressure tracing of the airway pressure during APRV (purple line). You can see that the only airway pressure tracing that remains within the safe zone is APRV.

When attempting to mechanically ventilate these patients with ARDS and/or ALI, using pressures that are outside the safe zone may lead to alveolar collapse and alveolar derecruitment or alveolar over distension and may lead to VILI. This is particularly true when the restrictive component of the disease is severe.

One of the hallmarks of the hypoxemic respiratory failure in ARDS and ALI is the loss of alveolar stability resulting in alveolar derecruitment during the end-expiratory phase when the alveoli are at their lowest volume. This cyclic collapse and re-opening of alveoli damages lung tissues and is consequently referred to as “Atelectrauma” or the “RACE Cycle” which is an acronym for “repeated airway closure and expansion.”

Re-opening these collapsed alveoli causes “stress and strain” to alveolar structures. In a concept borrowed from mechanical engineering, the terms of strain and stress have been established in lung physiology to describe the impact of mechanical ventilation on pulmonary structures. The term “stress” describes the condition of a trans-pulmonary pressure exerted across the lung. The term “strain” describes the condition of a tidal volume delivered to a lung in relation to its end expiratory lung volume. When the mechanical ventilator is unable to maintain alveolar gas volume and alveolar stability the possibility of VILI is the greatest. The lungs response to VILI may lead to the systemic inflammatory response syndrome or SIRS.

During SIRS a cascade of very dangerous chemical mediators are unleashed into the systemic circulation affecting all of the vital organs including the lung. These mediators set up an epithelial protein leak which causes tremendous damage to the alveolar structures and well as other vital organs.

### ARDS / Baby Lung Concept / Small Lungs rather than Stiff Lungs

The “baby lung” concept originated as an offspring of computed tomography examinations which showed that the lungs of patients with ARDS and ALI have very large areas of non-ventilated alveolar surface area, leaving a very small amount of lung to participate in gas exchange. The average 70 kilo adult with ARDS and ALI had the available alveolar surface area of approximately 300 -500 grams. This would be the total alveolar surface area in a 5 year old child. The ARDS / ALI lung is not “stiff” it is “small.” The disease process has created a very small surface area available for ventilation. This “baby lung” concept helps us to understand how to avoid VILI when treating adults

with ARDS / ALI. In this context if you were to calculate a safe tidal volume using the ideal body weight of 70 kilograms for an ARDS /ALI patient and multiplied this times 4-6 ml per kilogram you would arrive at a tidal volume range of 280 to 420 ml. This tidal volume may be much too large due to the baby lung effect of the disease process.

Looking at the “strain” provides a different way to judge the amount of tidal volume delivered to a lung, rather than relating it to predicted body weight which may underestimate the injurious effect of even small tidal volumes in patients with large non-aerated lung compartments.

Mechanical ventilation using tidal volumes that are too high “Volutrauma” will likewise damage the lung by over distending lung tissue. Unfortunately, due to their mechanical properties, the healthier alveoli with the faster time constants and greater compliance are particularly prone to this type of overstretch injury.

During the ARDS / ALI disease process, maintaining adequate end-expiratory alveolar volume or FRC during mechanical ventilation may be difficult or impossible depending on the severity of the disease process. When the ventilator has to attempt to re-open these alveoli with each mechanical breath the result may cause a RACE cycle type injury. The many factors of stress, strain, heat and friction can produce VILI and SIRS. This inflammatory response prompts the release of a number of substances into the bloodstream. The substances that are unleashed with this epithelial protein leak are tumor necrosis factor, interleukin 1 & 6 and the macrophage inflammatory protein. These substances may cause irreversible multi-organ failure and death. This process is very similar to the process that we see in sepsis.

Conventional modes such as SIMV and CMV may not be able to mechanically ventilate these patients while keeping pressures in the safe zone. We now know that conventional positive pressure mechanical ventilation has its side effects. Conventional approaches to mechanical ventilation, although life supporting, may paradoxically contribute to the high mortality still seen in patients with ARDS / ALI.

The purpose of this article is to promote the use and understanding of APRV therapy in the treatment of these difficult patients.

The hypothesis of the protective nature of any APRV therapy draws on the assumption that it achieves optimal gas exchange while keeping airway pressures in the “safe zone” of the pressure volume curve. APRV uses a nearly continuous airway pressure (CPAP), referred to as P HIGH to produce a dynamic end-expiratory lung volume or FRC to promote alveolar stability and alveolar recruitment. The dynamic FRC stability promotes improved gas exchange by recruiting most of the available alveolar surface area. The P High or CPAP pressure is held for several seconds allowing for maximum alveolar recruitment.

During APRV therapy, the patient does not need to be sedated and should be breathing spontaneously at the P High pressure level. This spontaneous breathing accounts for a portion of the CO<sub>2</sub> removal. Brief pressure releases facilitate forceful exhalations to promote gas exchange and the bulk of the elimination of CO<sub>2</sub>. These brief releases must be kept short

in order to maintain appropriate end-expiratory lung volumes (FRC) and avoid alveolar derecruitment. APRV therapy promotes alveolar recruitment due to the continuously elevated airway pressure exerted over several seconds. This is because alveolar recruitment not only depends on the pressure or volume applied, but also on the duration that this volume or pressure is applied.

No one mechanical ventilation mode fits every patient's needs. But by learning about the benefits of APRV, you may help reduce the complications of mechanical ventilation and increase patient comfort when treating the patient with ARDS, ALI and HRF.

## **Airway Pressure Release Ventilation APRV**

### **Here's what you should know about this ventilatory mode**

#### **The following information applies to APRV in the adult**

Airway Pressure Release Ventilation (APRV) is the application of a nearly continuous positive airway pressure high enough to maintain alveolar stability by keeping the alveoli open throughout the ventilatory cycle, thus promoting alveolar recruitment. This near continuous positive airway pressure or CPAP is briefly interrupted with timed releases of the airway pressure. These releases are very brief, never allowing the airway pressure to fall below the lower inflection point (LIP) which is the pressure where alveoli may collapse.

Imagine taking a deep breath and holding that breath for five seconds, then forcefully exhaling for 0.5 seconds, immediately taking another fast deep breath and holding it for another five seconds. This near continuous pressure keeps the alveoli open and slowly de-wrinkles and re-opens the more diseased alveoli which have the longer time constants or filling times.

This near continuous airway pressure facilitates alveolar recruitment by producing a dynamic functional residual capacity (FRC) and end-expiratory alveolar stability, thereby enhancing oxygenation. The pressure is said to be nearly continuous, because there are very brief releases of the airway pressure.

These brief airway pressure releases or forceful exhalations provide the bulk of the tidal ventilation, and is referred to as "bulk ventilation." Each release may be as much as 1000 ml. The bulk minute volume is created through these releases because immediately following each pressure release or forceful exhalation there is rapid inspiration as the airway pressure is restored to P High. This rapid inspiratory volume will be equal to the forceful expiration or release volume. This bulk mechanical ventilation provides most of the mechanical minute volume delivered to the patient and provides most of the elimination of CO<sub>2</sub>. The volume that is released during the release phase is called the "release volume" and this volume should be carefully monitored and recorded during APRV therapy.

### **The Unassisted Spontaneous Breathing Advantage**

Whenever possible unassisted spontaneous breathing (see definition below) should be preserved in mechanically ventilated patients to minimize dependent atelectasis (see definition below) and reduce the risk of ARDS, ALI and infection.

Dependent atelectasis is defined as atelectasis that affects a small portion of the lung. For the purpose of this paper, I will confine the cause of dependent atelectasis to patient positioning and lack of movement (being confined to an ICU bed). To make

matters worse, gravity will force a greater amount of pulmonary-capillary blood volume to these collapsed, dependent lung regions, increasing the amount of shunt and worsening the hypoxemic respiratory failure.

Permitting unassisted spontaneous breathing during APRV allows the patient to achieve alveolar recruitment of these dependent lung regions without the need for increased airway pressure.

Spontaneous breathing while the patient is receiving mechanical ventilation will fall into one of two categories:

#### ***Unassisted spontaneous breathing***

The patient breathes spontaneously without any mechanical assistance such as pressure support. The patient's normal breathing mechanics are responsible for the spontaneous breathing. During an unassisted spontaneous breath, the diaphragm contracts, pulling gas into the dependent lung regions as gas flow is coupled with patient effort. As a result, the patient receives only the flow they want.

#### ***Assisted spontaneous breathing (CMV & Pressure Support)***

Pressure Support Ventilation, for example, uses a fixed preset pressure and reacts to the initial patient effort or trigger. The resultant high flow rapidly outpaces the patient's demand or patient effort, effectively transitioning from a patient-controlled breath to a ventilator-controlled breath, pushing rather than pulling gas into the lung. This too may worsen dependent lung volume loss and derecruitment leading to alveolar collapse and respiratory infections.

Assisted spontaneous breathing during (CMV) on the other hand, pushes (positive pressure) most of the gas into nondependent lung regions and may worsen the dependent lung volume loss and derecruitment leading to alveolar collapse and respiratory infections.

Spontaneous breathing during APRV allows greater flexibility when adapting to the dynamic and rapidly changing pulmonary mechanics of critically ill patients.

Also, the cardio pulmonary benefits of unassisted spontaneous breathing will reduce the negative physiological effects of mechanical breaths on the patient's hemodynamic status.

In contrast, lack of spontaneous breathing may contribute to worsening respiratory dysfunction by increasing the risk of the alveolar collapse, derecruitment and the formation of atelectasis and pulmonary infections. Complications of mechanical ventilation increase over time, and successful liberation from mechanical ventilation depends on spontaneous breathing.

APRV facilitates spontaneous breathing throughout the entire ventilatory cycle which also contributes to the elimination of CO<sub>2</sub>. This spontaneous breathing enhances patient comfort throughout the respiratory cycle and yields the many benefits of spontaneous breathing during mechanical ventilation. These benefits include;

- Decreased need for sedation medications during mechanical ventilation
- Improved alveolar stability and alveolar recruitment
- Reduced work of breathing



- Reduced cardiovascular side effects
- Improved organ perfusion
- Improved muco-ciliary escalator
- Better dependant lung ventilation
- Improved muscle tone
- Less ventilator days

When initiating APRV the clinician must set the following ventilator settings:

P High  
P Low  
T High  
T Low  
FIO2

Slope is always zero — ATC is always on

This paper will discuss each of these settings in detail

### The P High Setting

The P High pressure setting is the near continuous airway pressure or CPAP. The starting point for setting P High is established by converting the plateau pressure of the conventional mode (CMV) and adding 2 cm of water pressure. For instance, if the plateau pressure of the conventional mode (CMV) is 24 cm of water pressure you would add 2 cm of water pressure and your starting P High pressure would be 26 cm of water pressure. The clinician will adjust P High to achieve an expired minute volume of 2-3 L/M less than when on the conventional mode (CMV). The ceiling level for P High is normally 35 cm of water pressure. The P High facilitates oxygenation by optimizing (dynamically increasing) FRC and therefore improving alveolar recruitment and alveolar stability. The P High will determine the size of the FRC, obviously the higher the P High the greater the volume of FRC. Adjustments will be made to T High according to the arterial blood gases and the release volumes.

Loss of airway pressure during APRV results in immediate loss of alveolar recruitment, alveolar stability, decreasing lung volume (FRC) and therefore oxygenation. It may take hours to re-recruit (de-wrinkle) the gains you have previously made. The lung may never be able to recover from the volume loss and its consequences, leading to worsening hypoxemic respiratory failure. Therefore, every effort must be made to avoid this loss of airway pressure. The respiratory therapist must be very familiar with and able to perform the “clamp off technique” used to preserve the patients FRC during the rare instances that the circuit must be broken.

Clamp off technique: Situations will arise that require opening (breaking) the circuit to accomplish a specific task. Utilizing this clamp off technique will maintain P High throughout the time that the circuit is broken. Maintaining the P High will maintain the dynamic FRC, alveolar stabilization and prevent derecruitment. The therapist will clamp the endotracheal tube at the onset of P High, thus maintaining the P High pressure in the patient’s lungs. Now the circuit can be opened (broken) and the respiratory therapist can accomplish the necessary task. Once the circuit has been re-connected, the respiratory therapist removes the clamp and allows a release phase to take place. This procedure guarantees that the patient cannot have a complete exhalation resulting in loss of alveolar stability and alveolar recruitment.

### Calculating Mean Airway Pressure during APRV

The mean airway pressure generated during APRV can be calculated as follows:

$$\frac{(P \text{ High} \times T \text{ High}) + (P \text{ Low} \times T \text{ Low})}{T \text{ High} + T \text{ Low}}$$

### The P Low Setting

P Low is set at 0 cm of water pressure. A P Low of 0 cm of water pressure produces minimal expiratory resistance, thus accelerating expiratory flow rates, facilitating rapid pressure drops or releases. These releases are terminated before the point of derecruitment.

### Calculating the CPAP %

The percentage of CPAP is a vital component of APRV. The CPAP % should be maintained at 90-93%

The formula is T High divided by (T High — T Low) = %

$$\text{Example} = \frac{T \text{ High } 6.0 \text{ seconds}}{T \text{ High } 6.0 \text{ seconds} - T \text{ Low } 0.4 \text{ seconds}} = 93\%$$

### The T High setting

The T High is the duration of the P High (CPAP) in seconds. The goal is to achieve a CPAP % of 90 - 93% or greater. T High is normally set at 4.5 to 6 seconds. Setting the T High less than 4 seconds may lead to a reduction in mean airway pressure, potentially resulting in lower lung volumes (FRC), alveolar collapse and derecruitment, reducing the available alveolar surface area for gas exchange.

During conventional mechanical ventilation the respiratory therapist may want to increase the mechanical minute volume delivered to the patient. Increasing the mechanical minute volume in a conventional mode is accomplished by increasing the mechanical breathing rate or tidal volume. Increasing the tidal volume is usually not a safe ventilator strategy. It leaves the mechanical breathing rate as the variable the respiratory therapist would use to increase the delivered mechanical minute volume. During APRV therapy the T High can be adjusted to increase the mechanical minute volume. This is because the T High plus the T Low equals the total cycle time. The total cycle time has two components, one is the T High or the duration of P High (CPAP) and secondly the T Low where the release phases occur. Increasing or decreasing the number of releases per minute will increase or decrease the mechanical minute volume delivered to the patient.

As discussed earlier, the release phase represents the bulk of the mechanical ventilation during APRV. These release volumes or forceful exhalations are immediately followed by a rapid inspiration as the airway pressure is restored to P High. Releases of 1000 ml are fairly common and account for the bulk of the mechanical ventilation during APRV therapy.

The lower the T High the greater the number of release phases per minute. It is simple math, as you increase the number of releases per minute you also increase the mechanical minute volume delivered to the patient, eliminating more CO2.

For instance, assume a release volume of 1000 ml per release; I will calculate the mechanical minute volume delivered to the patient using a T High of 7 seconds and a T High of 4 seconds.

### A T High of 7 Seconds

T High setting of 7 seconds and a T Low setting of 0.4 seconds will result in a total cycle time of 7.4 seconds (T High + T Low = Total Cycle Time) and would result in 8.11 releases per minute (dividing 7.4 seconds into 60 seconds will result in 8.11 releases per minute) Assuming a release volume of 1000ml per release, the resulting release minute volume would be 8.11 L/M.

### T High of 4 Seconds

Decreasing the T High setting to 4 seconds (assuming that T Low setting remained at 0.4 seconds) will result in a total cycle time of 4.4 seconds (T High + T Low = Total Cycle Time) and will result in 13.64 releases per minute (dividing 4.4 seconds into 60 seconds would result in 13.64 releases per minute). Assuming a release volume of 1000ml per release phase the resulting minute volume would be 13.64 L/M.

Changing in the T High setting from 7 to 4 seconds resulted in increasing the mechanical minute volume delivered to the patient by 5.53 L/M. An increase in the mechanical minute volume of this magnitude would obviously have a significant effect on the elimination of CO<sub>2</sub>.

In contrast, lengthening the T High may increase alveolar recruitment, dynamic FRC allowing increased diffusion respiration further eliminating CO<sub>2</sub>.

The patient's spontaneous breathing will supplement the mechanical minute volume. This spontaneous breathing (tidal volume) when added to the mechanical exhaled release minute volume, will equal the total exhaled minute volume during APRV.

### *Hypersensitivity pneumonitis...continued from page 50*

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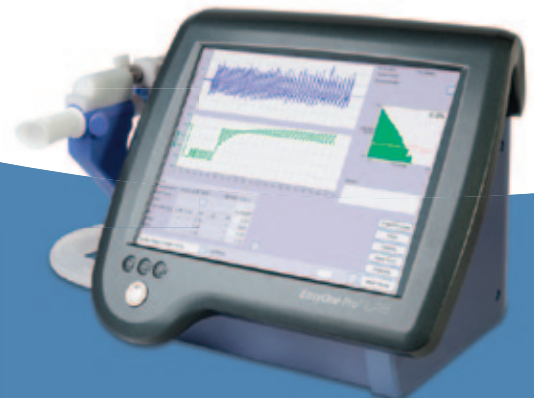
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