Elevated exhalation of hydrogen peroxide and thiobarbituric acid reactive substances in patients with community acquired pneumonia

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Summary Background: Bacterial pneumonia involves influx of activated phagocytes into distal airways. These cells release oxidants including H₂O₂, that may be exhaled or induce peroxidative damage to lung tissues with formation of thiobarbituric reactive substances (TBARs).

Study objectives: To determine whether concentrations of H₂O₂ and TBARs in exhaled breath condensate (EBC) is elevated and correlate with systemic response to pneumonia during 10 days of hospital treatment.

Design: The concentration of H₂O₂ and TBARs was measured in EBC of 43 inpatients with community acquired pneumonia (CAP) and 20 healthy never smoked subjects over 10 days and were accompanied by monitoring of WBC count, serum concentration of C-reactive protein (CRP) and peroxyl radical-trapping capacity.

Results: Patients with CAP exhaled 4.6-, 3.7-, 3.9-, 3.3-times more H₂O₂ than healthy controls at 1st, 3rd, 5th and 10th day of treatment (P<0.05), respectively. EBC concentrations of TBARs were elevated at 1st and 3rd day. H₂O₂ and TBARs levels decreased along with treatment course. Correlation (P<0.05) was found between H₂O₂ levels and CRP and WBC count (r=0.31) at 1st day and between TBARs and CRP at 5th (r=0.34) and 10th day (r=0.46). The mean H₂O₂ exhalation estimated over ten days of treatment correlated with pneumonic chest X-ray score (r=0.42), CRP levels (r=0.46) and WBC count (r=0.33) at admission (P<0.05).

Conclusions: Pneumonia is accompanied by oxidative stress in airways that moderately correlates with intensity of systemic inflammatory response. Determination of H₂O₂ in EBC may be helpful for non-invasive monitoring of oxidants production during lower respiratory tract infection.

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Introduction

Bacterial pneumonia is characterized by rapid and large influx of activated phagocytes into distal airways. These cells release a lot of reactive oxygen species (ROS) including H₂O₂ that plays the central role in formation of highly reactive and cytotoxic hydroxyl radicals and hypochlorous acid. Both, these compounds contribute to non-specific host defence against invading microorganisms. However, enhanced ROS production may induce peroxidative damage to lipids and other biomolecules leading to accumulation of toxic products that are commonly detected by their reaction with thiobarbituric acid. Malondialdehyde is one of the most important of so-called thiobarbituric reactive substances (TBARs). Since, H₂O₂ and malondialdehyde are relatively stable and volatile they may be measured in exhaled breath condensate (EBC) of healthy subjects and those with chronic inflammatory lung disorders.

Increased levels of H₂O₂ were also reported in EBC obtained from mechanically ventilated patients due to acute respiratory insufficiency caused by severe pneumonia. However, these studies were mainly limited to H₂O₂ determinations in EBC collected at the first day after admission. No trials devoted to time-course of H₂O₂ and TBARs exhalation in subjects with pneumonia along with improvement of patients’ clinical status have been performed so far. Therefore, we decided to monitor the exhalation of H₂O₂ and TBARs in subjects with community acquired pneumonia (CAP) during successful 10 day treatment versus age- and sex-matched healthy controls. Furthermore the associations between exhaled compounds and pneumatic chest X-ray score, serum peroxyl radical-trapping capacity (sPRTC) and selected markers of systemic inflammatory response were also investigated.

Materials and methods

Patients and treatment

The study population included 43 patients (12 women, 31 men) with CAP admitted to Institute of Internal Medicine in the 1st Academic Teaching Hospital of Medical University of Lodz from May 2000 to May 2001 (Table 1). Each enrolled patient had to fulfil the following inclusion criteria: (1) age ≥ 18 years; (2) presence of a new infiltrate (s), consolidation or pleural effusion consistent with pneumonia on a chest radiograph at the day of admission; (3) at least two of the following signs and symptoms: new or increased cough, purulent sputum, rales at auscultation and evidence of pulmonary consolidation, tachypnoea or hypoxemia, pleuritic chest pain; (4) at least one of the following signs and symptoms: fever (tympanic temperature of >38.5°C) or a history of fever for the current episode of CAP, total peripheral white blood cells (WBC) count of >10 000 cells/mm³ or >15% immature neutrophils (bands) regardless of total WBC count or leucopenia with total WBC count <4500 cells/mm³; (5) negative urine pregnancy test (for women of child-bearing potential) at the day of admission. The exclusion criteria were: (1) female patient who is pregnant or lactating (breast feeding); (2) aspiration pneumonia or hospital acquired pneumonia; (3) cystic fibrosis, active tuberculosis, bronchiectases, active malignancies, signs of disseminated infection, renal impairment (creatinine clearance of <30 ml/min), liver impairment (alanine-amino transferase—ALT, aspartate-amino transferase—AST or alkaline phosphatase levels greater than 3 times the upper limit of normal) or presence of any serious unstable underlying disease; (4) active alcohol or drug abuse; (5) not refraining from cigarette smoking within 12 h before EBC collection. Angiotensin converting enzyme (ACE) inhibitors-controlled hypertension and chronic bronchitis related to cigarette smoking were the only allowed concomitant diseases. The empiric antibacterial therapy started at the day of admission and drugs were administered daily in the standard dosages for 7 days. Nineteen patients were treated with cephalosporins, 9 with quinolones, 9 with combination of

<table>
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<th>Table 1 Baseline characteristic of study subjects.</th>
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<tr>
<td>CAP patients</td>
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<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>Sex F/M</td>
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<tr>
<td>Mean age, yrs</td>
</tr>
<tr>
<td>Smokers</td>
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<tr>
<td>Non-smokers</td>
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<tr>
<td>BMI</td>
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<tr>
<td>FVC%</td>
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<tr>
<td>FEV₁%</td>
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<tr>
<td>FEV₁/FVC</td>
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<tr>
<td>Pneumonic score</td>
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CAP—community acquired pneumonia, FVC—forced vital capacity, FEV₁—forced expiratory volume in the first second, BMI—body mass index, FEV₁ and FVC are expressed as percent of predicted value [35]. Chest X-ray was not done and pneumatic chest X-ray score was assumed to be 0 on the basis of patient medical history and result of physical examination. *—P<0.05 vs. control.
ciclosporin plus aminoglycoside, 2 with combination of ciclosporin plus quinolone and 4 with amoxicillin/clavulanate, respectively. Concomitant medication included, N-acetylcysteine (NAC) effervescent tablets 600 mg/day \( (n = 41) \), theophylline 300 mg twice a day \( (n = 39) \) and ACE inhibitors, captopril 12.5 mg or 25 mg two or three times a day, or enalapril 10–20 mg once a day \( (n = 12) \). Treatment with ACE inhibitors was a continuation of outpatient medication started at least one month before patient admission. The control healthy subjects included 20 volunteers (Table 1) who had never smoked and had not suffered from any infectious disease for at least 3 months prior to the study. They were free from any medication and had no history of respiratory or atopic disease. All patients involved in the study gave informed consent and the study protocol was approved by Ethics Committee of Medical University of Lodz.

**Study protocol**

At the day of admission chest X-ray, serum chemistry, haematology, urinalysis has been performed and blood and sputum specimens for culture were collected from patients with CAP. The chest X-ray was analyzed by pulmonologist and radiologist and the intensity of pneumatic changes was recorded on a scale from 0 (no symptoms) to 10 points. The number of pulmonary fields (from 0 to 6 points) involved by inflammatory infiltrate (consolidation) was the first evaluated element. One or two points were added if the opacity was inhomogeneous and mostly hazy or dense and coalesce to form confluent areas of pulmonary shadowing, respectively. Additional one or 2 points were calculated when pleural effusion or bilateral effusion was present. Thus, maximal score 10 could be calculated for patient who had bilateral pleural effusion or bilateral consolidation. This had no significant influence on measured variables. Each subject wore a noseclip and rinsed their mouth with distilled water just before and at 7 and 14 min of collection. EBC specimens were collected between 8 and 10 a.m., at 1st, 3rd, 5th and 10th (discharge) day of hospitalization. Patients who were current smokers were asked to refrain from cigarette smoking for 12 h preceding EBC collection. If a patient failed to refrain from smoking collection was performed the day later. This occurred in 4 patients; 2 at 3rd day and 2 at 5th day, respectively. EBC from healthy subjects was collected at the same time-points. To avoid any bias each healthy subject was randomly paired with one patient with CAP and the EBC collections were performed at the same days. The spirometry was performed with Flowscreen (Eringer GmbH Co., Germany) at 1st and 10th day just after EBC collection under conditions as previously described. The following parameters were also measured: serum concentration of C-reactive protein (CRP) with Beckman Array 360 at 1st, 5th, 10th day of treatment; sPRTC at the same time-points as EBC collection, and WBC count at 1st and 10th day, respectively.

**Collection of exhaled breath condensate**

The collecting device consisted of a plastic mouthpiece (Art.-No. 892103, Jaeger Toennies, Hochberg, Germany) and saliva trap connected to a glass Liebig tube-cooler (cooling and collecting tube 55 cm length, internal diameter 10 mm, the external jacket diameter 36 mm) (Labmed, Lodz, Poland cat no 6010). The tube was cooled with ethanol pumped in the closed circuit and its temperature was kept at \(-9^\circ C\) with Multi Temp III (Pharmacia Biotech). This temperature was the lowest one that allowed to collect liquid EBC in the sterile plastic tube covered with ice (Sarstedt, Numbrecht, volume 13 ml, internal diameter 14 mm) mounted at the base of Liebig tube-cooler. Further decrease in ethanol temperature caused congealment of EBC inside the cooling tube and stopped its collection. Patients were asked to breathe out through a mouthpiece and to breathe in with the mouthpiece removed, for 20 min. The respiratory rate (tidal breathing) ranged from 17 to 27 breaths/min for patients with pneumonia and from 16 to 19 breaths/min for healthy controls. This had no significant influence on measured variables. Each subject wore a noseclip and rinsed their mouth with distilled water (resistance \( > 18 \Omega \cdot cm \)) just before and at 7 and 14 min of collection. EBC specimens were collected from patients with CAP to yielding a volume of up to 1 ml. All aliquots of EBC were stored in Sarstedt tubes on ice (but not frozen) until \( \mathrm{H}_2\mathrm{O}_2 \) and TBARs measurement. After each EBC collection the plastic parts of collecting device were washed with detergent solution (Merida, Wroclaw, Poland) and then disinfected with Sekusept solution with addition of Sekusept activator (Henkel-Ecolab GmbH, Dusseldorf, Germany) according to manufacturer’s instruction. The tube-cooler was washed with 30% ethanol solution and then rinsed 3-times with sterile deionized water (resistance \( > 18 \Omega \cdot cm \)), HPLC Water Purification System USF ELGA, England).
**Measurement of H$_2$O$_2$ and TBARs in exhaled breath condensate**

The concentration of H$_2$O$_2$ was measured within 30 min after EBC collection according to the method of Ruch et al. with some modifications. The lower limit of H$_2$O$_2$ detection was 0.083 M. The intra-assay variability did not exceed 2% for standard H$_2$O$_2$ solutions ranging from 0.1 to 0.5 M. The content of TBARs in EBC was determined as previously described. Tetramethoxypropane (0.01–50 M) was used as an external standard and the method sensitivity was 0.05 M. The intra-assay variability did not exceed 3% for 0.1 and 0.5 M tetramethoxypropane solution. The intra-assay variability of measured H$_2$O$_2$ and TBARs levels was 9.7% and 14.9% as determined with 10 subjects (6 patients with CAP and 4 healthy controls) asked to attend 2 EBC collection sessions in 30 min intervals.

**Measurement of serum peroxyl radical-trapping capacity**

In this assay antioxidants present in serum sample inhibit oxidation of 2,2’-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) by peroxyl radicals generated from thermal decomposition of 2,2’-azobis (2-amidopropane) hydrochloride. Briefly, 3 ml of pre-wormed to 37°C 0.1 M sodium phosphate buffer (pH 7.0) was mixed with 90 ml of 5 mM 2,2’-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) solution and different volumes of serum. Thereafter 300 ml of 200 mM 2,2’-azobis (2-amidopropion) hydrochloride was added and the reaction was carried at 37°C. Control samples received phosphate buffer instead of serum and the absorbance was recorded continuously at 414 nm in double beam spectrophotometer (CARY 1, Varian). The induction time of the reaction defined as the time from 2,2’-azobis (2-amidopropano) hydrochloride addition to the onset of the absorbance rise was proportional to the amount of antioxidants present in the sample and was used as the measure of sPRTC. Results were expressed as the serum volume that increased 2-fold the induction time of reaction.

**Statistical analysis**

Data are expressed as mean ± SD. Part of EBC specimens, especially those obtained from healthy controls revealed no detectable TBARs. In this case the TBARs concentration was assumed 0.025 M (half of the detection limit). The time-courses of variables were analyzed using Student t and Wilcoxon matched pairs tests according to sample distribution. The differences between groups were computed with Mann-Whitney U test or Friedman ANOVA test. Correlation coefficients were calculated by the Pearson test or Spearman test. In all cases a P-value of < 0.05 was considered significant.

**Results**

In 25 patients the etiologic agent was found on the basis of sputum and blood culture. The most common bacteria were *Streptococcus pneumoniae* (n = 14) and *Haemophilus influenzae* (n = 7). Serum screening for presence of antibodies against *Chlamydia pneumoniae*, *Chlamydia trachomatis*, *Chlamydia psittaci*, *Mycoplasma pneumoniae* and *Legionella pneumophila* revealed no current infection with these pathogens in any case. In 18 remaining patients the pathogenic bacteria was not determined. The empiric antibiotic treatment was successful and all enrolled patients with CAP finished the study. However, 10 patients were discharged after 7–8 days of treatment due to rapid recovery. Therefore, in these patients we were not able to collect EBC and blood specimens at the 10th day of treatment, nevertheless, they

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Day of treatment</th>
<th>1st</th>
<th>3rd</th>
<th>5th</th>
<th>10th</th>
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<tbody>
<tr>
<td>WBC × 10$^3$/µl</td>
<td></td>
<td>10.2 ± 5.7</td>
<td>ND</td>
<td>ND</td>
<td>8.4 ± 5.0*</td>
</tr>
<tr>
<td>CRP mg/dl</td>
<td></td>
<td>8.7 ± 4.1</td>
<td>ND</td>
<td>3.5 ± 2.7*</td>
<td>2.4 ± 1.8*</td>
</tr>
<tr>
<td>sPRTC µl</td>
<td></td>
<td>15.2 ± 5.7</td>
<td>16.2 ± 4.9</td>
<td>15.5 ± 5.0</td>
<td>13.8 ± 4.8*</td>
</tr>
<tr>
<td>FVC%</td>
<td></td>
<td>58.2 ± 17.2</td>
<td>ND</td>
<td>ND</td>
<td>74.2 ± 21.6*</td>
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<tr>
<td>FEV$_1$/FVC</td>
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<td>55.6 ± 18.9</td>
<td>ND</td>
<td>ND</td>
<td>67.8 ± 23.7*</td>
</tr>
<tr>
<td>FEV$_1$/FVC</td>
<td></td>
<td>92.2 ± 19.6</td>
<td>ND</td>
<td>ND</td>
<td>93.5 ± 16.6</td>
</tr>
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</table>

WBC—white blood cell count, CRP—C-reactive protein, sPRTC—serum peroxyl radical-trapping capacity, ND—not determined. * vs. value at 1st day; ** vs. value at 3rd day; P<0.05, **—vs. value at 3rd day; P<0.05.
were included in statistical analysis. The significant improvement in forced vital capacity (FVC) and forced expiratory volume in the first second (FEV₁) was observed in patients with CAP. This was accompanied by gradual normalization of serum CRP levels and WBC count. sPRTC was stable over the first 5 days of treatment and then the rise in this parameter was observed (Table 2).

**Time course of H₂O₂ and TBARs exhalation in CAP patients and healthy controls**

Patients with CAP exhibited elevated H₂O₂ levels in EBC (Fig. 1). At 1st, 3rd, 5th and 10th day of treatment H₂O₂ exhalation was 4.6 ± 1.7-, 3.7 ± 1.9-, 3.9 ± 1.5- and 3.3 ± 1.4-fold higher (P < 0.05) than in healthy controls. The highest mean EBC H₂O₂ levels were at 1st and 3rd day of treatment. Then the H₂O₂ exhalation gradually decreased revealing the significant differences between values found at 3rd and 5th day and at 3rd and 10th day (P < 0.05), respectively. The mean H₂O₂ exhalation estimated over the whole treatment period (calculated as a mean of measurements performed at day 1st, 3rd, 5th and 10th) was also higher in CAP patients than in healthy subjects (Table 3). In accordance with our previous studies³ healthy subjects exhaled only trace amounts of TBARs. At 1st and 3rd day of TBARs exhalation monitoring no EBC specimen from healthy subjects revealed detectable amounts of TBARs at 5th and 10th day of study. The ratio of positive TBARs readings in CAP patients ranged between 0.21 and 0.37 over the treatment period. Thus, TBARs exhalation was higher in patients with CAP than in healthy controls, however, only at 1st and 3rd day of treatment the differences were significant (Table 4). Mean TBARs exhalation estimated over the treatment period was higher in CAP patients than in healthy controls (Table 3).

**Correlations between exhaled compounds and clinical parameters**

Exhaled H₂O₂ moderately correlated with WBC count (r = 0.31, P < 0.05) and serum CRP (r = 0.31, P < 0.05) at the day of admission. The weak, but significant (P < 0.05) positive association between pneumatic chest X-ray score and EBC H₂O₂ levels at 3rd (r = 0.14) and 5th day (r = 0.18) of treatment was observed. TBARs levels correlated only with serum CRP concentrations at 5th (r = 0.34, P < 0.05) and 10th (r = 0.46, P < 0.05) day of treatment. No other significant associations were noted between exhaled variables and clinical parameters (data not shown). A moderate negative correlation between exhaled H₂O₂ and TBARs was noted in CAP group (r = −0.42, P < 0.05) at the 10th day of treatment. On the other hand mean H₂O₂ exhalation estimated over the treatment period correlated significantly with pneumatic chest X-ray score (Fig. 2), CRP levels (Fig. 3) and WBC count (r = 0.33, P < 0.05) at the day of admission. In the case of mean TBARs level estimated over the treatment period the only association was with sPRTC at 5th day (r = −0.42, P < 0.03). No associations between exhaled variables and treatment with various antibiotics.

**Table 3** Comparison of mean H₂O₂ and TBARs exhalation estimated over the whole treatment period in healthy subjects and patients with community acquired pneumonia (CAP).

<table>
<thead>
<tr>
<th>Variable (µM)</th>
<th>CAP patients</th>
<th>Healthy controls</th>
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<tbody>
<tr>
<td>H₂O₂</td>
<td>0.59 ± 0.24*</td>
<td>0.16 ± 0.06</td>
</tr>
<tr>
<td>TBARs</td>
<td>0.07 ± 0.03*</td>
<td>0.03 ± 0.01</td>
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The mean H₂O₂ and TBARs exhalation estimated over the treatment period was calculated as a mean of four consecutive measurements performed at day 1st, 3rd, 5th and 10th. *—vs. healthy controls, P < 0.05.
Discussion

We found that adult patients with CAP exhale increased amounts of H$_2$O$_2$ and TBARs over 10 day period of successful treatment. TBARs concentrations were elevated up to 3rd day of monitoring while the EBC H$_2$O$_2$ levels decreased along with treatment but at the day of discharge they were still higher than in healthy controls. This may result from persistence of alveolar inflammatory infiltrate with H$_2$O$_2$ producing cells that may be visible on chest-X-ray for few weeks after the disease onset. Elevating H$_2$O$_2$ and TBARs exhalation proves the occurrence of oxidative stress in the respiratory tract related to lower airways infection and is compatible with previous studies showing increased levels of circulating markers of peroxidative damage to biomolecules in subjects with bacterial pneumonia.

We suppose that activated polymorphonuclear leukocytes, monocytes and macrophages present in alveolar inflammatory infiltrate are the main source of exhaled H$_2$O$_2$. In patients with bronchiectasis EBC H$_2$O$_2$ levels positively correlated with percentage of neutrophils in induced sputum. Exhaled H$_2$O$_2$ correlated also with plasma lysozyme (a measure of in vivo neutrophil turnover) in patients with adult respiratory distress syndrome. In addition intrapulmonary oxygen consumption rose in mechanically ventilated patients with pneumonia what may be a consequence of increased oxidative metabolism of polymorphonuclear leukocytes and macrophages constituting alveolar infiltrate. On the other hand, macrophages and polymorphonuclear leukocytes contain catalase and peroxidases that decompose H$_2$O$_2$. Thus larger phagocyte influx and degranulation may increase catalase activity in the airways. Type II pneumocytes also contain catalase and are able to release H$_2$O$_2$ into the alveolar spaces. These may be responsible for week correlations between exhaled compounds and pneumonic chest X-ray score. It should be noted that pneumonic chest X-ray score as a simple and non-expensive...
measuring the size and severity of inflammatory alveolar infiltrate has some limitations that may affect analyzed correlations. This parameter did not include spatiality of infiltrate and changes in airflow in the close neighborhood of inflamed areas that is necessary for \( \text{H}_2\text{O}_2 \) movement into EBC. Antibiotic treatment by killing of invading microorganisms exerts strong anti-inflammatory activity\(^\text{24}\) and seems to be responsible for decline in \( \text{H}_2\text{O}_2 \) and TBARs exhalation. Theophylline can inhibit \( \text{H}_2\text{O}_2 \) release from human alveolar macrophages\(^\text{25}\) and polymorphonuclear leukocytes\(^\text{26}\) and may contribute to decrease in EBC \( \text{H}_2\text{O}_2 \) levels too. Almost all patients with CAP received \( N \)-acetylcysteine that posses direct antioxidant properties and serves as a precursor for reduced glutathione synthesis.\(^\text{27}\) In a placebo controlled study \( N \)-acetylcysteine 600 mg a day significantly decreased \( \text{H}_2\text{O}_2 \) exhalation after 6 month administration whilst TBARs levels were not changed in subjects with stable chronic obstructive pulmonary disease.\(^\text{11}\) Therefore, treatment with \( N \)-acetylcysteine seems to be not responsible for decrease in \( \text{H}_2\text{O}_2 \) and TBARs exhalation in CAP patients. However, \( N \)-acetylcysteine may contribute to the rise in sPRTC observed at the end of study. \( \text{H}_2\text{O}_2 \) and TBARs correlated positively with WBC count and serum CRP levels what indicates associations between systemic inflammatory response and ROS formation in the lower airways during pneumonia. Human plasma contains detectable amounts of \( \text{H}_2\text{O}_2 \).\(^\text{28}\) It can not be excluded that \( \text{H}_2\text{O}_2 \) released from circulatory phagocytes may diffuse from blood stream through pulmonary endothelium into the lower airways and undergo exhalation.

This may partially explain the association between EBC \( \text{H}_2\text{O}_2 \) levels and WBC count. However, plasma, erythrocytes and pulmonary endothelium contain variety of antioxidants\(^\text{29,29}\) making unlikely the \( \text{H}_2\text{O}_2 \) flow from blood into lungs in patients with CAP. We did not find any significant positive association between \( \text{H}_2\text{O}_2 \) and TBARs concentrations in EBC collected at all time-points. This is consistent with our previous study showing no correlation between elevated EBC levels of \( \text{H}_2\text{O}_2 \) and TBARs in subjects with stable chronic obstructive pulmonary disease over one year observation.\(^\text{5,11}\) Exhaled \( \text{H}_2\text{O}_2 \) represents a pool which is not involved in free radical reactions leading to TBARs formation. Moreover, TBARs are also generated in enzymatic (independent of ROS) processes of prostaglandin \( \text{H}_2 \) conversion into thromboxane \( \text{A}_2 \) that are usually enhanced at site of inflammation.\(^\text{2,30}\) There is evidence that expression and activity of antioxidant enzymes may secondarily rise in response to inflammatory processes.\(^\text{29,31}\) \( \text{H}_2\text{O}_2 \) and other ROS activate nuclear factor NF-\( \kappa \)B\(^\text{32}\) that via cytokines (e.g. IL-1, TNF-\( \alpha \)) may induce synthesis of antioxidant enzymes including superoxide dismutase, catalase and glutathione peroxidase.\(^\text{33,34}\) The release of catalase from ROS-damaged cells can also increase antioxidant screen of airways secretion.\(^\text{22}\) These may break peroxidative damage to lung tissue and be responsible for negative association between exhaled TBARs and \( \text{H}_2\text{O}_2 \) and sPRTC that was noted at the end of treatment.

In summary, patients with CAP had elevated EBC \( \text{H}_2\text{O}_2 \) and TBARs levels that decreased along with disease resolution. These prove occurrence of pulmonary oxidative stress during distal airways bacterial infection. However, weak or moderate correlations of exhaled variables with common markers of systemic inflammatory response and pneumonic chest X-ray score suggest limited predictive value of EBC \( \text{H}_2\text{O}_2 \) and TBARs monitoring in respect of size and severity of pneumonic infiltrate. On the other hand, high \( \text{H}_2\text{O}_2 \) exhalation at 1st and 3rd day of treatment suggests usefulness of EBC \( \text{H}_2\text{O}_2 \) monitoring as an index of ongoing lower respiratory tract infection. This requires further studies with inpatients at high risk of pneumonia (e.g. patients hospitalised in intensive care unit).

References

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