Research Article

Transforming Growth Factor β1 Genotypes in Relation to TGFβ1, Interleukin-8, and Tumor Necrosis Factor Alpha in Induced Sputum and Blood in Cystic Fibrosis

O. Eickmeier, 1 L. v. d. Boom, 2 F. Schreiner, 2 M. J. Lentze, 2 D. NGampolo, 2 R. Schubert, 1 S. Zielen, 1 and S. Schmitt-Grohé 2

1 Department of Pediatric Pulmonary, Goethe University Hospital, Theodor-Stern-Kai 7, 60590 Frankfurt, Germany
2 Department of Pediatrics, University Hospital, Adenauerallee 119, 53113 Bonn, Germany

Correspondence should be addressed to S. Schmitt-Grohé; s.schmitt.grohe@uni-bonn.de

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Background. High-producer TGFβ1 genotypes are associated with severe lung disease in cystic fibrosis (CF), but studies combining IL-8, TNF-α, and TGFβ1 (+genotype) levels and their impact on CF lung disease are scarce. Aim. Assessing the relationship between TGFβ1, IL-8, and TNF-α and lung disease in CF in an exacerbation-free interval. Methods. Twenty four patients delta F508 homozygous (median age 20.5y, Shwachman score 75, FEV1(%) 83) and 8 controls (median age 27.5y) were examined. TGFβ1 was assessed in serum and induced sputum (IS) by ELISA, for IL-8 and TNF-α by chemiluminescence in IS and whole blood. Genotyping was performed for TGFβ1C−509T and T+869C utilizing RFLP.

Results. TGFβ1 in IS (CF/controls median 76.5/59.1pg/mL, \(P < 0.074\)) was higher in CF. There was a negative correlation between TGFβ1 in serum and lung function (LF) (FEV1 \(r = -0.488, P = 0.025\)), MEF 25 \(r = -0.425, P = 0.055\)), and VC \(r = -0.572, P = 0.007\)). Genotypes had no impact on TGFβ1 in IS, serum, and LF. In IS TGFβ1 correlated with IL-8 \(r = 0.593, P < 0.007\) and TNF-α \(r = 0.536, P < 0.018\) in patients colonized by bacteria with flagellin. Conclusion. TGFβ1 in serum not in IS correlates with LF. In patients colonized by bacteria with flagellin, TGFβ1 correlates with IL-8 and TNF-α in IS.

1. Introduction

It is well known that a higher TGFβ1 production and a high-producer TGFβ1 genotype are associated with the development of increased lung fibrosis [1]. Arkwright et al. [1] provided as the first evidence that individuals with the TGFβ1 +869TT genotype developed a more rapid decline in FEV1 compared to patients carrying one or two TGFβ1 +869C alleles in a cohort of 171 CFTR F508del homozygous patients from the UK. Though they could not confirm this association in 261 CF patients with delta F508 homozygous or compound mutations from Classes I, II and III in the CFTR gene [2]. The association of TGFβ1 codon 10 CC genotype and the TT genotype of −509 with more severe lung disease in delta F 508 homozygous cystic fibrosis patients was shown by Drummond and coworkers [3] in a large trial involving 808 CFTR T508 del homozygous patients. In contrast to the findings of Arkwright, they showed a significant association of the TGFβ1 +869CC and not +869TT genotype with more severe lung disease. A cohort of 329 French and German CF patients (out of them 171 F508del homozygous) were examined by Corvol et al. [4]. A less pronounced rate of decline in forced expiratory volume in 1 sec (FEV1) and forced vital capacity (FVC) in patients heterozygous for TGFβ1 +869 (+869CT) was observed, when compared to patients carrying either TGFβ1 +869TT or +869CC genotypes.

TGFβ1 is secreted by endothelial, hematopoietic, and connective tissue cells [5]. Major effects include inhibition of epithelial proliferation, induction of expression of genes encoding components of the extracellular matrix promoting fibrosis, and inhibition of expression of metalloprotease genes.

TGFβ1 is an important effector molecule in the development of pulmonary edema after acute lung injury [6].
Blocking TGFβ1 also prevents pulmonary edema in response to intratracheal endotoxin [7]. It directly increases the permeability of pulmonary endothelial monolayers and also increases the permeability of alveolar epithelial monolayers [6].

So far, few studies have measured TGFβ1 levels in cystic fibrosis patients. One study measured TGFβ1 in plasma of CF patients with a forced expiratory volume in 1 second (FEV1) <40% and found significantly higher values than in controls [8]. A recent study [9] has evaluated TGFβ1 in 11 samples of bronchoalveolar lavage samples in infants and young children and found a direct correlation with functional residual capacity (FRC).

Another study evaluated TGFβ1 in BAL in older children, with a pulmonary exacerbation [10]. TGFβ1 was elevated compared to controls and increase was associated with neutrophilic inflammation, diminished lung function, and recent hospitalization. In a second study [11] this group obtained TGFβ1 in BAL as well as in serum and plasma in children (pre- and postintravenous antibiotic therapy) hospitalized for pulmonary exacerbation. Plasma TGFβ1 was inversely associated with diminished lung function after therapy. Both studies describe short-time incidents.

To our knowledge there is no data comparing TGFβ1 levels in serum and in induced sputum and relating it to clinical data in an exacerbation-free interval which should reflect the long-term effect. We prefer that induced sputum as bronchoalveolar lavage is an invasive procedure and potentially risky and harmful to the patient.

There is scarce evidence that high TGFβ1 levels do have an impact on cystic fibrosis lung disease. So far it was shown that there is an association of such genotypes (that postulate high producer phenotypes) with severe lung disease in CF.

Recent research focused on the impact of bacterial flagellin on the expression of TGFβ1 and interleukin-8 [12] via mitogen-activated protein kinases (MAPK) in normal bronchial epithelial cells. So we were interested in Interleukin-8 (IL-8) and tumor necrosis factor alpha (TNF-alpha) as well. To our knowledge, there is so far no data comparing TGFβ1 and cytokines like IL-8 and TNF-alpha in induced sputum and blood in CF.

As TGFβ1 not only promotes fibrosis but also increases alveolar endothelial permeability, this might promote transfer of hematopoietic cells and TGFβ1 from blood into the lung. So we were interested in the relationship of TGFβ1 and leukocytes measured in induced sputum as well as in blood. To adjust for genetic heterogeneity in the CFTR gene only, individuals homozygous for delta F 508 were enrolled. As TGFβ1 inhibits CFTR biogenesis and prevents functional rescue of del F 508 in human bronchial epithelial cells [13], it seems even more important to examine individuals homogenous for del F 508.

Patients were examined in an exacerbation-free interval to exclude the stimulatory effects of ongoing acute infections.

The aim of the study was to provide evidence that TGFβ1 genotypes (+869T>C, −509C>T) as modifiers of CF lung disease correlate with ex vivo TGFβ1 assessed in serum and sputum in delta F 508 homozygous CF patients. Moreover, we were interested in the interaction of TGFβ1 and the levels of other proinflammatory cytokines in blood and sputum.

The findings of this study provide evidence that lung function correlates with TGFβ1 in serum but not in induced sputum. Genotypes in this small cohort did not have an impact on TGFβ1 in serum, sputum or lung function. There was a significant correlation between TGFβ1 in sputum and IL-8 as well as TNF-alpha in patients colonized by bacteria with flagellin.

2. Methods

2.1. Subjects. Patients with the delta F 508 (homozygous) mutation were recruited from the Cystic Fibrosis Outpatient Clinic of the Children’s Hospital Medical Center at the University of Bonn and the Department of Pediatric Pulmonary of the University of Frankfurt. Healthy individuals served as controls. Exclusion criteria were clinical or laboratory signs (CRP > 20 mg/L) of an exacerbation, treatment with systemic steroids 14 days preceding this trial, or participation in another study within the past 30 days. All subjects performed spirometry, gave a blood sample, and induced sputum. The protocol was approved by the ethics committee of the Universities of Bonn and Frankfurt, respectively. Informed consent was obtained from all patients, respective parents.

2.2. Spirometry. Lung function tests (vital capacity (VC), forced expiratory volume in one second (FEV1), maximum expiratory flow at 25% of forced vital capacity (MEF25)) were performed using a Master Screen Body, Fa. Viasys, Wuerzburg, Germany. To accurately assess the individual lung function, the median of three lung function tests (LFT No. 1–3) was used (No. 1 LFT app. 3 months before the cytokine measures were taken, No. 2 at the time the sputum and blood sample was provided, and No. 3 LFT app. 3 months after that).

2.3. Cytokine Assessment. Blood (9 mL) was collected in endotoxin-free collection tubes (EDTA, SARSTEDT Monovette, Nuembrecht, Germany). TGFβ1 was assessed in serum as well as in induced sputum (IS) by an ELISA kit (R&D Systems, Wiesbaden, Germany) according to the manufacturer’s manual.

According to the manufacturer, this assay has a high intra-assay precision for TGFβ1 (coefficient of variation (CV) of 1.9–2.9%), interassay precision (CV of 6.4–9.3%), and a sensitivity (mean) of 4.61 pg/mL. Concerning specificity as the assay recognizes both natural and recombinant TGFβ1, cross-reactivity was tested, and no significant cross-reactivity or interference was observed.

Interleukin-8 (IL-8) and TNF alpha were measured as previously described [14, 15]. In sputum (after processing following the subsequently mentioned protocol) IL-8 and TNF alpha were assessed by chemiluminescence (Immulite, Siemens Healthcare Diagnostics, Eschborn, Germany, formerly DPC Biermann).
2.4. Transforming Growth Factor β Genotype. DNA was extracted from EDTA blood samples using the QIAamp Kit (Qiagen, Germany). Genotypes for polymorphisms +869T/C and −509C/T were determined by standard PCR and restriction fragment length polymorphism (RFLP) after digestion with enzymes MspAI (+869T/C) and Bsu36I (−509C/T), respectively. Primer sequences and reaction conditions are available on request.

2.5. Sputum Processing, Cell Counting, and Cell Differentiation. The original protocol for sputum processing had been developed by Holz et al. [16] for preparation of induced sputum in asthma patients. Sputum of CF patients is viscous, often purulent and firm, and could not be processed by this method. So the protocol was modified to be suitable for CF sputum.

Inhalation of antibiotics was performed 8 hours prior to the sputum induction. In order to minimize bronchial constriction, patients inhaled 200 μg of salbutamol 10 minutes prior to sputum induction and then 3% saline solution for 10 to 12 minutes. The patients then expectorated sputum in a sputum tube. This was immediately put on ice and processed in the laboratory.

The sputum was weighed and transferred into a conical tube. The sample was diluted 1:3 with dithiothreitol 0.1% (DTT, Sigma Germany), vortexed, and incubated for 15 minutes at 38 °C with constant agitation. Thereafter, it was diluted 1:5 with phosphate buffered saline (PBS, Gibco, Invitrogen Corp., UK) and vortexed. Some undissolved sputum residues in the specimen were filtered with a cell strainer, placed into a new, weighed conical tube, and then centrifuged with the strainer (Falcon, USA) for 10 minutes at 350 g. After this, there was sputum residue in the cell strainer, as well as a supernatant and a cell pellet in the tube. The tube was again weighed without the cell strainer in order to calculate the amount of sputum in the tube as well as sputum residue in the cell strainer. The supernatant was distributed into 6 Eppendorf tubes and frozen at −80 °C for cytokine analysis.

The cell pellet was resuspended with 500 μL PBS/bovine serum albumin (BSA, Serva) 2%. An aliquot was diluted 10:1 with Trypan blue 0.4% (Sigma Aldrich, Germany) and a cell count was created by using a hemocytometer, and the amount of viable and dead cells (also using Trypan blue) was subsequently calculated.

2.6. Statistical Analysis. We compared outcomes for two groups using the Mann-Whitney U test for unpaired samples and the Wilcoxon test for paired samples. The correlations between quantitative data were estimated using Spearman correlation coefficient. All calculations were done by SPSS (Version 21.0).

3. Results

3.1. Patient Characteristics. Twenty-four patients (delta F 508 homozygous) (14 male and 10 female subjects) and eight controls (3 male and 5 female subjects) were recruited. Median age was 20.5 years (range 6–44 years) in patients and 27.5 years (range 25–38 years) in controls. Transforming growth factor β1 (TGFβ1) into sputum was available from all patients and controls, and TGFβ1 in serum was measured in 22 CF patients. Leukocyte counts in sputum were available in 23 patients and 8 controls. Blood leukocytes were counted in 23 patients and 4 controls. Twenty three patients were able to perform lung function. Nine patients had microbiologic evidence of Pseudomonas aeruginosa colonization. Eleven patients were colonized with S. aureus, 3 of them as well with Pseudomonas aeruginosa. Stenotrophomonas was detected in 5 patients. Serratia in 1 patient, who was colonized with Pseudomonas aeruginosa as well. Candida was found in 8 patients and 5 of them were colonized with Pseudomonas aeruginosa as well. There was microbiologic evidence of Aspergillus fumigatus in 6 patients; one was positive for Pseudomonas aeruginosa as well. Details are shown in Table 1.

| Table 1: Patients characteristics. | CF patients (n = 24) | Controls (n = 8) |
|----------------------------------|---------------------|-----------------|
| ΔF 508 (homozygous)              | +                   | –               |
| Age (years)                      | 20.5                | 27.5            |
| Sex (m/f)                        | (14/10)             | (3/5)           |
| BMI (kg/m²)                      | 20.4                | 21.6            |
| P. aeruginosa +                  | 9                   | –               |
| Shwachman score                  | 75                  | –               |
| FEV1 (% predicted)               | 83                  | –               |
| MEF 25 (% predicted)             | 36.7                | –               |
| VC (% predicted)                 | 84.9                | –               |

ΔF 508 (homozygous): homozygous for the ΔF 508 mutation; m: male; f: female; P. aeruginosa +: Pseudomonas aeruginosa colonization; FEV1 (% predicted): forced expiratory volume in 1 s in % predicted; MEF 25 (% predicted): maximum expiratory flow at 25% of forced vital capacity in % predicted; VC (% predicted): vital capacity in % predicted.

3.2. Transforming Growth Factor β in Serum and Induced Sputum. There was a trend for a significant difference for TGFβ1 in induced sputum between patients and controls (median 76.5/59.1 pg/mL, mean 79.53/57.85 pg/mL, range 42.2–195/36.1–70.6 pg/mL; P < 0.074). In CF patients TGFβ1 was significantly lower in induced sputum (IS) than in serum (median IS/WB 76.5/35.1 × 10³, mean 79.53/34.29 × 10³, range 42.2–195/(9.8–53.7) × 10³ pg/mL; P < 0.0001) (see Table 2). For TGFβ1 in serum and IL-8 in whole blood there was no correlation. This was also true for TGFβ1 in serum and TNF alpha in whole blood. But for TGFβ1, there was a significant correlation with IL-8 (r = 0.549, P < 0.0007) and TNF alpha (r = 0.491, P < 0.015) in induced sputum. Analyzing the correlation by carrier status of bacteria with flagellin (P. aeruginosa, S. aureus, or S. maltophilia), the data are more distinctive. For those who were negative, there was no correlation, but for those who had microbiological evidence of at least one bacteria the correlation was positive (TGFβ1/IL-8 r = 0.593, P < 0.007; TGFβ1/TNF alpha r = 0.536, P < 0.018) (see Figures 1 and 2).
### Table 2: TGFβ1 and leucocytes in blood and sputum.

|                  | CF patients (n = 24) | Control (n = 8) |
|------------------|----------------------|----------------|
| **TGFβ1 (pg/mL)**|                      |                |
| Serum            | 35.1 × 10^3          | —              |
| Sputum           | 76.5                 | 59.1           |
| Leucocytes (/μL) |                      |                |
| EDTA blood       | 6600                 | 6800           |
| Sputum           | 520                  | 60             |

*p < 0.074, *P < 0.036.

### Table 3: IL-8 and TNF-alpha in whole blood and sputum.

|                  | CF patients (n = 24) | Control (n = 8) |
|------------------|----------------------|----------------|
| **IL-8 (pg/mL)** |                      |                |
| Whole blood      | 12                   | 5*             |
| Sputum           | 5791                 | 28.3*          |
| **TNF-alpha (pg/mL)** |                |                |
| Whole blood      | 11.6                 | 17             |
| Sputum           | 29.6                 | 16.8*          |

*p < 0.01.

#### 3.3. Interleukin-8 in Whole Blood and Induced Sputum.

For IL-8 in whole blood, there was a significant difference between patients and controls (median 12/5 pg/mL, mean 46.5/10.8 pg/mL, and range 5–357/5–51.4 pg/mL; *P < 0.008). There was a significant difference for IL-8 in induced sputum between patients, and controls (median 5791/28.3 pg/mL, mean 9901.7/52.5 pg/mL, and range 52847–33.2/148–5 pg/ml; *P < 0.0001). In CF patients IL-8 was significantly higher in induced sputum (IS) than in whole blood (median IS/WB 5791/12, mean 9901.7/46.5, and range 52847–33.2/5–357 pg/mL; *P < 0.0001) (Table 3).

#### 3.4. Tumor Necrosis Factor Alpha in Whole Blood and Induced Sputum.

For TNF-alpha in whole blood, there was no significant difference between patients and controls (median 11.6/17 pg/mL, mean 64.91/17.2 pg/mL, and range 7.7–1000/8.4–373 pg/mL). There was a significant difference for TNF-alpha in induced sputum between patients and controls (median 29.6/16.8 pg/mL, mean 45.8/16.1 pg/mL, and range 13.6–146/13.4–178 pg/mL; *P < 0.0001). In CF patients TNF-alpha was significantly higher in induced sputum (IS) than in whole blood (median IS/WB 29.6/11.6, mean 45.8/64.9, and range 13.6–146/7.7–1000; *P < 0.024) (Table 3).

#### 3.5. Leukocyte Counts.

For leukocytes in induced sputum, there was a significant difference between patients and controls (median 520/60, mean 1253/81, and range 2–8480/10–240/μL; *P < 0.036). There was no significant difference between leukocytes in EDTA blood (median 6600/6800, mean 7353/6763, and range 4200–16290/6000–7450/μL) (Table 2).

#### 3.6. Transforming Growth Factor β1 and Lung Function.

As younger children have smaller lung volume, lung function data is only analyzed as percent predicted. There was no correlation between TGFβ1 in induced sputum and lung function. But there was a negative correlation between TGFβ1 in serum and FEV1 (*r = −0.488, *P = 0.025) (Figure 3). Moreover, there was a trend for a significant correlation between TGFβ1 in serum and MEF25 (*r = −0.425, *P = 0.055) (Figure 4) and a significant negative correlation between TGFβ1 in serum and VC (*r = −0.572, *P = 0.007) (Figure 5).
3.7. Interleukin-8 and Tumor Necrosis Factor Alpha and Lung Function. For IL-8 in induced sputum as well as whole blood, there was no correlation with lung function and between IL-8 in induced sputum and whole blood. But there was a significant negative correlation ($r = -0.508, P < 0.013$) for TNF-alpha in whole blood for MEF 25 as well as for FEV1 ($r = -0.447, P < 0.033$). For VC, there was no correlation with IL-8 as well as for lung function and tumor necrosis factor alpha in induced sputum.

3.8. Transforming Growth Factor β1 Genotypes. All subjects were genotyped for TGF-β1−509C/T and codon 10 (T+869C) polymorphism via PCR-RFLP, though this study was not sufficiently powered to evaluate for significant associations between TGFβ1 genotype and TGFβ1 serum levels. For C−509T subjects with one T (mutant = CT + TT) polymorphism were combined and for codon 10 we combined subjects with one C polymorphism (mutant = CT + CC).

3.8.1. Patient Characteristics and Influence on TGFβ1 and Leukocytes in Induced Sputum and Blood. This paragraph refers to the 23 patients who were able to perform lung function. TGFβ1 mutants (C−509T mutant/wildtype $n = 9/14$ (39%/61%)), respectively, and T+869C mutant (CT + CC/wildtype TT) (9/14 (39/61%) were equally distributed among patients. Patient characteristics did not show any significant differences with the exception of the sex distribution (Tables 4 and 5). Genotypes had no influence on levels of TGFβ1 in induced sputum (C−509T mutant/wildtype median 80.2/71.8pg/mL; T+869C mutant/wildtype median 80.2/71.8pg/mL, n.s) and serum (C−509T mutant/wildtype median $3.58 \times 10^3$/34.9 $\times 10^3$pg/mL, n.s; T+869C mutant/wildtype median $3.58 \times 10^3$/34.9 $\times 10^3$pg/mL, n.s) on leukocytes in induced sputum (C−509T mutant/wildtype median 651/495/μL, n.s; T+869C mutant/wildtype median 651/495/μL, n.s) and in EDTA blood (C−509T mutant/wildtype median 6325/6990pg/mL, n.s; T+869C mutant/wildtype median 6325/6990pg/mL, n.s) (Tables 6 and 7), lung function resp FEV1(%) (C−509T mutant/wildtype median 68.6/86.7%, n.s; T+869C mutant/wildtype median 68.6/86.7%, n.s) or BMI (C−509T mutant/wildtype median 21.9/19.2pg/mL, n.s; T+869C mutant/wildtype median 21.9/19.2, n.s).

4. Discussion

We were able to show that TGFβ1 in serum correlates negatively with lung function in cystic fibrosis. Moreover, we provided evidence that TGFβ1 in induced sputum is significantly lower than in serum in CF patients and that there is a trend for significantly higher TGFβ1 levels in CF.
patients than in healthy controls for induced sputum in an exacerbation-free interval.

A significant negative correlation between lung function in TGFβ1 in serum but not in induced sputum is an interesting finding. TGFβ1 can be activated either by an αβ6 or an αβ8-mediated pathway. The αβ6-mediated activation appears to be absolutely dependent on direct cell-cell contact and does not release any diffusible free TGFβ1 [17]. Such a pathway is ideally suited to the alveolar space. So TGFβ1 activated by this pathway can have an impact on lung function and will be influenced by high producer genotypes but will not be measureable in BAL, induced sputum, or blood. Release of free TGFβ1 is provided by activation by αβ8 integrin in the conducting airways [18]. This mechanism does not depend on direct cell-cell contact and should provide TGFβ1 able to diffuse away and to affect cells at a distance. Moreover, αβ8 mRNA is also expressed on a variety of leukocytes [19]. So our protocol was only able to assess the αβ8-dependent part of TGFβ1 contributing to lung disease.

Another reason for a significant negative correlation between lung function in TGFβ1 in serum but not in induced sputum could be attributed to higher stability of TGFβ1 in blood and its regulation. The circulatory system is characterized by an in and outflow, but the airways are a one-way system. So the influences of confounders like other inflammatory mediators in the lung can be an explanation for the lack of a correlation sputum TGFβ1 and lung function.

We could find higher TGFβ1 levels in serum in CF patients than in the CF cohort of Schwarz and co-workers [8]. The differences between their findings and ours can be explained by the following, we assessed TGFβ1 in serum and they measured it in plasma of heparinized blood.

Moreover, Harris et al. [11] also reported higher TGFβ1 levels in serum than in plasma.

One reason why we were not able to see any difference by genotype might be that we did not compare extreme phenotypes. But most importantly this study was not sufficiently powered to evaluate for significant associations between TGFβ1 genotype and serum TGFβ1 levels. Interestingly the two mutants examined occurred together in all but one patient (pt no. 9, excluded from the analysis as he was too young to perform lung function). So, we can speculate about a linkage disequilibrium. Evidence of a linkage disequilibrium (D’ = 0.94) for carriers of the C–509T and T869C SNP was provided by Guo et al. [20] for patients with increased risk of gastric cardiac adenocarcinoma.

An open question is why Peterson-Carmichael et al. [9] were able to provide evidence of a significant correlation between lung function (FRC) and TGFβ1 in BAL. First we did not measure FRC; second we cannot exclude that in a cohort of a median age of 86 weeks with 55.6% P. aeruginosa colonization the interaction of endotoxin and TGFβ1 [7] had an impact on lung function. In our cohort (median age 20.5 y), only 36% were colonized with P. aeruginosa. The TGFβ1 in the BAL was higher compared to our patients (median 107 versus 76.5 pg/mL, range (45–354) versus (42.2–195)). In addition, we cannot exclude that the percentage of a high-producer genotype was higher in their cohort. The data from Harris et al. [11] on TGFβ1 in BAL from older children (median 9.1 y) do not provide evidence that the high-producer genotype has an impact on TGFβ1 levels as only one out of 25 genotyped patients had the CC codon 10 genotype. Moreover, as BAL samples were collected in children experiencing a respiratory exacerbation, secondary effects of ongoing infections cannot be ruled out. The higher TGFβ1 levels in their study compared to our cohort might also be attributed to that (135 versus 76.5 pg/mL). Second,
as only 68% of their patients were delta F508 homozygous, the groups are not homogenous in terms of their CFTR mutation.

Different to the study by Harris et al. [11] with an inverse association of plasma TGFβ1 with diminished lung function after antibiotic therapy of a pulmonary exacerbation, we were able to show a significant negative correlation between lung function and TGFβ1 in serum in an exacerbation-free interval. The reason to assess TGFβ1 in serum and not in plasma was to study a mechanism of disease. We were interested in the propensity to produce TGFβ1, to prove the high-producer hypothesis. According to the manufacturer's manual, serum serves this purpose better than plasma. As discussed in the second paragraph, the possibility to assess TGFβ1 ex vivo is limited and it cannot be ruled out that the majority of TGFβ1 effects cannot be assessed ex vivo. Our aim was not to establish a biomarker, which was one of the results of the intervention-related study of Harris et al.

The only study which could provide evidence of a correlation between TGFβ1 in plasma of 56 CF patients and TGFβ1 genotype is the French-German study by Corvol et al. [4]. Higher plasma levels of TGFβ1 were observed in patients carrying the TGFβ1 +869TT genotype (mean value 35.0 ng/mL). The +869CT genotype had an intermediate TGFβ1 level (22.9 ng/mL) and the +869 CC genotype had lower TGFβ1 levels (8.7 ng/mL). Interestingly, this genotype as well as the higher producer +869TT level had a higher rate of decline in LFT than the +869CT genotype. Those with the lowest TGFβ1 levels in plasma had more severe phenotype than those with the CT genotype. Their data might question the value of measurements of TGFβ1 in plasma. For the TGFβ1 polymorphism at position −509 there was no significant association with TGFβ1 plasma levels.

Vital capacity values in this study correlated better with TGFβ1 in serum than FEV1 and MEF 25%. Concerning the proinflammatory cytokines IL-8 and TNF-alpha, there was no correlation with VC, reflecting the profibrotic effect which is a specific feature of TGFβ1.

Interestingly, cytokines in induced sputum as IL-8 and TNF-alpha correlated significantly with TGFβ1. An explanation might be provided by the following; bacterial flagellin is part of bacteria like P. aeruginosa [21], S. aureus [22], and S. maltophilia [23]. Yang et al. [12] provided evidence that flagellin from P. aeruginosa induces TGFβ1 and IL-8 expression in normal bronchial epithelial cells in vitro via MAP kinases.

In our study there were correlations for TGFβ1 and IL-8 as well as TNF-alpha in sputum regardless if the patients were positive or negative for P. aeruginosa. But if analyzing the correlation by carrier status of bacteria with flagellin (P. aeruginosa, S. aureus, or S. maltophilia), the data are more distinctive. For those who were negative, there was no correlation, but for those who had microbiological evidence of at least one bacteria the correlation was positive (TGFβ1/IL-8 $r = 0.593, P < 0.007$; TGFβ1/TNF alpha $r = 0.536, P < 0.018$).

So colonization with bacteria with flagellin (P. aeruginosa, S. aureus, or S. maltophilia) might be the reason for coexpression of TGFβ1 and cytokines like IL-8 or TNF-alpha in the CF lung. This might prompt the clinician to favor eradication of these bacteria.

What is striking are the extremely high IL-8 levels in IS compared to TNF alpha. Explanations are the following: downregulation of IL-8 receptors in the presence of elastase [24], ribonuclear protein hnRNP (A2B1) binding to the IL-8 promoter, and hyperproduction of IL-8 mRNA in bronchial epithelial cells [25]. Moreover, Sagel et al. [26] also found tremendous differences between IL-8 and TNF alpha in IS in a longitudinal cohort study with 35 CF children with annual measurement for a period over 3 years.

Another effect of TGFβ1 is the increase in alveolar endothelial permeability [7]. We interpret the higher leukocyte levels in sputum of CF patients compared to controls in this regard. This effect is robust even when analyzing only patients who are negative for P. aeruginosa.

In conclusion, the findings of this study provide evidence that lung function correlates with TGFβ1 in serum but not in induced sputum. Genotypes in this small cohort did not have an impact on TGFβ1 in serum or sputum neither lung function. In IS, there might be a concomitant upregulation of TGFβ1 and IL-8 as well as TNF alpha in CF patients colonized by bacteria with flagellin like P. aeruginosa, S. aureus, and S. maltophilia.

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