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Sputum colour: a useful clinical tool in non-cystic fibrosis bronchiectasis

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ABSTRACT: This study explored the utility of sputum colour in clinically stable patients with bronchiectasis.

Interpretation of sputum colour between the doctor and the patient was reliable (intraclass correlation coefficient 0.83 (95% confidence interval 0.76–0.89). Sputum colour predicted bacterial colonisation (5% in mucoid sputum; 43.5% in mucopurulent sputum; 86.4% in purulent sputum; p<0.0001). On multivariate logistic regression analysis, independent factors associated with purulent sputum were bacterial colonisation, varicose or cystic bronchiectasis, forced expiratory volume in 1 s <80% predicted and diagnosis of bronchiectasis aged <45 yrs.

KEYWORDS: Bacterial colonisation, bronchiectasis, sputum colour

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Bronchiectasis is characterised by a persistent cough, excessive sputum production and recurrent chest infections [1, 2]. A vicious cycle of damaged airways, excessive neutrophilic inflammation and chronic bacterial colonisation exists, perpetuating the constant symptoms [3].

In patients with chronic bronchitis and bronchiectasis, STOCKLEY *et al.* [4] demonstrated that with increasing sputum purulence there is increasing neutrophilic airways inflammation. The aim of the present study was to explore the utility of sputum colour in clinically stable patients with bronchiectasis. We assessed the interobserver reliability of interpretation of sputum colour between doctor and patient, assessed whether sputum colour can predict bacterial colonisation and explored independent factors associated with expectoration of purulent sputum.

METHODS

This was a 29-month prospective cohort study of patients attending the bronchiectasis clinic, approved by the Lothian Research Ethics Committee (Lothian, UK). Additional information on the methodology can be found in the supplementary material.

Sputum colour chart

We developed a sputum colour chart using photographs of bronchiectasis sputum representing the three typical gradations of colour: mucoid (M; clear), mucopurulent (MP; pale yellow/pale green) and purulent (P; dark yellow/dark green) (fig. 1a). The reliability of the chart for doctor and patient interpretation was assessed and internal consistency measured.

Assessment in clinically stable disease

All patients had an established diagnosis of bronchiectasis based on clinical history and computed tomography (CT) scanning of the chest [5].

Inclusion criteria were: clinically stable (no requirement for antibiotics in the preceding 4 weeks) and CT chest scan within 3 yrs of study inclusion (or within 12 months, in the case of clinical deterioration or decline of >200 mL and 12% in forced expiratory volume in 1 s (FEV_1) [6]).

Exclusion criteria were: cystic fibrosis; active tuberculosis or active allergic bronchopulmonary aspergillosis or active sarcoid; poorly controlled asthma; chronic obstructive pulmonary disease (COPD) [7]; regular oral corticosteroids or non-steroidal anti-inflammatory drugs (NSAIDs) or long-term antibiotics (LTABx); and current and ex-smokers of ⩽2 yrs.

Sputum collection and analysis

Patients collected all sputum expectorated on the morning of their clinic appointment in a sterile container (colour graded by A.T. Hill). For patients with multiple appointments, only the first sample was used.

Sputum bacteriology

All samples with >25 polymorphonuclear leukocytes and <10 squamous cells on gram stain were

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considered as valid sputum samples and processed for qualitative bacterial culture [8]. Mycobacterial and fungal cultures were not performed. Patients with mixed normal flora or no growth were defined as ''not colonised''.

Lung function

FEV1 and forced vital capacity (FVC) were measured by pulmonary function technicians according to standardised guidelines on the day of sputum collection [9].

Systemic inflammation

All patients had venous blood sampled for C-reactive protein (CRP) on the day of sputum collection (normal CRP is <10 mg·L^{-1}).

Radiology

CT scans were assessed for the number of lobes involved (the lingula was considered a separate lobe) and the maximum type of bronchial dilatation was recorded: cylindrical, varicose or cystic [10].

Health-related quality of life

The St George's Respiratory Questionnaire (SGRQ) was completed immediately prior to the clinic appointment [11]. The total score ranges from 0 to 100, a higher score indicating a poorer health-related quality of life (HRQoL). A 4-unit difference is thought to be clinically significant.

Statistics

Statistical analysis was performed using SPSS for Windows, Version 16 (SPSS, Chicago, IL, USA). The intraclass correlation coefficient and Cronbach's α-coefficient were used to assess reliability and internal consistency of the colour chart. For subsequent analysis, the doctor colour score was used. A multivariate forward logistic regression analysis was performed to assess the risk factors for purulent sputum. A p-value of <0.05 was used for entry into the model. Multicollinearity was assessed using the variance inflation factor (VIF), with a VIF <2.5 regarded as excluding any significant interaction [12]. The dependent variable was purulent sputum. Independent variables were age >65 yrs; FEV1 $<80\%$ predicted; CRP >10 mg·L^{-1}; inhaled corticosteroids; *Pseudomonas aeruginosa*; *Haernophilus influenzae*; other potential pathogenic micro-organisms (PPMs); varicose or cystic bronchiectasis; >1 lobe affected; aetiology (post-infective, idiopathic or other causes); age <45 yrs at diagnosis. Data are presented as median (interquartile range (IQR)). Fisher's exact test and the Kruskal–Wallis test were used to compare groups. A two-tailed p-value of <0.05 was considered statistically significant.

RESULTS

Sputum colour chart

A total of 141 individual patients' sputum samples were graded using the colour chart by both doctor and patient.

Agreement was 80.9% in the mucoid group, 90.3% in the mucopurulent group and 76.3% in the purulent group. In all cases of disagreement, except five (21.7%), the doctor interpretation was of greater purulence than the patient interpretation.

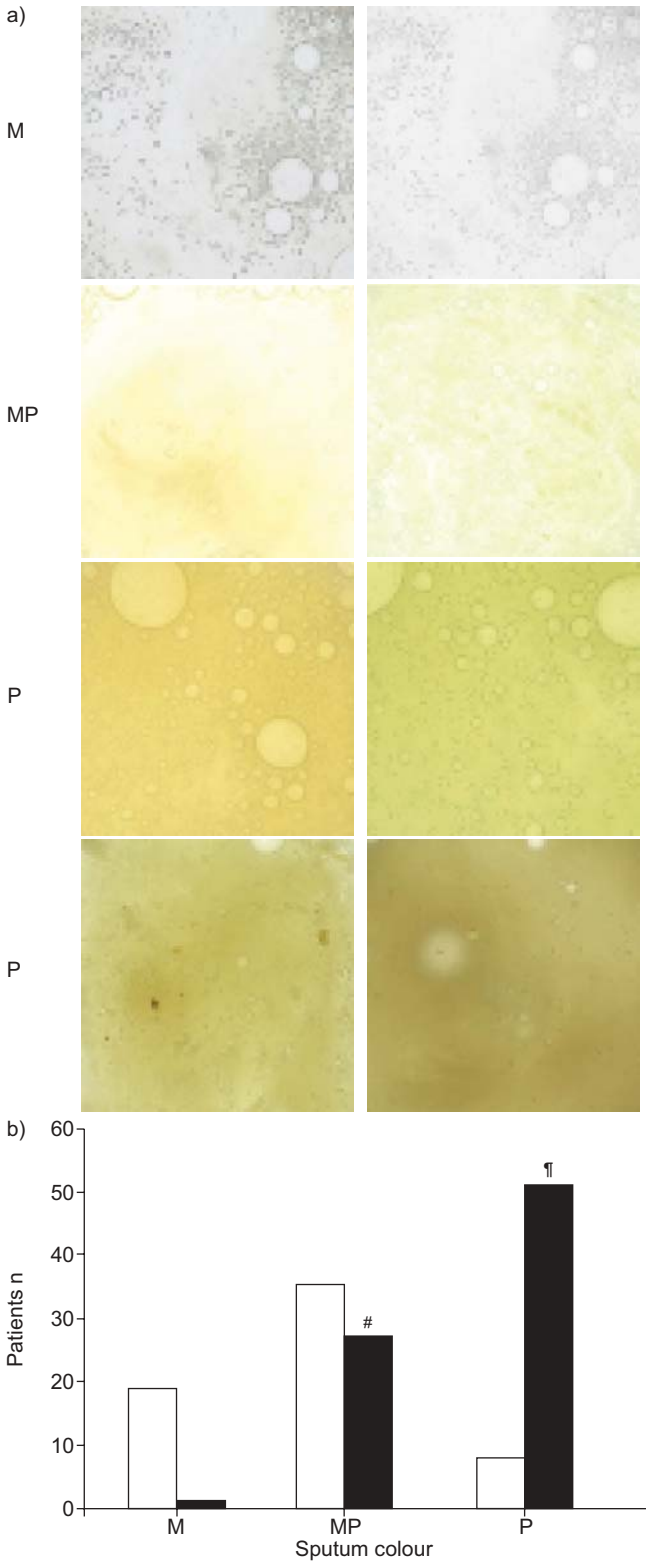

FIGURE 1. a) Sputum colour chart. b) Sputum colour and bacterial colonisation. M: mucoid; MP: mucopurulent; P: purulent. □: no pathogens present; ■: pathogens isolated. #: p=0.001 when comparing bacterial colonisation in mucopurulent sputum with presence in mucoid sputum; ¶: p<0.0001 when comparing bacterial colonisation in purulent sputum with colonisation in mucopurulent and mucoid sputum.

TABLE 1 Clinical features and characteristics of patients with mucoid, mucopurulent and purulent sputum

Variable	Mucoid	Mucopurulent	Purulent	p-value
Patients n	20	62	59	
Age yrs	70.5 (66.2–74)	69 (59–77)	64 (57–71.5)	0.06
Males	5 (25)	25 (40.3)	21 (35.5)	0.4
Age at diagnosis yrs	64.5 (58.5–70)	58 (43–70)	49.5 (36–66)	0.03
FEV_1 L	1.6 (1.16–2.11)	1.90 (1.35–2.5)	1.52 (1.28–1.90)	0.03
FEV_1 % pred	78.7 (54.6–92.7)	78.2 (62.2–94.8)	65 (50–77)	0.005
FVC L	2.26 (1.8–3.04)	2.45 (2.07–3.72)	2.43 (1.98–3.17)	0.2
FVC % pred	83 (76–98)	86.5 (74.1–99.7)	77 (64–89)	0.03
FEV_1/FVC	0.76 (0.67–0.87)	0.70 (0.59–0.81)	0.68 (0.52–0.76)	0.03
FEV_1/FVC % pred	98 (70–113)	93 (75–99)	85 (68–95)	0.09
Lobes affected n	2 (2–4)	3 (2–5)	4 (3–5)	0.03
Varicose or cystic dilatation	7 (35)	25 (40.3)	48 (81.3)	<0.0001
Inhaled steroids	4 (20)	29 (46.7)	37 (62.7)	0.004
Beclomethasone equivalent daily dose [13] μg	1500 (550–2000)	1000 (950–2000)	2000 (1000–2000)	0.52
CRP $mg \cdot L^{-1}$	3 (1–10)	4 (1–8)	5 (2–10)	0.2
SGRQ total score units	30.0 (15.7–41.9)	29.9 (18.5–57.5)	46.2 (27.0–58.7)	0.04

Data are presented as median (interquartile range) or n (%), unless otherwise stated. FEV_1: forced expiratory volume in 1 s; % pred: % predicted; FVC: forced vital capacity; CRP: C-reactive protein; SGRQ: St George's Respiratory Questionnaire.

The intraclass correlation coefficient was 0.83 (95% CI 0.76–0.87; $p<0.0001$) and Cronbach's α-coefficient was 0.91.

Aetiology

Aetiology was idiopathic (29.8%), post-infective (53.2%), inactive allergic bronchopulmonary aspergillosis (7.8%), immunoglobulin (Ig)G_2 deficiency (<2.41 $g \cdot L^{-1}$) (3.5%); inactive sarcoidosis (2.1%), inflammatory bowel disease (2.1%) and connective tissue disease (1.5%).

Bacterial colonisation

A total of 20 patients had mucoid sputum. One (5%) was colonised (*P. aeruginosa*).

62 patients had mucopurulent sputum. 27 (43.5%) were colonised (*P. aeruginosa* (n=11), *H. influenzae* (n=7), *Streptococcus pneumoniae* (n=4), *Moraxella catarrhalis* (n=3), *Staphylococcus aureus* (n=2)).

59 patients had purulent sputum: 51 (86.4%) were colonised (*H. influenzae* (n=21), *P. aeruginosa* (n=15), *S. aureus* (n=5), *S. pneumoniae* (n=4), *M. catarrhalis* (n=2), *Serratia marcescens* (n=2), *Stenotrophomonas maltophilia* (n=1), methicillin-resistant *S. aureus* (n=1)).

More patients with purulent sputum were colonised than patients with mucopurulent and mucoid sputum (86.4 *versus* 43.5 and 5% respectively; $p<0.0001$) (fig. 1b).

Disease severity

Table 1 details the age, sex, lung function, radiological features, systemic inflammation and HRQoL for each grade of sputum: for patients with purulent sputum, bronchiectasis was diagnosed younger; FEV_1 was lower; number of lobes involved and presence of varicose or cystic bronchiectasis was greater; HRQoL was worse and more were on inhaled corticosteroids.

Independent factors predictive of purulent sputum

All factors had a VIF of <2.0. Independent factors were FEV_1 <80% pred, varicose or cystic bronchiectasis, bacterial colonisation and bronchiectasis diagnosed aged <45 yrs. (table 2).

DISCUSSION

We developed a quantitative method that allows clinicians to report sputum colour. The colour chart is unique, as it uses photographs of bronchiectasis sputum, providing accurate representation of the three major grades of colour, and had good interobserver reliability between the doctor and patient.

This study involved patients with stable bronchiectasis only and found that sputum purulence correlated with bacterial colonisation. Sputum colour may therefore be a useful adjunct to clinical management while awaiting formal sputum microbiology results.

TABLE 2 Multivariate logistic regression analysis of factors predictive of purulent sputum in clinically stable bronchiectasis

Factor	Adjusted OR (95% CI)	p-value
FEV_1 <80% pred	4.9 (1.7–14.3)	0.004
Pseudomonas aeruginosa	5.5 (1.5–20.8)	0.01
Haemophilus influenzae	5.8 (1.6–21.2)	0.007
Other potentially pathogenic micro-organisms	10.9 (2.3–50.3)	0.002
Varicose or cystic bronchiectasis	8.7 (2.8–26.7)	<0.0001
Diagnosed aged <45 yrs	3.1 (1.04–9.5)	0.04

FEV_1: forced expiratory volume in 1 s; % pred: % predicted.

Independent factors for expectoration of purulent sputum were pathogenic organism (independent of type), presence of varicose or cystic bronchiectasis, FEV_1<80% pred and age <45 yrs at initial diagnosis. Bacterial colonisation of the airways promotes neutrophilic airways inflammation causing increased sputum purulence [4, 14, 15]. The number of lobes involved on CT scan was not found to be an independent risk factor, implying that the severity of bronchial dilatation alone independently predicts sputum purulence. An impaired FEV_1 (<80% pred) was associated with purulent sputum, probably reflecting the severity of bronchiectasis, as patients with COPD or poorly controlled asthma were excluded. These findings are similar to those of ANGRILL *et al.* [16], who demonstrated both the presence of varicose or cystic bronchiectasis and an FEV_1 <80% pred to be independent risk factors for bacterial colonisation. ANGRILL *et al.* [16] found age <14 yrs at diagnosis to be a risk factor for bacterial colonisation. Our study confirmed an earlier diagnosis of bronchiectasis was similarly associated with purulent sputum, but with an older cut-off age (<45 yrs).

We observed that patients with purulent sputum had a poorer HRQoL, which supports previous studies that have explored the effect of bacterial colonisation on HRQoL [17].

Study limitations include the timing of the CT scan, inclusion of patients on inhaled corticosteroids and use of a non-highly sensitive CRP assay. CT scans in this study were not performed contiguously with grading of sputum colour. SHEEHAN *et al.* [18] have demonstrated that radiological progression may occur in a 28-month interval. All scans were, however, performed within a 36-month period and no patient required a repeat CT scan during this time for clinical deterioration. We excluded patients who had been prescribed long-term oral corticosteroids (11.8%) and NSAIDs (1.2%), as these drugs may reduce airways inflammation, and also those prescribed LTABx (3.5%), because of the potential affect on airway colonisation. However, patients receiving inhaled corticosteroids (41.4%) were included. Inhaled corticosteroids over 4 weeks have been shown to reduce sputum inflammatory indices but long-term studies have not shown them to affect sputum purulence or microbiological profile [19–21]. Our study did not observe any association between purulence and systemic inflammation but we did not use a highly sensitive CRP assay (<10 $mg \cdot L^{-1}$ was considered normal). Furthermore, patients were studied when clinically stable, not during exacerbations when systemic inflammation may have a greater role.

In conclusion, assessing sputum colour using a chart in bronchiectasis may provide both patients and physicians with a consistent, simple and noninvasive method to assess and monitor disease.

SUPPORT STATEMENT

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STATEMENT OF INTEREST

None declared.

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