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Independent Association of Younger Age with Hemoptysis in Adults with Pulmonary Tuberculosis

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Abstract

Background—The risk factors for mild to moderate hemoptysis in patients with pulmonary tuberculosis (PTB) are not entirely clear. The objective of this study was to evaluate factors for their independent association with the occurrence of hemoptysis in patients with PTB.

Design—Cross-sectional study of adult patients newly diagnosed with microbiologically proven PTB in a New York City hospital. Patients were categorized into subjects with and without hemoptysis and compared via univariate analysis. Independent associations of variables with hemoptysis were estimated with multivariate logistic regression.

Results—Of 194 subjects with PTB, 44 (23%) had hemoptysis. In univariate analysis, subjects with hemoptysis were significantly younger ($p=0.003$) and more likely to be undocumented foreign-born ($p=0.038$) compared to subjects without hemoptysis. In multivariate analysis, only younger age was independently associated with hemoptysis. This association was significant for a continuous decrease in age per year, or per decade (OR_{adj} 1.59; $p=0.003$).

Conclusions—Younger age is an independent risk factor for hemoptysis in PTB. It is conceivable that a stronger inflammatory response in younger compared to older age could contribute to pulmonary pathogenesis and injury in PTB.

Keywords

inflammation; immunologic factors; pathogenesis

Introduction

Globally, more than 9 million persons develop active tuberculosis (TB) annually.¹ Even in the U.S. where the incidence continues to decline, TB remains an important cause of morbidity, especially in urban settings where high proportions of foreign-born persons from TB endemic countries live.² Although less common than other pulmonary TB (PTB) related symptoms such as cough, fever, night sweats and weight loss, hemoptysis is one of the

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hallmark symptoms which occurs in an estimated 15–28% of PTB patients.^{3–5} While massive hemoptysis occurs less frequently (1–5%),⁶ any amount of blood in the sputum is an important and alarming symptom that can be coupled with considerable morbidity. Massive hemoptysis is presumably due to rupture of a dilated bronchial artery which is typically associated with various degrees of ulceration and dilatation of blood vessels within or near the cavitory wall.^{6–9} However, several studies indicate additional possible mechanisms involved in fatal hemoptysis,^{6–7} and the underlying mechanisms of mild to moderate hemoptysis remain largely unclear. Importantly, while many PTB patients have cavitory lesions only a proportion of those develop hemoptysis for which the risk factors are mostly unknown.

In a recent study of PTB patients in New York City, we found a significantly increased frequency of hemoptysis in undocumented foreign-born compared to US-born persons, although cavitory lesions were present in a similar proportion in both groups.¹⁰ In that study, undocumented foreign-born compared to US-born persons were significantly longer symptomatic prior to initial medical evaluation (median of 8 versus 4 weeks, respectively; $p=0.014$) and were also significantly younger (mean of 33 ± 10 versus 45 ± 12 years, respectively; $p<0.001$). These results suggest a potential association of longer symptom duration and/or younger age with hemoptysis. The association with younger age is supported by several studies that found a higher occurrence of hemoptysis in younger (mostly 16–59 or 16–64 years old) compared to older (over 59 or 64 years old) adults with PTB, although in a meta-analysis only 5/10 studies supported such findings (reviewed in ¹¹ and ^{12–13}). In addition, cavitory lesions were also more common in younger compared to older adults in some of these studies (reviewed in ¹¹ and ^{12–13}). However, none of the studies examined associations via multivariate analysis, and thus, to our knowledge, no study as of to date has determined whether younger age is an independent risk factor for hemoptysis. Furthermore, these studies were limited by dichotomization of age into “young” and “old” with various cut-offs levels. Therefore, the objective of the here presented study was to identify factors that are independently associated with hemoptysis in patients with PTB. Identification of such risk factors could generate new hypotheses regarding the immunopathogenesis of pulmonary damage in TB and might also have diagnostic and therapeutic implications.

Methods

Design, Setting and Study Population

In this cross-sectional study we reviewed the medical records of all identifiable patients 18–99 years old who were diagnosed with PTB between April 1999 and March 2005 at Bellevue Hospital Center, a public hospital located in midtown Manhattan, New York, NY. Records of patients who were reported to the Department of Health as new probable active TB were screened, and the records of patients with microbiologically proven TB were reviewed. Patients whose diagnosis of PTB was confirmed by growth of MTB in a respiratory specimen were included in the analysis. Patients were excluded from analysis if they were diagnosed with extrapulmonary TB without microbiologically proven pulmonary disease, if they were diagnosed with TB and treated at a different setting prior to admission to Bellevue Hospital Center, or if information was missing on important variables such as

documentation status or clinical symptoms. Exempt status for a retrospective chart review was obtained from the Institutional Review Boards of the New York University School of Medicine and Bellevue Hospital Center.

Measurements

Our main variable of interest was the presence of hemoptysis. Any degree of blood reported in the sputum was considered as hemoptysis. Subjects with PTB were categorized into two groups, patients with and without hemoptysis. Information on reported variables was extracted from the patients' medical records. The patients' self-reported location of birth was extracted from the physician's note, while self-reported information on documentation status was extracted from the social worker's note. Chest X-ray results were recorded as either unilobar versus multilobar or miliary infiltrates with separate scoring for the presence of cavitary lesions. Sputum smears for acid fast bacilli (AFB) were recorded as positive if at least one of the initial three smears was positive regardless of quantity of AFB seen per microscopy slide. Furthermore, taking the smear with the highest quantity of AFB into account, the degree of smear-positivity was categorized into no, rare (1–10), moderate (11–20) and numerous (>20) AFB per slide. The patients' self-reported symptoms that were recorded as potentially suggestive of pulmonary TB included the presence of hemoptysis, cough, fever, night sweats, and weight loss over 4 lbs. For each of these symptoms the duration was recorded in weeks prior to hospital evaluation. The longest duration of any one of these symptoms was recorded as the symptom duration.

Statistical Analysis

Statistical analysis was performed using STATA software, version 9.2 (StataCorp, College Station, TX). A two-tailed $\alpha < 0.05$ was considered to be statistically significant. For univariate analysis, depending on distribution, we used the *t* test for normally distributed variables and the Mann-Whitney *U* test for skewed variables. For categorical variables we used the chi-square test without correction for continuity. Multivariate logistic regression models were constructed to test whether there was an independent association between the outcome variable hemoptysis and other variables. Our main dependent variables of interest were age (in years or decades), symptom duration, and documentation status. We explored age by creating a lowess univariable smoothed scatterplot on the logit scale for hemoptysis.¹⁴ This plot showed a linear decrease from age 20 to 80 supporting the treatment of age as a continuous variable in our logistic regression models. Symptom duration, due to skewed distribution, was dichotomized with a cutoff of 8 weeks based on the median duration of 7 weeks for all subjects included in the analysis. Other variables whose association with outcome had a *p* value < 0.2 in univariate analysis or which were known or considered to have an impact on the presence of hemoptysis, such as presence of cavitary lesions, were initially included in the model. In an additional analysis, we tested for independent associations of variables with the presence of cavitary lesions. Adequacy of the final models was assessed by the goodness-of-fit test.

Results

Two-hundred ten patients with newly diagnosed microbiologically proven PTB were identified of whom 194 were eligible for inclusion in the analysis. Sixteen patients were excluded from analysis because of incomplete clinical data such as missing information on duration of symptoms. Of the 194 PTB patients, 44 (23%) reported the presence of hemoptysis at their initial hospital evaluation. In the majority of records the degree of hemoptysis was not further quantified. However, none of the subjects were reported to have massive hemoptysis requiring an intervention. The subjects' age ranged from 18–79 years.

Comparison of demographic characteristics between subjects with and without hemoptysis

In univariate analysis, subjects with hemoptysis were significantly younger ($p=0.003$) and more likely to be undocumented foreign-born ($p=0.038$) compared to subjects without hemoptysis (Table 1). Otherwise there were no significant differences in the distribution of demographic characteristics between the two groups.

Comparison of diagnostic test results and clinical symptoms between subjects with and without hemoptysis

In univariate analysis, no significant differences in the presence of HIV infection, multilobar or miliary infiltrates, detectable cavitary lesions or sputum smear-positivity were found between subjects with compared to subjects without hemoptysis (Table 2). In contrast, subjects with hemoptysis had a significantly higher occurrence of cough ($p<0.001$) and a significantly longer symptom duration ($p=0.038$) prior to hospital evaluation than subjects without hemoptysis.

Independent association of variables with the presence of hemoptysis

In multivariate analysis, only younger age was independently and statistically significantly associated with the presence of hemoptysis. This association was significant for a continuous decrease in age per each year (odds ratio (OR) 1.05, $p=0.003$), or per decade (OR 1.59, $p=0.003$; Table 3a–b). Neither foreign birth nor documentation status, nor symptom duration, nor presence of detectable cavities, or quantity of AFB in sputum, was significantly associated with the presence of hemoptysis, and no interactions between these variables and age was found. Because several studies report an increased occurrence in cavitary lesions in younger compared to older adults in univariate analysis, we performed an additional multivariate analysis to test for independent associations of variables with the presence of cavitary lesions. A positive HIV status significantly decreased the odds of having cavitary lesions (OR 0.37, $p=0.003$; Table 4a–b), while prolonged symptom duration over 7 weeks was nearly significantly associated with the presence of cavitary lesions (OR 1.80, $p=0.056$). In contrast, neither age nor any of the other demographic or clinical variables were associated with the presence of detectable cavitary lesions.

Discussion

To our knowledge, this is the first study demonstrating that younger age is an independent risk factor for hemoptysis in adults with PTB. This finding is supported by several studies which, in univariate analysis, found that hemoptysis occurs significantly more common in younger compared to older adults (reviewed in ¹¹ and ¹²). The evaluation of such association in multivariate analysis is important in order to adjust for other potentially confounding and clinically relevant factors, such as the presence of cavitory lesions which could also be associated with hemoptysis. Furthermore, we demonstrate for the first time that not only age dichotomized into young and old (as in prior studies), but also a continuous decrease of age per year or decade is independently associated with hemoptysis. These findings suggest that age plays an independent role in the immunopathogenesis of pulmonary damage in TB.

The clinical manifestations of TB are strongly influenced by the host immune response.^{15–16} On the one hand, immunodeficiency is permissive of increased bacillary replication and subsequent disease development; on the other hand a potent immune response can also lead to disease manifestations via strong inflammatory responses resulting in host damage. The best example of the latter is the paradoxical worsening of signs and symptoms of TB in temporal relation to immune restoration. This can occur in association with initiation of antiretroviral treatment in HIV-infected individuals ^{17–19} or with withdrawal of immunosuppressant therapies.²⁰ The benefit of the adjunctive use of immunosuppressant drugs (e.g. corticosteroids) in certain TB cases, such as tuberculous meningitis and pericarditis, is further evidence of host damage by a strong immune response.^{21–24} Therefore, one of the possible hypotheses for the independent association of decreasing age with hemoptysis is pulmonary damage caused by a more aggressive immune response in earlier compared to later adult life.

Immunosenescence is a well-known state of profound age-related changes in the immune system. In humans as well as in animal models these changes are mostly manifested by an overall decline of the adaptive immunity but also lead to a decline of the innate immunity.^{25–28} For example, reductions in neutrophil function and superoxide production have been observed with aging in humans.^{29–30} Regarding age-related impaired immune responses in the lungs, compared to younger mice older animals infected with sublethal doses of influenza virus have a delayed accumulation of granulocytic and conventional dendritic cells.³¹ The aged animals also show a delayed infiltration of antigen presenting cells in the lung which correlated with delayed detection of cytokines and chemokines, thereby demonstrating the considerable impact of age on immune responses in the lungs.

We neither found a significant difference in the presence of detectable cavitory lesions between patients with and without hemoptysis in univariate analysis, nor a significant association between cavitory lesions and hemoptysis in multivariate analysis. We also did not find a significant association of prolonged symptom duration with hemoptysis. Because several studies report an increased occurrence in cavitory lesions in younger compared to older adults in univariate analysis (reviewed in ¹¹ and ¹³), we performed an additional multivariate analysis to test for independent associations of variables with the presence of cavitory lesions. Prolonged symptom duration but not age was nearly significantly

associated with the presence of cavitory lesions. In contrast, HIV infection significantly decreased the odds of having cavitory lesions. These findings are not surprising and in concordance with many studies reporting clinical manifestations of TB. Pulmonary cavitory lesions are often found in patients from resource-limited countries who have been symptomatic for many months supporting the association between prolonged duration of untreated disease and the formation of cavities. The impairment of granuloma formation in HIV-associated TB is likely contributing to the lower rates of cavitation reported in many radiographic studies (reviewed in ¹⁵). However, in contrast to some prior studies we did not find any significant association between younger age and the detectable presence of cavitory lesions.

The occurrence of hemoptysis in our study population was with 23% similar to the range of 15 to 28% reported in other studies.^{3–5} Our study was limited by the lack of quantification of hemoptysis similar to most of the studies we reviewed. We assume that the majority of our study subjects had mild-moderate hemoptysis because none were reported to have massive hemoptysis requiring any kind of intervention. While we concur that massive hemoptysis due to rupture of bronchial arteries is likely due to the erosion of the vessel walls caused by cavitory lesions,^{6–9} even fatal pulmonary hemorrhage appears to be more common between the ages of 20 to 39 compared to 40 and older.⁶ Our findings suggest that additional mechanisms are responsible for mild to moderate hemoptysis in PTB patients. The independent association of an incremental decrease in age with the occurrence of hemoptysis suggests that the stronger inflammatory response observed in younger compared to older age could contribute to the damage of small pulmonary vessels.^{29–33} Hence, the question arises whether young adults with PTB-associated hemoptysis might benefit from immunomodulating therapy. Although adjunctive corticosteroid therapy has not demonstrated any long-term benefit in PTB and tuberculous pleurisy, it has resulted in significantly faster resolution of clinical manifestations which would be critical in the setting of hemoptysis.^{34–35}

In conclusion, our study demonstrates an independent association of younger age with hemoptysis in adults with PTB. It is conceivable that our findings could be due to a stronger inflammatory response in younger compared to older adults causing a higher degree of pulmonary damage. Further studies are warranted to investigate whether age plays a critical role in the immunopathogenesis of TB.

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Table 1

Demographic characteristics of 194 subjects with PTB according to presence or absence of hemoptysis

Characteristic	PTB with hemoptysis N=44	PTB without hemoptysis N=150	P value
Male sex, n (%)	27 (61)	110 (73)	0.125 ^a
Age, mean±SD	35±11	41±12	0.003 ^b
Race, n (%)			
Black	7 (16)	42 (28)	0.196 ^a
Hispanic	11 (25)	34 (23)	
Asian	25 (57)	64 (43)	
White	1 (2)	10 (7)	
Location of birth and documentation status (%)			
US-born *	9 (20)	52 (35)	
Documented foreign-born	11 (25)	51 (34)	
Undocumented foreign-born	24 (55)	47 (31)	
Health insured ^e , n (%)	15 (34)	71 (48)	0.104 ^a
Unemployed, n (%)	27 (61)	108 (72)	0.177 ^a

* Includes Puerto Rico and US Virgin Islands;

^a Chi-square test;

^b *t* test;

^c Mann-Whitney *U* test;

^d Information on years in the US available in 122/133 (92%) foreign-born persons;

^e Health insurance information available for 192 (99%) subjects

Table 2

Diagnostic test results and clinical symptoms of 194 subjects with PTB according to the presence or absence of hemoptysis

	PTB with hemoptysis N=44	PTB without hemoptysis N=150	P value
Diagnostic test results			
Multilobar or miliary infiltrates, n (%)	29 (66)	100 (68)	0.925 ^a
Presence of cavitory lesion(s), n (%)	19 (43)	50 (33)	0.230 ^a
Smear+ ^c , n (%)	30 (68)	90 (60)	0.326 ^a
HIV+ ^f , n (%)	4/25 (16)	30/93 (32)	0.111 ^a
Presence of symptoms suggestive of PTB^d			
Cough, n (%)	44 (100)	104 (69)	< 0.001 ^a
Fever, n (%)	23 (52)	87 (58)	0.500 ^a
Night sweats, n (%)	14 (32)	52 (35)	0.726 ^a
Weight loss ^e , n (%)	26 (59)	66 (44)	0.078 ^a
Symptom duration suggestive of PTB			
Symptom duration ^f , median weeks (range)	8 (1–104)	6 (0–104)	0.038 ^b

^a Chi-square test;

^b Mann-Whitney *U* test;

^c At least one of initial three sputum smears positive for AFB regardless of quantity;

^d Symptoms self-reported by patients;

^e self-reported weight loss of more than 4 lbs;

^f Longest duration of any one or several symptoms suggestive of PTB; f: HIV-1/2 serology results available for 118 (61%) subjects

Table 3a

Adjusted association of decreasing age (per decade) with hemoptysis in PTB patients including presence of cavitory lesions and symptom duration in the model

Variable	Adjusted OR	95% CI	P value
Decreasing age (per decade)	1.56	1.14–2.12	0.005
Presence of cavitory lesion(s)	1.28	0.62–2.61	0.504
Symptom duration over 7 weeks	1.66	0.82–3.38	0.158

Table 3b

Final model for association of decreasing age (per decade) with hemoptysis in PTB patients

Variable	Adjusted OR	95% CI	P value
Decreasing age (per decade)	1.59	1.17–2.16	0.003

Table 4a

Adjusted association of symptom duration over 7 weeks with presence of cavitary lesions in PTB patients

Variable	Adjusted OR	95% CI	P value
Symptom duration over 7 weeks	1.76	0.96–3.24	0.068
Decreasing age (per decade)	1.16	0.90–1.49	0.250
HIV status ^c			
HIV negative	Reference		
HIV positive	0.39	0.16–0.98	0.046
HIV unknown	0.53	0.28–1.03	0.064

Table 4b

Final model for association of symptom duration over 7 weeks with presence of cavitary lesions in PTB patients

Variable	Adjusted OR	95% CI	P value
Symptom duration over 7 weeks	1.80	0.98–3.31	0.056
HIV status ^c			
HIV negative	Reference		
HIV positive	0.37	0.15–0.93	0.034
HIV unknown	0.52	0.27–1.01	0.053