Indian J Med Res 137, January 2013, pp 87-94

Identification of a threshold for biomass exposure index for chronic bronchitis in rural women of Mysore district, Karnataka, India

P.A. Mahesh, B.S. Jayaraj, A.K. Prabhakar*, S.K. Chaya & R. Vijaysimha*

*Departments of Pulmonology & *Community Medicine, JSS Medical College & Hospital, JSS University, Mysore, India*

Received February 22, 2011

***Background & objectives*: Exposure to air pollution due to combustion of biomass fuels remains one of the significant risk factors for chronic respiratory diseases such as chronic bronchitis. There is a need to identify the minimum threshold level of biomass index that is significantly associated with chronic bronchitis. This study was undertaken to identify a threshold for biomass exposure index in a rural women population in Mysore district, south India.**

***Methods*: A cross-sectional survey was conducted in a representative population of Mysore and Nanjangud *taluks*. Eight villages each from Mysore and Nanjangud were randomly selected based on the list of villages from census 2001. A house-to-house survey was carried out by trained field workers using the Burden of Obstructive Diseases questionnaire, which evaluated the biomass smoke exposure and chronic bronchitis. All the women aged above 30 yr were included in the study.**

***Results*: A total of 2011 women from Mysore and 1942 women from Nanjangud participated in the study. All women were non-smoking and used biomass fuels as the primary fuel for cooking. A threshold of biomass fuel exposure of 60 was identified on multivariate analysis in Mysore district after adjusting for age, passive smoking and working in a occupational exposure to dust, as the minimum required for a significant association with chronic bronchitis. One in every 20 women in Mysore district exposed to biomass fuel exposure index of 110 or more developed chronic bronchitis.**

***Interpretation & conclusions*: The minimum threshold of biomass exposure index of 60 is necessary to have a significant risk of developing chronic bronchitis in women. The number needed to harm to develop chronic bronchitis reduces with increasing biomass exposure index and women residing in rural Nanjangud have a higher risk for developing chronic bronchitis as compared to women in Mysore.**

Key words Biomass - biomass exposure index - biomass fuel - chronic bronchitis - number needed to harm - threshold for biomass

Exposure to air pollution due to combustion of biomass fuels remains one of the significant risk factor for chronic respiratory diseases in the developing countries[1]. It is estimated that an average woman in India may be subjected to 60,000 h of exposure to smoke due to combustion of biomass fuels in her life time[2]. Combustion of biomass fuels is the most important source of indoor air pollution in the world[3]. About 50 per cent of deaths from chronic obstructive pulmonary disease (COPD) in developing countries are attributed to exposure to biomass fuel smoke and 75 per cent of these deaths are in women[4]. Studies both in India and other countries have confirmed that exposure to biomass fuels has a significant association to chronic respiratory symptoms such as chronic cough, chronic phlegm and chronic respiratory diseases such as chronic bronchitis, asthma, cor pulmonale and respiratory failure[2,5-14], a decline in objective lung function parameters has been demonstrated, though not consistently[1,2,11,15,16], and a higher mortality and morbidity[3,17]. A recent meta-analysis has shown that biomass fuel exposure is associated with a significant risk for chronic bronchitis and COPD[18] and the strength of association was similar to that of cigarette smoking[19]. The major components of biomass affecting respiratory health are particulate matter, polycyclic aromatic hydrocarbons and carbon monoxide[3,20]. Chronic bronchitis is an important phenotype of COPD and is associated with a steeper decline in FEV_1[21] and higher mortality rates[22].

It is essential to have clinically meaningful exposure thresholds established for biomass fuel exposure. Exposure includes along with the concentration of the pollutants, the time spent by the person in that environment (person-time)[3]. Though assessment of biomass fuel exposures are estimated by measuring indoor concentrations of various pollutants including particulate matter (SPM_{10} and $SPM_{2,5}$), personal exposures and breath levels of different pollutants[3], these are difficult to apply in everyday clinical practice. A simple, easily applicable 'biomass exposure index' that was calculated utilizing the average hours spent on cooking per day multiplied by the number of years of cooking was developed by Behera *et al*[2]. The objective of this study was to identify the minimum threshold level of biomass index that is significantly associated with chronic bronchitis in the general population.

Material & Methods

Study design and subjects: The study was a cross-sectional survey to estimate the prevalence of COPD in a representative population in rural Mysore district[23]. The present study was a sub-study of this study and included all women above the age of 30 yr. Briefly, a two stage sampling was performed, with two *taluks* randomly selected out of five *taluks* in Mysore and eight villages in each *taluk* were randomly selected out of a list of all the villages. The sample size was estimated utilizing the available information on the prevalence of COPD in India[14,24]. With a 5 per cent prevalence and a 10 per cent error on the estimate, the sample size for the study was calculated to be 8000 adults. The sampling unit of the study was "household" and all the eligible persons in the households were included in the study. Nearly 25-30 per cent of the population is above 30 yr of age[25] and thus a total of 32,000 population was needed to be covered to identify 8000 eligible subjects for the study. With an average village size of 2000, 16 villages were covered. The villages (n=16) were randomly selected, eight villages in each *taluk* from the list of all villages according to the census 2001.

Field work and definition of outcome variables:The total duration of the study for the field work in both Mysore and Nanjangud was three years from June 2006 to May 2009. A validated 'Burden of Obstructive Lung Disease' questionnaire[26] was utilized for the study and was administered by trained field workers after a house-to-house visit. The questionnaire included demographic variables, various respiratory symptoms and risk factors including biomass fuel exposure. The questionnaire was translated into the local language according to standard procedures for translation and back-translation and pilot tested in the population studied. The questionnaire was read out to the patient in exactly the same order as listed in the questionnaire and sufficient time was given to the patient to respond to the questions. If the patient did not understand the questions, it was repeated. If the patient still was doubtful about the answer, it was recorded as "No". The survey was conducted both at morning and in the evening to ensure compliance. The field workers visited all the houses in the selected villages. Cases of 'chronic bronchitis' were identified in both the identification and validation stages on the basis of a positive response to the question 'Do you cough for at least 3 months in a year for at least two consecutive years?' according to the definition of the Medical Research Council, UK (MRC)[27]. Biomass exposure index was calculated as the average number of hours spent on cooking daily for cooking multiplied by the total number of years spent in cooking personally[2]. Information was collected on potential confounders relevant for chronic bronchitis such as passive smoking and working in a occupational exposure to dust. Passive smoking and working in a occupational exposure to dust were defined as present if an answer was "Yes" to the questions 'Does anyone living in your home, smoke cigarettes or *beedies* regularly inside your home?' and 'Have you ever worked for an year or more in a occupational exposure to dust?'.

Statistical analysis:The data analysis was carried out utilizing EPIINFO 8 and SPSS Inc. SPPS13 for Windows, Chicago: SPSS Inc., 2005 to calculate the odds ratios and 95% CI (confidence interval) for different biomass index exposures varying from 20 to 110 to identify the initial threshold of biomass index exposure significantly associated with chronic bronchitis in women. Fischer's exact test was used to determine the level of significance. A linear regression line was fitted between the log odds of the disease and increasing dose of biomass exposure to assess if there was a significant linear relationship between dose of biomass exposure and the odds of having the disease. A multiple logistic regression analysis was performed to assess independent association of biomass exposure index and chronic bronchitis after adjusting for potential confounders such as age, passive smoking and working in a occupational exposure to dust in Mysore district.The number needed to harm (NNH) values were calculated for chronic bronchitis for Mysore and Nanjangud among women exposed to various thresholds of biomass fuel exposure. The online calculator from Graphpad was used (*http://www.graphpad.com/quickcalcs/NNT2.cfm*). A receiver operator characteristic (ROC) curve was constructed for different thresholds of biomass index and the significance of the area under the curve was analysed.

The study protocol was approved by the institutional ethics committee of the JSS Medical College, Mysore.

Results

A total of 3953 women 30 yr of age were studied from Mysore district, (2011 and 1942 women from Mysore and Nanjangud *taluks*, respectively).The demographic variables and the biomass fuel exposure indices for the study subjects from Mysore district and from Mysore and Nanjangud *taluks* are presented in Table I. The distribution of the number of cases of chronic bronchitis across various biomass exposure indices are presented in Table II. All the women were non-smokers. The prevalence of chronic bronchitis in Mysore district was 133 (3.36%), Mysore *taluk*, 36 (1.79%) and in Nanjangud *taluk* 97 (4.99%). Women in Nanjangud had a higher prevalence of chronic bronchitis along with a higher mean biomass index exposure as compared to women in Mysore. A linear regression analysis was performed and the log odds was regressed using biomass exposure index. The regression was found to be highly significant (P=0.002) for Mysore district (Fig.1a), Mysore *taluk* (P=0.008) (Fig. 1b) and Nanjangud *taluk* (P=0.001) (Fig.1c). The prevalence of chronic bronchitis in women with a biomass exposure index of <60 was 1.6 (95% CI 1.08-2.50), between 60-120 was 3.15 (95% CI 2.46-4.02) and >120 was 8.26 (95% CI 6.27-10.80). A significant dose-response relationship was observed with a higher

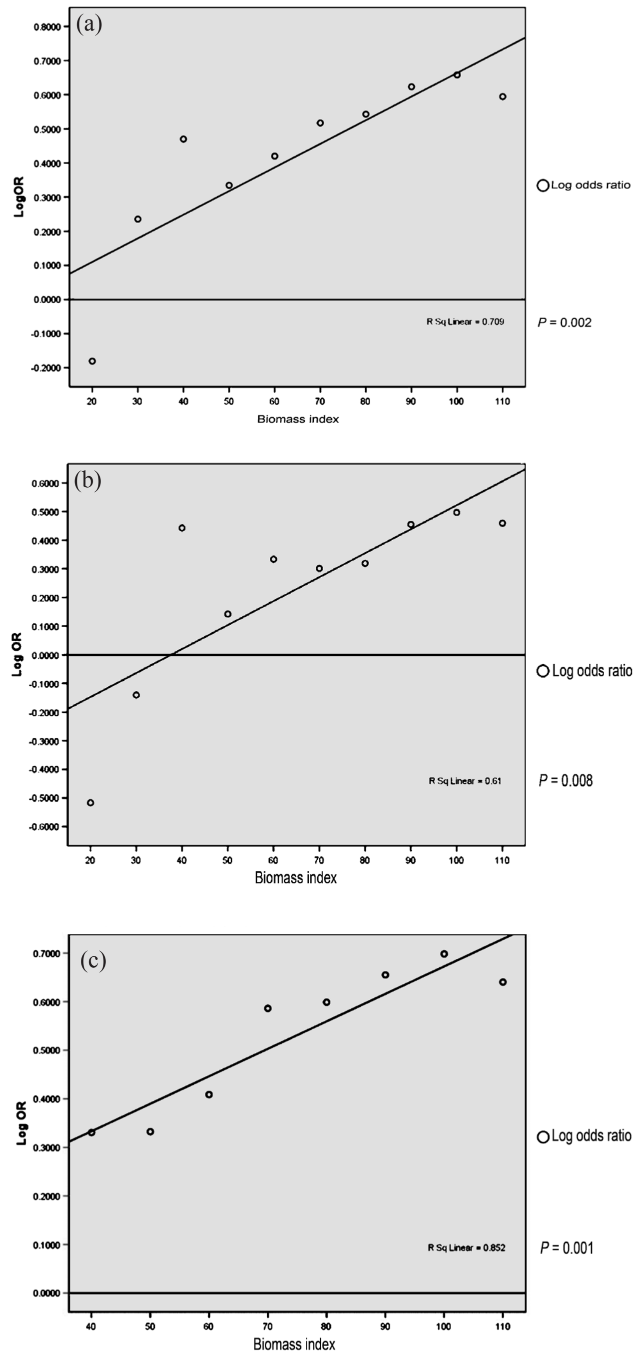

Fig. 1. (a) Linear regression plot of increasing biomass smoke exposure and log odds of chronic bronchitis among women in rural Mysore district, **(b)** Mysore district *Taluk* and **(c)** Nanjangud *Taluk*.

Table I. Demographic characteristics and biomass exposure indices in rural women in Mysore and Nanjangud

Characteristics		Mysore district (n=3953)		Mysore *taluk* (n=2011)		Nanjangud *taluk* (n=1942)	
	Classification	Number	(%)	Number	(%)	Number	(%)
Age (yr)	<40	1639	(41.46)	836	(41.57)	803	(41.35)
	40 - 60	1686	(42.65)	846	(42.07)	840	43.25)
	>60	628	(15.89)	329	(16.36)	299	15.40)
Primary household fuel							
Biomass	Yes	3953	(100)	2011	(100)	1942	100)
	No	0	0	0	0	0	0
Time personally spent on cooking	Hours/day						
	< 2	1113	(28.16)	774	(38.49)	339	17.46)
	3 – 4	2622	(66.33)	1196	(59.47)	1426	73.43)
	> 4	218	(5.51)	41	(2.04)	177	9.11)
	Mean ± SD (range)	3.04 ± 0.89 (1-6)		2.77 ± 0.83 (1-6)		3.32 ± 0.86 (1-5)	
	Total number of years						
	<10	1	(0.03)	0	(0)	1	(0.05)
	11 - 20	1065	(26.94)	479	(23.82)	586	(30.17)
	21 - 30	1452	(36.73)	677	(33.66)	775	(39.91)
	>30	1435	(36.3)	855	(42.52)	580	(29.87)
	Mean ± SD (range)	28.01 ± 8.28	(10-48)	29.28 ± 8.54	(12-43)	26.69 ± 7.78	(10-48)
Biomass index	<50	633	(16.01)	435	(21.63)	198	(10.20)
	50 – 100	1967	(49.76)	946	(47.04)	1021	(52.57)
	> 100	1353	(34.23)	630	(31.33)	723	(37.23)
	Mean ± SD (range)	85.94 ± 38.31	(18-215)	82.45 ± 38.57	(19-215)	89.56 ± 37.71	(18-200)
Occupational exposure to dust	Yes	1854	(46.9)	865	(43.01)	989	(50.93)
	No	2099	(53.1)	1146	(56.99)	953	(49.07)
Passive smoking	Yes	548	(13.86)	453	(22.53)	95	(4.89)
	No	3405	(86.14)	1558	(77.47)	1847	(95.11)

risk of developing chronic bronchitis with increasing biomass exposure as compared to subjects with a biomass exposure index of >60 in women from Mysore district [biomass exposure of 60-120 (OR 1.9; 95% CI 1.14-3.19) 2 and >120 (OR 5.36; 95% CI 3.12-9.27)]. A multiple logistic regression analysis was performed for independent association of biomass exposure index in Mysore district and chronic bronchitis after adjusting for potential confounders such as age, passive smoking and working in a occupational exposure to dust, and a significant association was observed from a biomass exposure index of 60 (Table III). Age >50 yr was found to be significantly associated with chronic bronchitis and no association could be found for occupational exposure to dust and passive smoking across various biomass exposure indices (data not shown). A receiver operator characteristic (ROC) curve (Fig. 2) constructed for different thresholds of biomass index and the area under the curve (AUC) was found to be significant (0.7; $P<0.000$). The cut-off of biomass index with the combination of highest sensitivity and specificity was found to be 97.5.

The number needed to harm for the various exposure thresholds of biomass indices in women of

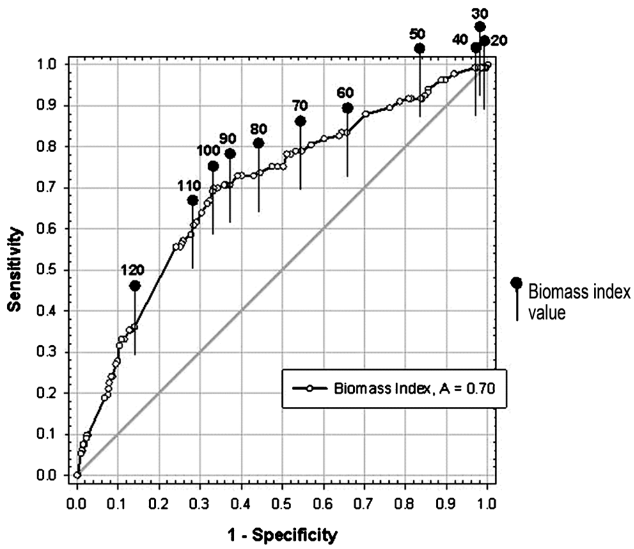

Fig. 2. ROC curve for biopass smoke exposure and development of chronic bronchitis.

Mysore district, Mysore and Nanjangud *taluks* to cause chronic bronchitis are presented in Table IV. Of the 39 women exposed to a biomass exposure of 60 or more, one will develop chronic bronchitis, and of the 20 women exposed to a biomass exposure of 110 or more, one will develop chronic bronchitis in rural women in Mysore district. A differential risk was observed on sub-group analysis of women from Mysore and Nanjangud *taluks*. Of the 85 women exposed to a biomass exposure of 60 or more, one will develop chronic bronchitis and of the 47 women exposed to a biomass exposure of 110 or more, one will develop chronic bronchitis in rural women in Mysore *taluk*. In contrast, of the 28 women exposed to a biomass exposure of 60 or more, one will develop chronic bronchitis and of the 13 women exposed to a biomass exposure of 110 or more, one will develop chronic bronchitis in rural women in Nanjangud *taluk*. For the same levels of biomass index exposure

Table II. The distribution of number of cases of chronic bronchitis across different thresholds of exposure to biomass index in rural women in Mysore

Exposure	Mysore district		Mysore *taluk*		Nanjangud *taluk*	
	Chronic bronchitis		Chronic bronchitis		Chronic bronchitis	
Biomass index	Yes	No	Yes	No	Yes	No
< 20	1	19	1	17	0	2
> 20	132	3801	35	1958	97	1843
< 30	1	49	1	40	0	9
> 30	132	3771	35	1935	97	1836
< 40	5	395	2	277	3	118
> 40	128	3425	34	1698	94	1727
< 50	11	622	6	429	5	193
> 50	122	3198	30	1546	92	1652
< 60	22	1310	8	753	14	557
> 60	111	2510	28	1222	83	1288
< 70	28	1786	12	988	16	798
> 70	105	2034	24	987	81	1047
< 80	35	2119	15	1182	20	937
> 80	98	1701	21	793	77	908
< 90	39	2428	15	1325	24	1103
> 90	94	1392	21	650	73	742
< 100	41	2559	15	1366	26	1193
> 100	92	1261	21	609	71	652
< 110	52	2736	17	1423	35	1313
> 110	81	1084	19	552	62	532

Table III. Multiple logistic regression analysis of various thresholds of biomass index and chronic bronchitis among women in Mysore district

Exposure	Univariate	Adjusted#
Biomass index	Odds ratio (95% CI)	Odds ratio (95% CI)
>40	2.95 (1.2-7.26)*	2.15 (0.87-5.33)
>50	2.16 (1.16-4.02)*	1.49 (0.79-2.83)
>60	2.63 (1.66-4.18)*	1.74 (1.07-2.85)*
>70	3.29 (2.16-5.02)*	2.15 (1.35-3.41)*
>80	3.49 (2.36-5.16)*	2.49 (1.64-3.78)*
>90	4.20 (2.88-6.14)*	2.97 (1.95-4.54)*
>100	4.55 (3.13-6.62)*	3.27 (2.13-5.02)*
>110	3.93 (2.76-5.61)*	2.65 (1.73-4.06)*

#Multiple logistic regression analysis with odds ratio and 95% CI adjusted for age, passive smoking and dusty occupation
*$P<0.05$

there is a substantial difference in risk in genetically homogeneous population from the same district.

Discussion

Biomass fuel exposure has been found to be significantly associated with chronic bronchitis[2]. 'Biomass exposure index' is a simple clinically applicable tool that has the potential to be widely applicable in subjects exposed to biomass fuels, similar to pack years of smoking or smoking index that are used to assess exposure to tobacco smoking and quantify the risk of developing disease. For biomass exposure index to be clinically applicable there is a need to identify the minimum threshold of exposure beyond which there is a significant risk of developing disease. This study identified the minimum threshold of biomass exposure index that was significantly associated with the development of chronic bronchitis in the general population. In Mysore district, the minimum amount of biomass exposure required to be significantly associated with chronic bronchitis was a biomass exposure index of 60 after adjusting for potential confounders. Age and biomass exposure index were found to be independently associated with chronic bronchitis. A linear regression analysis confirmed the dose response relationship of increasing biomass exposure and chronic bronchitis in women from Mysore district. On sub-group analysis, a stronger association was observed in women in Nanjangud who also had a mean higher exposure levels to biomass fuels as compared to women in Mysore. This study also demonstrated the number needed to harm for varying levels of biomass exposure indices and found a clear association of increasing chronic bronchitis with increasing biomass exposure. Interestingly, the number needed to harm for biomass exposure in women in Nanjangud was much lower than for women in Mysore for the same degree of exposure. Further studies are required to elucidate reasons for this; whether it is related to poorer ventilation in houses in Nanjangud which leads to a higher exposure to indoor air pollutants; whether presence of heavy industries in Nanjangud is contributing to a higher outdoor air pollution; whether the biomass fuels used or cooking practices adopted in Nanjangud produces higher levels of indoor air pollutants; whether it is related to an increased susceptibility in women in Nanjangud or whether it is related to poor nutrition, prior respiratory infections, overcrowding and other poverty associated factors. A ROC curve analysis showed that the cut-off for the combination of highest sensitivity and specificity was observed at a biomass index of 97.5.

Approximately, half the world's population and around 90 per cent of rural households are exposed to biomass fuels for their daily energy needs[1,3]. World

Table IV. Number needed to harm (NNH) to develop chronic bronchitis in rural women exposed to various thresholds of biomass exposure index in Mysore and Nanjangud

Biomass exposure index	NNH to develop chronic bronchitis Mysore district NNH (95%CI)	NNH to develop chronic bronchitis Mysore *taluk* NNH (95%CI)	NNH to develop chronic bronchitis Nanjangud *taluk* NNH (95%CI)
> 60	39(27.7-64.4)	85 (43.8-1061.6)	28 (18.5-55.2)
>70	30 (22.5-43.7)	86 (42.9-5549.8)	20 (14.3-29.1)
>80	27 (20.0-37.8)	76 (38.7-1460.6)	18 (13.1-26.2)
>90	22 (16.5-29.3)	50 (29.0-173.2)	15 (11.2-21.3)
>100	20 (15.0-26.3)	45 (26.7-134.7)	14 (10.0-18.6)
>110	20 (15.1-28.2)	47 (26.9-174.3)	13 (9.6-19.1)

Health Organization attributes more than 1.6 million deaths per year and 38.5 million disability-adjusted-life years to indoor smoke from biomass fuels that predominantly affect women and children[28]. Indoor air pollution due to biomass fuels is ranked 10th among most preventable risk factors for global disease burden and ranked 4th when only developing countries are considered[3]. Biomass smoke is a complex mixture of hundreds of volatile and particulate matter including organic and inorganic compounds and most of these (>90%) are in the respirable range (<10 microns)[3,20]. The most important toxic constituents are solid particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen and sulphur oxides, aldehydes such as formaldehyde, polycyclic aromatic hydrocarbons such as benzopyrene, volatile organic compounds and free radicals[3,20]. Cooking is the most common activity involving combustion of biomass fuels and in developing countries is conducted in open fireplaces which result in significant emissions and the mean 24 h PM_{10} values may range from 300 to 3000 μg/m^3 and may reach 30,000 μg/m^3 during cooking[3]. The mean 24 h carbon monoxide values ranged from 2-50 ppm and peak of 500 ppm during cooking[3].

There is strong evidence linking inhalation of biomass fuel smoke and chronic bronchitis in women aged above 30 yr with a relative risk of 3.2 (95% CI 2.3-4.8)[3].Population based studies have demonstrated a clear link between exposure to smoke from biomass fuels and COPD in India[2,5], Colombia[8], China[13], Spain[29] and Mexico[11]. The Colombian[18] study with more than 5500 subjects showed that the exposure to biomass fuels for more than 10 years is a risk factor for COPD (OR 1.50; 95% CI 1.36-2.36).Reducing the indoor air pollution proved to be of benefit. Two studies, in Guatemala[30] and Mexico[31]showed that using modified cooking stoves to reduce indoor air pollution was associated with reduction of chronic respiratory symptoms over a follow up of more than a year.

In conclusion, our findings demonstrated that a minimum threshold of biomass exposure index of 60 was necessary to have a significant risk of developing chronic bronchitis. The number needed to harm to develop chronic bronchitis reduces with increasing biomass exposure index and women residing in rural Nanjangud have a higher risk for developing chronic bronchitis as compared to women in Mysore, the reasons for which need to be ascertained. Future research on the effect of use of modified cooking stoves that reduces indoor air pollution including the cost-effectiveness is required to develop preventive strategies.

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Reprint requests: Dr P.A. Mahesh, Professor, Department of Pulmonary Medicine, JSS Medical College & Hospital
1397, 4th Cross, Krishnamurthypuram, Mysore 570 004, India
e-mail: mahesh1971in@yahoo.com