The Cost-Effectiveness of a Questionnaire as a Screening Test for Chronic Obstructive Pulmonary Disease among the Bangkok Elderly†

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Abstract

This study aimed to explore the cost-effectiveness of using a questionnaire as a screening test for Chronic Obstructive Pulmonary Disease (COPD) among the Bangkok elderly residing around Siriraj Hospital. The gold standard used for diagnosing COPD followed the guidelines of the Thoracic Society of Thailand. The questionnaire consisted of 10 questions on smoking status, respiratory symptoms and previous history of pulmonary tuberculosis. There were 3,094 elderly who participated, completed the questionnaire, and underwent spirometry as well as chest radiography in the community. The results showed that elderly individuals who are smokers (> 0.5 pack-year) or have ever experienced sudden cough with chest oppression or dyspnea when the weather changes or who have expectorated more than two tablespoons of sputum would be suspected of having COPD with a sensitiviy of 81.4 per cent (95% CI 79.4-83.4), specificity of 62.2 per cent (95% CI 60.4-64.0) false negative rate 1.2 per cent (95% CI 0.7-1.7) and false positive rate 38 per cent (95% CI 35.3-40.7) and subsequently required spirometry and chest X-ray for definitive diagnosis. The test needed to screen 17 elderly individuals to detect one COPD case at a cost of 1,538 baht. This questionnaire is also a self-assessment tool for COPD screening among the elderly in order to encourage them to seek for early medical attention and it is recommended that this should be publicized *via* the mass media.

Key word : Cost-Effectiveness, Questionnaire, Screening, COPD, Elderly

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Chronic Obstructive Pulmonary Disease (COPD) is one of the leading causes of morbidity and mortality worldwide and results in a substantial and increasing socio-economic burden. Many COPD patients are still first identified when they present to the hospital with an exacerbation and those requiring intensive care are clearly at an advanced stage of their illnesses. Delaying diagnosis and assessment until this point in the illness remains unacceptable. The corresponding efforts to increase early identification of COPD and greater efforts to campaign to stop smoking can help reduce the morbidity and mortality that are associated with COPD in a population at risk. Our previous study showed a high prevalence and incidence of COPD among the urban Bangkok elderly (1). A nation-wide survey of the elderly population to estimate the size of the COPD problem is needed and a cost-effective screening test needs to be explored.

Questionnaires concerning the respiratory symptoms are meaningful. COPD prevalence data based on self report of respiratory symptoms (chronic cough, sputum production, wheezing and shortness of breath) include people at risk for COPD or stage zero of the GOLD guidelines(2) as well as those with airflow limitation yield the maximum prevalence estimate. The cost-effectiveness of using a questionnaire as a screening method for COPD among the elderly has not previously been reported. This field study was the second part of the 11th project out of 16 projects under the mega project of the Faculty of Medicine Siriraj Hospital on the Integrated Health Research Program for the Thai Elderly (IHRE) and aimed firstly to identify the suitability of a questionnaire as a screening test for COPD among the elderly using criteria based on the guidelines of the Thoracic Society of Thailand(3) as a gold standard, and secondly to evaluate its cost-effectiveness.

MATERIAL AND METHOD

The study was approved by the Ethics Committee on Human Rights involving Human Research of the Faculty of Medicine Siriraj Hospital. The design of the study was cross-sectional. The subject inclusion criteria were all 3,123 elderly people aged 60 years and over in 124 communities located within a radius of 10 km around Siriraj Hospital in January 1998 who were ambulatory and agreed to participate throughout the study. The exclusion criterion was the presence of upper respiratory tract infection on the day of study. A questionnaire interview, spirometry and postero-anterior (PA), lateral chest radiography were performed in the community. Only data of those who could complete the questionnaire, spirometry and the PA and lateral chest radiography were analyzed.

The spirometer used was the electronic turbine, flow sensing pneumotachometer "Pony Graphic 3.0", Cosmed Co. Ltd. Italy which is acceptable to the standards of the American Thoracic Society(4). Volume and flow were recorded in BTPS. Spirometry was performed in a sitting position with a nose clip guided by a group of experienced respiratory technicians. $FEV_{1.0}$ and FVC were the maximal values from three acceptable graphs. Pre as well as post bronchodilator spirometry values were recorded using two puffs of salbutamol from a metered dose inhaler *via* a spacer. The gold standard for diagnosing COPD was based on the Thoracic Society of Thailand guidelines i.e., a ratio of $FEV_{1.0}$/FVC less than 70 per cent and reversibility of less than 15 per cent increase in postbronchodilator $FEV_{1.0}$ in the absence of parenchymal lesions and cardiomegly on chest radiography (3). The severity of COPD was defined as an $FEV_{1.0}$ $\geq$ 70 per cent, 50-69 per cent and less than 50 per cent of predicted value as mild, moderate and severe degree of airways obstruction respectively.

A questionnaire consisting of 10 questions on respiratory symptoms, smoking data and history of previous pulmonary tuberculosis (Table 1) was developed.

Cost-effectiveness of questionnaire

Two screening cut-off points were assessed, firstly; the cut-off point (Z) of best average accuracy i.e., (sensitivity + specificity) / 2 and secondly, the most cost-effective cut-off point i.e., at lowest grand total cost. In the screening program using the questionnaire, the cost of an examination included the cost of the questionnaire followed by the cost of the gold standard examination (CXR and spirometry) in suspected cases. The cost of each test in this study includes the costs of materials and all involved personnels. The cost of the questionnaire test includes the following; paper, ink, copying machine (depreciation), master paper, salaries e.g., technicians, drivers, etc. Cost of the chest radiography for the survey included X-ray film, solvent, X-ray machine (depreciation), film cassette, X-ray room, film envelope, electricity etc. and personnels' salary. The cost of spirometry includes spirometer, battery, mouth pieces, ink, master paper, calibrator, nose clip, bronchodilator, electricity etc. and personnels' salary.

Cost for diagnosis = $[(T^+ + T^- + F^+ + F^-)\ 15.99] + [(T^+ + F^+) \times (92.4 + 80.65)$ baht

where Cost for one questionnaire	15.99	baht
One spirometry	92.40	baht
Two views of chest radiography	80.65	baht

T^+ = True positive, T^- = True negative, F^+ = False positive, F^- = False negative

We know that influenza is the major cause of exacerbation in COPD (project 12th of 16 projects of IHRE). Therefore, the false negative cost and true positive cost were calculated as follows :-

F- cost = (No. of F^- x cost for influenza treatment by severity in non-vaccinated group)
T+ cost = (No. of T^+ x cost of vaccine) + {No. of T^+ x (1-efficacy of influenza vaccine) x average cost of influenza treatment for vaccinated group}

F- cost = (No. of F^-_{mild} x 1,682)+ (No. of $F^-_{moderate}$ x 5,726)+ (No. of F^-_{severe} x 7,765) baht
T+ cost = (No. of T^+ x 248.4)+ (No. of T^+ x 0.22 x 354) baht

Data from our influenza vaccination project showed that the cost of treatment for each subject i.e., with mild, moderate and severe COPD was 1,682, 5,726 and 7,765 baht respectively(5).

Statistical analysis

The comparison between COPD and non-COPD subjects was performed using the Chi-squared test for categorical variables and student's *t*-test for

Table 1. Questionnaire for predicting COPD among the elderly*.

1. Cigarette Smoking
   - 1.1. Have you ever smoked cigarette? Yes No
     (If the answer ≤ 0.5 pack-year - check No)
     If no - go to question No. 2
   - 1.2. How many cigarettes a day do you smoke on average _____ (cigarettes/day)
   - 1.3. How long have you been smoking _____ years _____ pack-year
     (The interviewer calculated pack-years)
   - 1.4. Are you current smoker Yes Quit How long ago? _____ years
2. Have you had almost daily productive cough more than 3 months per year?
   Yes No (If No, go to question No. 4)
3. Have you had the symptoms in question No. 2 for more than two consecutive years?
   Yes No
4. Have you experienced shortness of breath during a quick walk?
   Yes No
   (If No, go to question No. 6)
5. Has the symptom in question No. 4 been gradually progressive for more than one year?
   Yes No
6. Have you ever had a sudden cough with chest oppression or dyspnea on exposure to cigarette smoke, exhausted fumes, or a strong smell?
   Yes No
7. Have you ever had a sudden cough with chest oppression or dyspnea during a change of climate, cold weather or before it rains?
   Yes No
8. Have you ever produced more than 2 tablespoonsful of sputum per day?
   Yes No
9. Do you find you produce more sputum as you change your position e.g., from lying on your back to lying on your side or sitting up?
   Yes No
10. Have you ever been diagnosed with pulmonary tuberculosis or had a lung spot on your chest X-ray?
    Yes No

* The score was 1 for yes and zero for no.

Table 2. The characteristics of the elderly with COPD compared with the elderly without COPD.

	Population	COPD	Non-COPD	P-value*	Test
Number (cases)	3,094	220	2,874		
Age, mean ± SD (years)	67.9 ± 6.4	70.2 ± 6.7	67.7 ± 6.3	< 0.001	*t*-test
Sex (male : female)	0.6 : 1	2.6 : 1	0.6 : 1	< 0.002	χ^2
Smoker (%)	1,134 (36.6)	166 (75.5)	968 (33.7)	< 0.002	χ^2
Pack-year, mean ± SD	25.8 ± 24.4	32.8 ± 26.4	24.7 ± 23.8	< 0.001	*t*-test
Previous smoker (%)	449 (14.5)	64 (29.1)	385 (13.4)	< 0.002	χ^2
Current smoker (%)	685 (22.2)	102 (46.4)	583 (20.3)	< 0.002	χ^2
Non-smoker** (%)	1,959 (63.3)	54 (24.5)	1,905 (66.3)	< 0.002	χ^2

* COPD *vs* non-COPD, ** Tobacco smoking ≤ 0.5 pack-year

Table 3. Univariate analysis of questionnaire.

Questions	Sen	Spf	PPV	PNV	RR	95% CI	P-value
1. Smoking status.	0.75	0.66	0.15	0.97	6.03	4.39-8.28	< 0.001
2. Almost daily productive cough > 3M/year.	0.22	0.91	0.16	0.94	2.89	2.05-4.09	< 0.001
3. No.2 symptom > 2 years.	0.41	0.70	0.10	0.94	2.77	1.82-4.24	< 0.001
4. Shortness of breath during quick walk.	0.13	0.95	0.16	0.93	1.53	1.16-2.02	< 0.001
5. No.4 symptom gradually progresive > 1 y.	0.54	0.57	0.09	0.94	1.65	1.25-2.18	0.002
6. Sudden cough with chest oppression or dyspnea with exposure to cigarrete smoke and irritants.	0.15	0.95	0.19	0.94	3.47	2.31-5.22	0.0004
7. Sudden cough with chest oppression or dyspnea during weather change.	0.17	0.96	0.26	0.94	3.30	2.20-4.95	< 0.001
8. Daily expectorated sputum > 2 tablespoonful.	0.10	0.98	0.27	0.93	5.31	3.56-7.91	< 0.001
9. Increasing expectorated sputum during position change.	0.17	0.93	0.16	0.94	5.18	3.08-8.71	< 0.001
10. Previous pulmonary tuberculosis or spot in CXR.	0.15	0.95	0.19	0.94	2.83	1.94-4.13	< 0.001

Sen = sensitivity, Spf = specificity, PPV = predictive positive value,
PNV = predictive negative value, RR = risk ratio, CI = confidence interval.

continuous variables. A p-value of < 0.05 indicates a statistically significant difference between the groups. The questionnaire was analysed by both univariate and multivariate analysis. The latter was done using a Forward (LR) logistic regression model. A Receiver Operating Characteristic (ROC) with sensitivity and specificity were calculated. The statistical analyses were done *via* SPSS 9.05 for Windows.

RESULTS

There were 3,094 cases (99.1% of total) who completed spirometry, chest radiography and a questionnaire interview and 220 subjects had COPD according to the accepted definition. The characteristics of those with COPD compared with non-COPD are shown in Table 2. The COPD subjects were older, predominantly males and tobacco smokers with a higher number of pack-year than the non-COPD group.

Univariate analysis of the 10 questions (Table 3) revealed that all questions were highly significant in predicting COPD ($p < 0.05$), but with various risk ratio (RR). The highest risk ratio was smoking status and the lowest was dyspnea during a quick walk.

Using multiple logistic regression for the above 10 significant questions to determine which questions would be associated in the equation of cut-off point for predicting COPD, only smoking status (Question No. 1), weather change (Question No. 7), copious sputum (Question No.8) and TB (Question No. 10) appeared in the following equation for the cut-off point (Z from 0-1)

$$Z = 1/1+e^{-[-3.72 + (1.65 * \text{smoking}) + (0.88 * \text{weather}) + (0.98 * \text{sputum}) + (0.60 * \text{TB})]} \quad \text{.....Equation (1)}$$

Improvement Chi square = 10.63 (p-value 0.001) Model Chi square = 202.91 (p-value 0.000)

The cut-off point (Z) of best average accuracy for screening COPD (Table 4) revealed Z = 0.05 which means that cases with Z ≥ 0.05 would be suspected of having COPD with a sensitivity of 81.4 per cent (95% CI 79.4-83.4) and a specificity of 62.2 per cent (95% CI 60.4-64.0) and an average accuracy of 71.8 per cent (95% CI 64.6-79.0).

The cost of one questionnaire test, the gold standard test i.e., CXR PA and lateral and one spirometry test were 15.99, 80.65 and 92.40 baht respectively. To calculate the false negative cost of a questionnaire test for each cut-off point, the numbers of COPD cases stratified by severity are shown in Table 5. The grand total costs for some cut-off points are also illustrated in Table 6.

Therefore, the cost-effective cut-off point for the questionnaire screening survey for COPD was at Z value = 0.04 which means that cases who answer the four questions from equation (1) with Z ≥ 0.04 would be suspected of having COPD.

For practical implementation, the complicated Z equation (1) is simplified to

$$A = (1.65 \times \text{smoking}) + (0.88 \times \text{weather}) + (0.98 \times \text{sputum}) + (0.6 \times \text{TB}) \quad \text{.....Equation (2)}$$

Hence, by answering four screening questions with a score Yes = 1, No = 0 :

The simplified cut-off point (based on highest average accuracy) illustrated that cases with A ≥ 0.78 would be suspected of having COPD. The cost-effective cut-off point, based on the cost-effectiveness of the questionnaire screening test in which cases with A ≥ 0.54 are suspected of having COPD surprisingly revealed the same average accuracy (71.8%) as the cut-off point at the highest average accuracy.

However, in clinical practice, with the modification of the questionnaire for self-assestment (from

Table 4. Average accuracy of questionnaires test at various cut-off points.

Cut-off point (Z score)	Sensitivity	Specificity	Average accuracy
0.50	1.4	99.9	50.65
0.30	7.7	99.0	53.3
0.15	30.5	92.9	61.7
0.10	76.4	65.9	71.1
0.05	81.4	62.2	71.8
0.04	84.5	59.0	71.7
0.02	100.0	0.0	50.0

Table 5. COPD cases and the severity distribution at various cut-off points.

Cut-off point (Z score)	Severity of COPD (no. of cases)			Total
	Mild	Moderate	Severe	
0.50	141	53	23	217
0.30	133	51	19	203
0.15	103	40	10	153
0.10	31	18	3	52
0.05	28	12	1	41
0.04	24	10	0	34
0.02	0	0	0	0

Table 6. Examples of cut-off points and related medical costs.

Cut-off point	Sen	Spf	T+	T-	F+	F-	Cost for diagnosis (baht)	Loss cost for influenza infection treatment		Grand total cost (baht)
								F- (baht)	T+ (baht)	
0.50	1.4	99.9	3	2,869	4	217	50,668	719,235	979	770,882
0.30	7.7	99.0	17	2,845	28	203	57,244	663,267	5,547	726,058
0.15	30.5	92.9	67	2,668	205	153	96,527	479,936	21,861	598,324
0.10	76.4	65.9	168	1,892	981	52	248,292	178,505	54,815	481,612
0.05	81.4	62.2	179	1,788	1,085	41	268,192	123,573	58,404	450,169
0.04	84.5	59.0	186	1,696	1,177	34	285,324	97,628	60,688	443,640
0.02	100	0	200	0	2,873	0	580,920	0	65,256	646,176

Sen = sensitivity, Spf = specificity, T^+ = true positive, T^- = true negative, F^+ = false positive, F^- = false negative.

equation 2) the screening test criteria at both cut-off points can be summarized. The answer "Yes", to at least 1 question of questions No. 1, No. 7, No. 8 (with an exclusion of question 10 where A = 0.6 and is rather borderlined) makes the subject suspected of having COPD and should undergo the gold standard test.

In our study using a questionnaire of ten questions as a screening test, the cost for screening 1 subject was 92.12 baht (Diagram 1) and needed 17 cases to detect one case of COPD (Table 7). Details of the cost-effectiveness of the questionnaire as screening test for COPD are shown in Diagram 1.

DISCUSSION

One interesting piece of evidence from this study is that a history of previous pulmonary tuberculosis is significantly associated with the diagnosis of COPD as shown by the equation (1) :

The explanation probably concerns the notoriously high percentage of tuberculous infection in the elderly and high prevalence of pulmonary tuberculosis in the Thai population as well as that of COPD which is a non-contagious disease or degenerative disease of high prevalence in the elderly, indicated by our previous study[1]. The common confounding risk factors of these two diseases may be poverty in term of income or/and low education which we could not demonstrate any statistically significant association (Table 8). The next possibility may be that the significant pathology of pulmonary TB causes air flow limitation. However, there were no evidence from visible parenchymal lesions on the chest X-ray to confirm this. The finding that the simplified cut-off point for a positive answer to only this TB factor yields a value of 0.6 which is not consistent with COPD (the criterion is $A \geq 0.78$) does not support to the above idea either.

$$Z = 1/1+e^{-[-3.72 + (1.65 * \text{smoking}) + (0.88 * \text{weather}) + (0.98 * \text{sputum}) + (0.60 * \text{TB})]}$$

And the A = (1.65 x smoking) + (0.88 x weather) + (0.98 x sputum) + (0.6 x TB) of equation (2)

Out of 10 questions, the final three best questions concerned smoking, dyspnea on weather change, and chronic daily copious sputum. It should be noted that in our study the personnel costs was rather high due to the high salary of our technicians. Moreover, the cost of performing a questionnaire with only three questions would even be less.

In practice, this study recommends that an elderly person who has a history of any of the following three i.e., smoking more than 0.5 pack-year; acute dyspnea or cough during weather change; chronic production of more than two tablespoons of sputum/day, should see the doctor for further investigation for COPD i.e., spirometry and CXR. This simple structured questionnaire for self-assessment should be publicized through the mass media.

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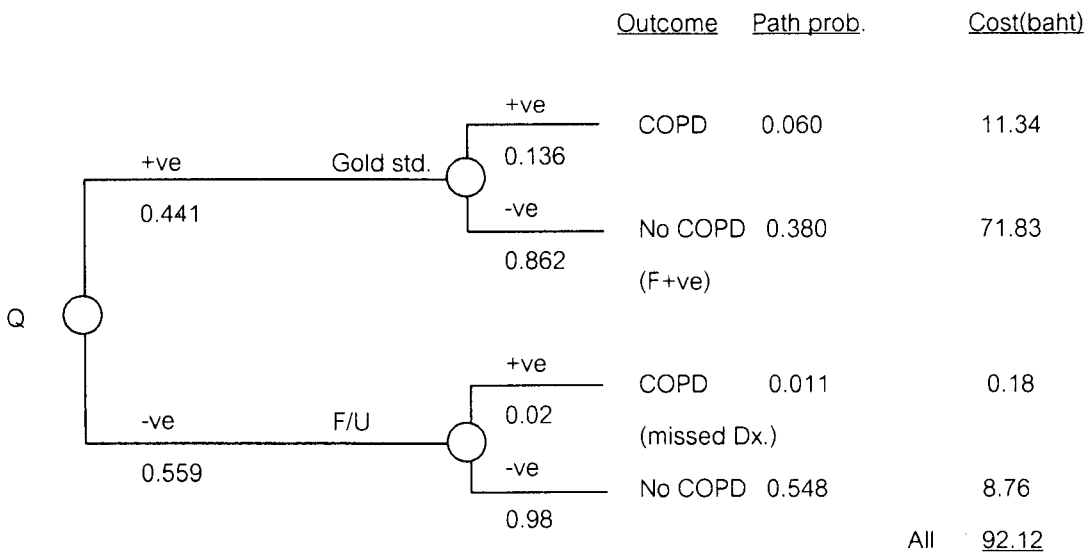

Diagram 1. Outcome, path probability and cost for screening one subject with the questionnaire.

Table 7. Data from the questionnaire screening test for diagnosing COPD.

No. of case detected per one screened subject	0.06	case
Missed diagnosis (%) (False negative)	1.20 (95% CI 0.7-1.7)	
False positive (%)	38 (95% CI 35.3-40.7)	
No. of subjects screened to detect one COPD case	16.7	cases
Cost to screen one subject	92.12	baht
Cost to detect one case of COPD	1,538	baht

Table 8. Univariate analysis of economic status and education of the elderly.

Factors	RR	95% CI	P-value
Income			
Not enough	1.4	0.82-2.39	0.14
Enough but no deposit	1.01	0.65-1.56	
Enough with deposit	1.0		
Education			
No formal education	1.22	0.73-2.0	0.70
Elementary school	1.13	0.74-1.72	
Secondary school or above	1.0		

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ประสิทธิภาพของแบบสอบถามในการตรวจคัดกรองโรคปอดอุดกั้นเรื้อรังในผู้สูงอายุของชุมชน กรุงเทพ ฯ†

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การศึกษานี้มีจุดประสงค์สร้างแบบสอบถามและหาความเชื่อมั่นสำหรับใช้เป็นวิธีคัดกรองผู้สูงอายุในชุมชนเพื่อให้การวินิจฉัยโรคปอดอุดกั้นเรื้อรังในเบื้องต้นและอิงวิธีการวินิจฉัยมาตรฐานของสมาคมอุรเวชช์แห่งประเทศไทย ด้วยการทดสอบสมรรถภาพปอดและตรวจภาพรังสีทรวงอก

แบบสอบถามประกอบด้วยคำถาม 10 ข้อ เกี่ยวกับการสูบบุหรี่, อาการทางระบบหายใจและประวัติวัณโรคปอดในอดีต คณะผู้วิจัยได้ทำการศึกษาผู้สูงอายุตั้งแต่ 60 ปีขึ้นไปใน 124 ชุมชน รอบโรงพยาบาลศิริราช มีผู้สูงอายุ 3,094 ราย ตอบแบบสอบถาม รับการตรวจสมรรถภาพปอดและรับการถ่ายภาพรังสีทรวงอก ท่าหน้าหลังและด้านข้างครบถ้วน

ผลการศึกษา พบว่า ผู้สูงอายุที่สูบบุหรี่มากกว่า 0.5 ซอง-ปี หรือไอหอบเหนื่อยแน่นหน้าอกเมื่ออากาศเปลี่ยน หรือมีเสมหะทุกวันมากกว่า 2 ช้อนโต๊ะ ให้สงสัยว่าน่าจะเป็นโรคปอดอุดกั้นเรื้อรัง สมควรไปพบแพทย์เพื่อตรวจสมรรถภาพปอดและถ่ายภาพรังสีทรวงอกเพื่อให้การวินิจฉัยโรคปอดอุดกั้นเรื้อรังเป็นขั้นสุดท้าย โดยวิธีคัดกรองนี้พบความไว 81.4% (95% CI 79.4–83.4) ความจำเพาะ 62.2% (95% CI 60.4–64.0) ผลลบเท็จ 1.2% (95% CI 0.7–1.7) ผลบวกเท็จ 38% (95% CI 35.3–40.7) ตรวจผู้สูงอายุ 17 รายจะพบเป็นโรคปอดอุดกั้นเรื้อรัง 1 ราย คำถามทั้ง 3 คำถามนี้ผู้สูงอายุและญาติสามารถนำไปตรวจสอบเพื่อวินิจฉัยโรคด้วยตนเองได้โดยง่าย จะทำให้ไปหาแพทย์ได้ในระยะแรกก่อนมีอาการรุนแรง จึงสมควรสนับสนุนให้มีการประชาสัมพันธ์เผยแพร่ต่อไป

คำสำคัญ : ประสิทธิภาพ, แบบสอบถาม, การตรวจคัดกรอง, โรคปอดอุดกั้นเรื้อรัง, ผู้สูงอายุ

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