Decision-Tree Sensitivity Analysis for Cost-Effectiveness of Chest 2-Fluoro-2-D-[^{18}F]Fluorodeoxyglucose Positron Emission Tomography in Patients With Pulmonary Nodules (Non-small Cell Lung Carcinoma) in Japan*

Shigeru Kosuda, MD; Kiyoshi Ichihara, MD, PhD; Masumi Watanabe, MD; Hideo Kobayashi, MD, FCCP; and Shoichi Kusano, MD

Context: **Recent studies have demonstrated the potential cost-effectiveness of using 2-fluoro-2-D-[^{18}F]fluorodeoxyglucose (FDG) positron emission tomography (PET) in the management of non-small cell lung carcinoma (NSCLC), but because of differences in health-care systems, those findings may not hold true in a Japanese hospital.**
Objective: **To assess the cost-effectiveness of the chest CT plus chest FDG-PET strategy in Japan.**
Design: **Decision-tree sensitivity analysis based on the two competing strategies of chest CT–alone vs chest CT plus chest FDG-PET.**
Study selection: **A simulation of 1,000 patients in whom NSCLC, stage IIIB or less, was suspected was created using baselines of other relevant variables in regard to sensitivity, specificity, mortality, life expectancy, and cost from published data.**
Methods: **We surveyed the relevant literature for the choice of variables.**
Main outcome measures: **Expected marginal cost and expected life expectancy gain for NSCLC patients.**
Results: **The chest CT plus chest FDG-PET strategy yielded an expected life expectancy gain of 0.607 years (7.3 months) per patient, compared with the alternative strategy of chest CT–alone. Using an FDG-PET examination cost of 1.0×10^5 yen (around $700 US) per study, the cost increment was 2.18×10^5 yen/yr/patient.**
Conclusions: **The chest CT plus chest FDG-PET strategy in patients with NSCLC is unlikely to be cost-effective in Japan. However, patient life expectancy gain would increase as a result of improved staging of NSCLC. These preliminary results should be confirmed by further studies for specific environments.** ***(CHEST 2000; 117:346–353)***

Key words: cost-effectiveness; 2-fluoro-2-D-[^{18}F]fluorodeoxyglucose positron emission tomography; life expectancy; non-small cell lung carcinoma

Abbreviations: FDG = 2-fluoro-2-D-[^{18}F]fluorodeoxyglucose; NSCLC = non-small cell lung carcinoma; PET = positron emission tomography; TBLB = transbronchial lung biopsy

Lung cancer continues to be a major health problem worldwide. The incidence and mortality of lung cancer are rapidly increasing, and lung cancer is the leading cause of cancer deaths in Japan as well as in other developed countries. Non-small cell lung carcinoma (NSCLC) accounts for approximately 75% of all lung cancers. In the early stages, NSCLC is surgically curable, but accurate preoperative staging diagnosis is imperative to avoid unnecessary operations and reduce medical costs.

Japan is currently faced with the serious economic problem of rapidly increasing health-care costs, as in the Western European countries and the United States. The rising demand for health-care services for lung cancer patients, coupled with stationary or slashed resources, is stimulating nuclear medicine specialists to take great interest in economic analysis of nuclear medicine procedures. Research on the

*From the Department of Radiology (Dr. Kosuda), Department of Surgery (Dr. Watanabe), and Department of Internal Medicine (Dr. Kobayashi), National Defense Medical College, Tokorozawa, Japan; and the Department of Diagnosis (Dr. Ichihara), Kawasaki Medical College, Kurashiki, Japan.
Partially supported by funding from the Working Group Project of the Japanese Society of Nuclear Medicine.
Manuscript received November 20, 1998; revision accepted August 19, 1999.
Correspondence to: Shigeru Kosuda, MD, Department of Radiology, National Defense Medical College, 3–2 Namiki Tokorozawa 359-8513, Japan; e-mail: nucleark@infokanto.ne.jp

economic aspects of nuclear medicine procedures for lung cancer has been reported,[1–7] and the published literature on their cost-effectiveness has shown that the 2-fluoro-2-D-[^{18}F]fluorodeoxyglucose (FDG) positron emission tomography (PET) strategy is cost-effective in the management of NSCLC.[1–5]

The costs of medical examinations in Japan differ greatly from their costs in the United States and European countries.[5,7] Furthermore, the current diagnostic strategy for lung cancer in Japan is also somewhat different from the strategy in these other countries. In general, physicians in Japanese hospitals are not performing mediastinoscopy, or are performing it less often, in patients who have or are suspected of having lung cancer, and they are performing bronchofibroscopy without general anesthesia more frequently.

Decision-tree sensitivity analysis is a useful tool for resolving uncertainty in decision making,[7–10] but many assumptions are usually used in the analysis. The validity of the analyses is more certain when actual clinical data or variables are employed instead of assumptions.

The aim of our study is to assess the cost-effectiveness of the chest CT plus chest FDG-PET strategy prior to the introduction of this technology in our Japanese hospital. We used decision-tree sensitivity analysis based on current clinical data from our hospital in patients with pulmonary cancer (NSCLC, stage IIIB or less).

Materials and Methods

Decision-tree sensitivity analysis was performed to determine expected marginal costs and expected life expectancy gain in NSCLC patients by using two competing strategies: (1) the chest CT–alone strategy, which is being utilized in most institutions in Japan, and (2) the new strategy of chest CT plus chest FDG-PET.

Baseline Patients and Variables

The population of those patients who had had a pulmonary nodule that was histopathologically confirmed by thoracotomy in our hospital between April 1996 and March 1997 was used to obtain baseline data. Of the total of 56 patients with pulmonary nodules, 40 had malignant disease (39 NSCLC, 1 carcinoid), and 16 had benign disease (5 hamartomas, 3 granulomas, 2 benign mesotheliomas, 2 intrapulmonary bronchial cysts, and 4 other benign diseases). Thus, the proportion of patients surgically treated for a pulmonary nodule in our hospital and who had malignant disease was 71.4%. The success rate of transbronchial lung biopsy (TBLB) in our hospital was 75.0% (42/56). TBLB failed in nine patients, and it was not attempted in the other five patients because of the nodule's peripheral location, small size, or concomitant pulmonary disease, such as advanced bullous emphysema.

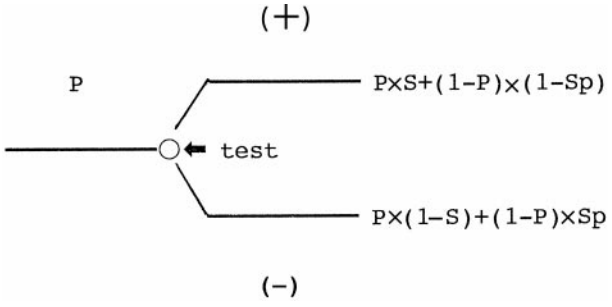
Baselines of other relevant variables in regard to sensitivity and specificity are shown in Table 1, with mortality and life expectancy shown in Table 2. Those values listed in the tables were obtained from a review of the medical literature[11–42] and were used in the decision trees. It was assumed that the prevalence of N3, contralateral, mediastinal involvement was 31%,[29–31] and that mediastinoscopic biopsy was 100% accurate. Chest CT sensitivity and specificity for the diagnosis of lung cancer were not incorporated into the current study, because the sensitivity of CT for the diagnosis of lung cancer is extremely high (99.7%), but its specificity is low (57.9%).[43–46] Actually, the chest CT findings had hardly any influence on the diagnosis of lung cancer in our hospital.

Cost

The mean costs of medical examinations and thoracotomy are shown in Table 3. The Japanese yen costs were based on the bills of outpatients and inpatients in our hospital between April 1996 and March 1997. The costs in US dollars were calculated at a yen-dollar conversion rate of 140 yen to $1.00 US. The costs of outpatient examinations and of thoracotomies for benign and malignant disease include the cost of diagnostic procedures for staging, such as whole-body skeletal scintigraphy, brain MRI or CT, abdominal CT or ultrasound, measurement of serum tumor markers, and so forth. Depreciation of the positron camera, personnel expenses, and overhead costs were not taken into account; the first two are estimated to total approximately 20,000 yen per examination in Japan.[47]

Decision Trees

The details of decision tree analysis have been described elsewhere.[8–10] Briefly, the decision tree in general is constructed of the choices and potential outcomes of the choices. All conditional probabilities of each outcome in the tree are calculated and obtained as a function of the variables listed in Tables 1 and 2 by using Bayesian analysis, that is,



where P = prevalence, S = sensitivity, and Sp = specificity.

Table 1—*Baseline of All Relevant Variables Used in the Decision Trees: Lung Cancer and Lymph Nodes*

Variables	Baseline	References
Lung cancer, %		
Prevalence	71.4	
PET sensitivity	96.3	11–20
PET specificity	78.6	11–20
Lymph nodes (N3), %		
Prevalence	31.0	1, 21, 23, 25–27
CT sensitivity	67.0	1, 21–28
CT specificity	73.0	1, 21–28
PET sensitivity	90.0	1, 29–31
PET specificity	91.0	1, 29–31

Table 2—*Baseline of All Relevant Variables Used in the Decision Trees: Mortality and Life Expectancy*

Variables	Baseline	References
Mortality, %		
PET	0	1
CT	0.0025	1, 38, 39
Thoracotomy	3.0	1, 32–37
Mediastinoscopic biopsy	0.3	1, 35
Life expectancy, yr		
Surgical cure	7.0	1, 40, 41
Radiotherapy in patients with N3	1.0	42
No therapy in patients with surgically curable cancer	1.0	1, 40, 41
Radiotherapy in patients with surgically curable cancer	2.0	1, 40, 41

Table 3—*Baseline of All Relevant Variables Used in the Decision Trees: Examinations and Therapies*

Examinations and Therapies	Baseline of Costs	
	Yen	$ US
Bronchofibroscopy	74,150	$ 530
Mediastinoscopy	120,450	$ 860
Outpatient examinations (malignant)	79,682	$ 569
Outpatient examinations (benign)	53,003	$ 379
Thoracotomy (malignant)	2,292,768	$16,377
Thoracotomy (benign)	1,165,284	$ 8,323

The adjunct assumptions below were assigned to each possible outcome of each decision tree prior to its construction. A simulation of 1,000 patients in whom NSCLC, stage IIIB or less, with no remote metastases, was suspected was set up in a context of a 71.4% prevalence of NSCLC and a 31.0% prevalence of N3. The FDG-PET study was preceded by chest CT in every patient. All of the patients categorized as N3 according to chest CT were assumed to have NSCLC. Mediastinoscopy was performed only when N3 was suspected on the basis of FDG-PET.

Sensitivity Analysis

The cost of an FDG-PET study has not yet been decided in Japan. We hear that the Welfare Ministry is currently planning to put the cost of an FDG-PET study at approximately 100,000 yen. Sensitivity analysis on the costs of FDG-PET in the chest CT plus chest FDG-PET strategy was performed to compute expected marginal costs by varying the FDG-PET costs per study. Sensitivity analysis of the specificity of FDG-PET for the diagnosis of lung cancer and the sensitivity of FDG-PET for the diagnosis of N3 were also carried out because the values may make a great difference in clinical settings and can vary with the institution, whereas the sensitivity of FDG-PET for the diagnosis of lung cancer and the specificity of FDG-PET for the diagnosis of N3 are similar at all institutions.[11–20,29–31] The relationships between prevalence of malignant disease, expected marginal costs, and life expectancy gain were analyzed by two-way sensitivity analysis.

Results

The decision trees for the 1,000-patient simulation and the results are shown in Figures 1, 2, which show

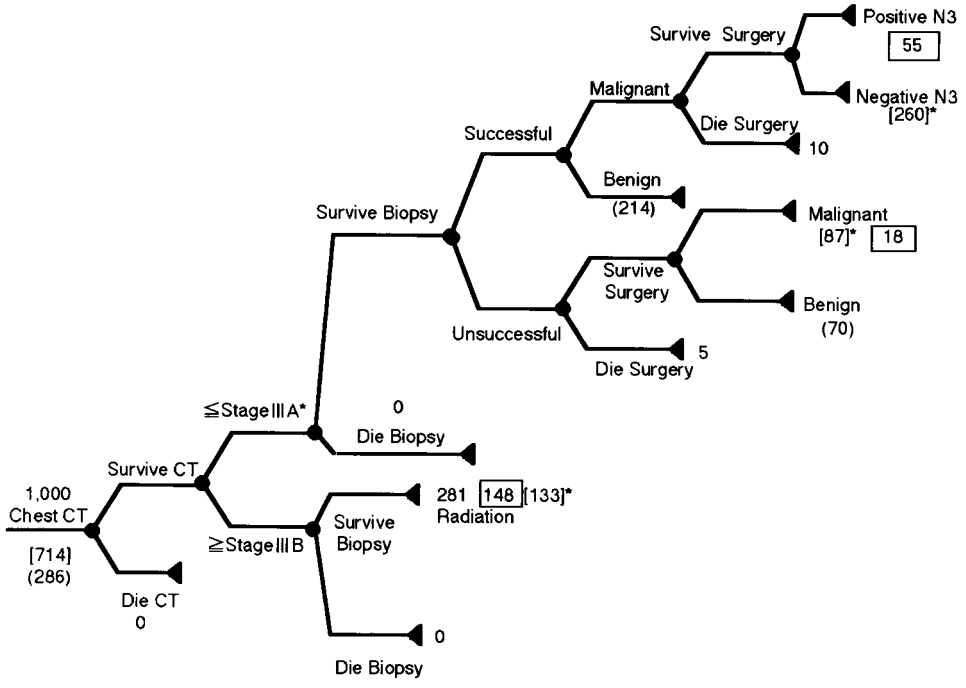


FIGURE 1. Decision tree and the results of the chest CT–alone strategy in a simulation of a 1,000-patient population with pulmonary nodules (71.4% prevalence of malignancy). Brackets indicate number of malignant tumors; parentheses, benign tumors; brackets with asterisk, number of patients ≤N2; in boxes, number of N3 patients.

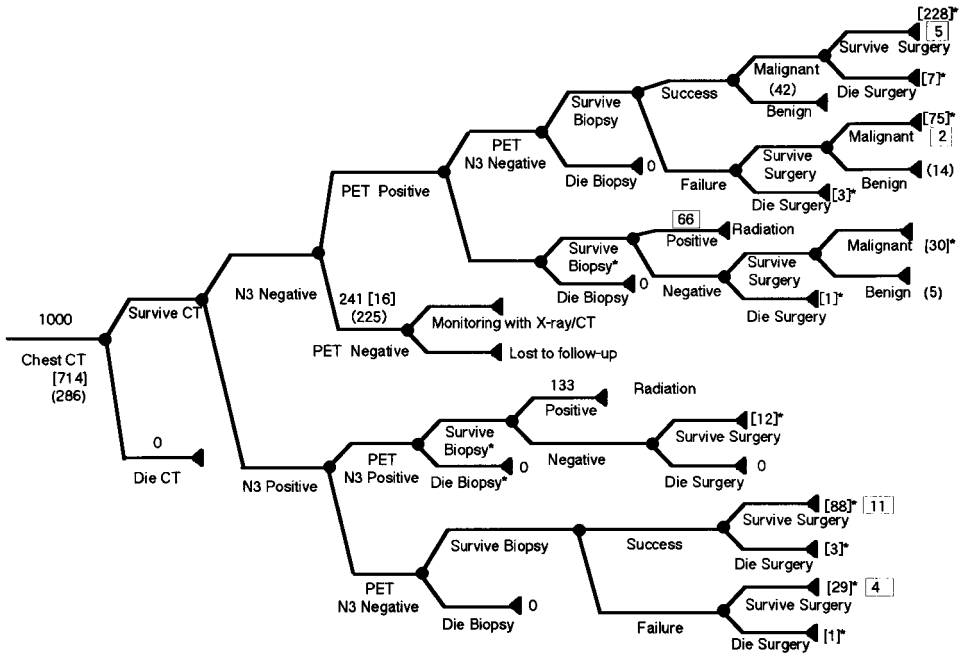


FIGURE 2. Decision tree and the results of the chest CT plus chest FDG-PET strategy in a simulation of a 1,000-patient population with pulmonary nodules (71.4% prevalence of malignancy). Biopsy* = mediastinoscopic biopsy. Brackets indicate number of malignant tumors; parentheses, benign tumors; brackets with asterisk, number of patients ≤N2; in boxes, number of N3 patients.

the decision trees for the chest CT–alone strategy and the chest CT plus chest FDG-PET strategy, respectively.

With the chest CT–alone strategy, 133 patients with resectable disease would undergo radiation therapy, and 55 patients with unresectable disease and 70 patients with benign disease would undergo an unnecessary attempt at curative surgery.

The chest CT plus chest FDG-PET strategy, which includes mediastinoscopy, is somewhat complicated, but because of improved NSCLC staging, curative surgery increased and noncurative surgery decreased. Table 4 shows the results of the two competing strategies. The CT plus FDG-PET strategy would reduce the number of bronchoscopies by approximately half (from 1,000 to 512 patients), with the result that the number of thoracotomies for benign diseases and the number of noncurative thoracotomies would decrease, while the number of mediastinoscopies and curative thoracotomies would increase.

Figure 3 shows the results of sensitivity analysis on the cost of FDG-PET, ranging from 30,000 to 200,000 Japanese yen in the chest CT–plus–FDG-PET strategy. Figure 3 shows that the chest CT–plus–FDG-PET strategy would not be economical, *ie*, not cost-saving, mainly because the examinations are very inexpensive. However, the patient life expectancy gain would increase as a result of improved staging of lung carcinoma.

The cost of FDG-PET is expected to amount to 100,000 yen per study in the near future. If FDG-PET costs 100,000 yen per study, the CT–plus–FDG-PET strategy would increase the total cost by 10.5%. However, the expected life expectancy gain would be 0.607 years per patient, and the expected cost for the life expectancy gain because of improved staging would be 218,000 yen/yr/patient (Table 4). This means that the cost for one NSCLC patient to survive an additional 1 year would be 218,000 yen.

The specificity of FDG-PET for the diagnosis of lung cancer and the sensitivity of FDG-PET for the

Table 4—*Results of Two Competing Strategies: Chest CT Alone vs Chest CT Plus Chest FDG-PET

	CT Alone	CT + FDG-PET
Bronchofibroscopy	1,000 pts	512 pts
Mediastinoscopy	0 pts	247 pts
Thoracotomy for benign disease	70 pts	19 pts
Thoracotomy for cancer	433 pts	499 pts
Thoracotomy for curable diseases	347 pts	462 pts
Thoracotomy for uncurable diseases	73 pts	22 pts
Surgical death	15 pts	15 pts
Total cost, yen	1.262×10^6	1.394×10^6
Life expectancy, yr/patient	10.33	10.94

*pts = patients. Cost of FDG-PET = 100,000 yen.

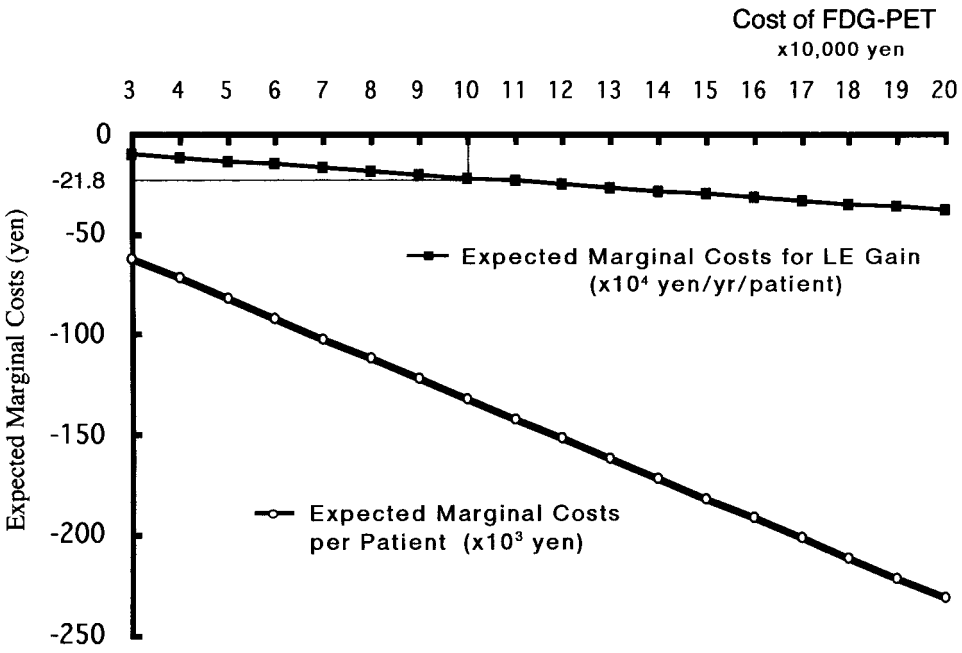


FIGURE 3. Results of sensitivity analysis of FDG-PET cost per study on expected marginal costs (measured in yen) and expected marginal costs for life expectancy gain (yen/yr/patient) calculated for the two competing strategies of chest CT alone vs chest CT plus chest FDG-PET. If the cost per study of FDG-PET examinations is estimated to be 100,000 yen, the expected cost for life expectancy gain would be 218,000 yen/yr/patient. LE = life expectancy.

diagnosis of N3 depend on the institution. These sensitivity analyses show that the marginal costs would decrease as the specificity for the diagnosis of lung cancer or the sensitivity for the diagnosis of N3 decreases, but that the life expectancy gain will be almost stable, regardless of the sensitivity and specificity values (Fig 4, 5).

The prevalence of malignant disease in our hospital was 71.4%, but the expected marginal costs and life expectancy gain vary widely at prevalences ranging from 10 to 90%. The threshold value of the marginal costs was approximately 40% (Figure 6). The prevalence of lung cancer is the key variable in cost-effective analysis.

DISCUSSION

The cost of medical care in Japan is rapidly increasing year by year, and it increased by 1 trillion yen a year in the 1990s. It is estimated that in 1999, medical care will cost more than 30 trillion yen, or approximately $\$2.14 \times 10^{11}$ US—around 8% of the gross domestic product.

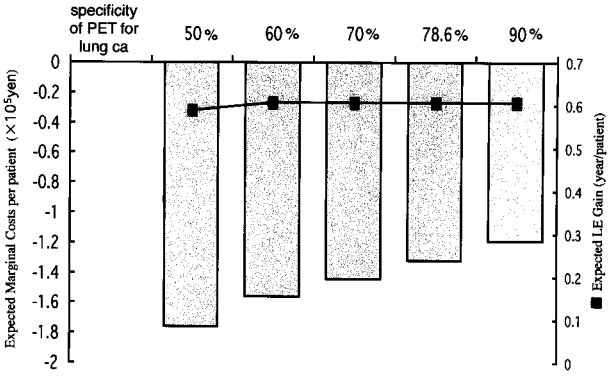


FIGURE 4. Results of the sensitivity analysis for the specificity of FDG-PET for lung cancer on expected marginal costs per patient (measured in yen) and expected life expectancy gain (year/patient). LE = life expectancy; ca = cancer.

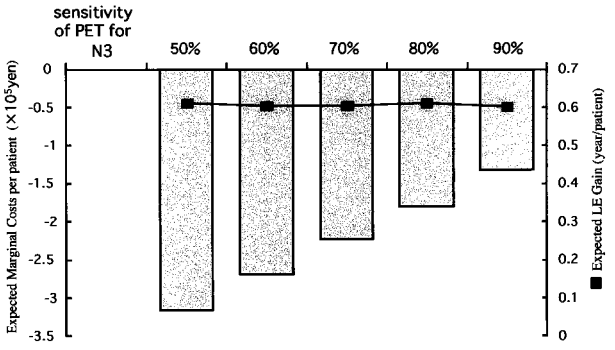


FIGURE 5. Results of the sensitivity analysis for the sensitivity of FDG-PET for N3 on expected marginal costs per patient (measured in yen) and expected life expectancy gain (yr/patient). LE = life expectancy.

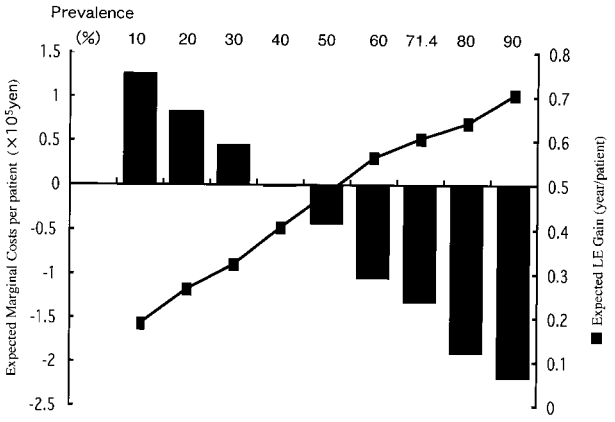


FIGURE 6. Results of the sensitivity analysis for the prevalence of lung cancer on expected marginal costs per patient (measured in yen) and expected life expectancy gain (yr/patient). The threshold value requires less than approximately 40% prevalence in order for the chest CT plus chest FDG-PET strategy to reduce costs. LE = life expectancy.

Our study may be criticized for using the baseline of 56 patients with pulmonary nodules who presented to the hospital during a 1-year period, because baseline data from a single hospital may raise the question of generalizability. That, however, is why we performed sensitivity analysis. As a matter of fact, there have been few documents with accurate figures for lung cancer patients in Japan. According to a few studies, the success rate of TBLB was 63.0%, and the prevalence of lung cancer in Japanese hospitals was 51.0 to 71.1%.[48–50] The variables in that study are similar to our own. The decision tree we constructed, which adds chest FDG-PET to the usual practice of diagnosing and treating patients with potential NSCLC, is now being utilized in most institutions equipped with a PET system in Japan.

The clinical results of using FDG-PET have been very promising in most common cancers, for which CT and MRI have major limitations.[51] However, the drawbacks of FDG-PET are limited availability and high cost, with it continuing to be one of the highest-priced medical studies. The cost of FDG-PET in the United States is approximately double that of MRI. By contrast, the cost-effectiveness analyses of FDG-PET in the management of NSCLCs or solitary pulmonary nodules have shown that a noninvasive strategy using FDG-PET can be more cost-effective than other approaches because of the reduction in the numbers of unnecessary medical examinations and open thoracotomies, and because it does not compromise patient survival.[1–4]

Despite the promising results described above, the cost-effectiveness of FDG-PET in the management of NSCLC may not always hold true in other countries, because health-insurance systems differ greatly from country to country. Therefore, economic analysis, which remains worthwhile and can provide significant information concerning the management of NSCLC, must be performed in each country. In view of the fact that lung cancer is now a major worldwide killer and that there is increasing pressure to lower costs and to gain the most benefit from the money spent, cost-effectiveness analysis of FDG-PET in the management of NSCLC appears to be imperative and crucial.

Contrary to the reports from the United States and European countries, our results based on the strict decision tree analysis showed that the introduction of FDG-PET studies would not bring about expected marginal costs in the management of NSCLC in Japan. The chest CT plus chest FDG-PET strategy will not be economical or cost-saving in Japan. Assuming that depreciation of the positron camera and personnel expenses are included into the total cost and the FDG-PET examination cost of 100,000 yen per study (including the cost of tracers, technical costs, and professional costs), the increase in deficit would amount to 152,000 yen/patient. On the other hand, mediastinoscopy need not be performed in any patient who is both CT-positive and FDG-PET–positive for N3. In that case, the saving of the mediastinoscopic cost is similar to the sum of depreciation and personnel expenses.

On the other hand, patient life expectancy gain would increase as a result of improved NSCLC staging. Life expectancy gain would be 0.607 years (7.3 months) per patient, and the cost increment would be 218,000 yen/yr/patient if the FDG-PET examination cost 100,000 yen (around $700 US) per study. In other words, NSCLC patients would gain 7.3 months of life for an outlay of $945 US. The Japanese economic situation should easily tolerate this increase in cost. In addition, our goal in NSCLC management is not cost saving itself, but improvement of patient outcome on the basis of quality of life.

The causes of the cost increment in the CT–plus–FDG-PET strategy include not only the higher cost of FDG-PET, but also the following factors. First, medical examinations in Japan are generally inexpensive. The cost of bronchofibroscopy, including biopsy, is especially low in Japan, approximately 15% of the cost in the United States. Thus, the fact that the CT–plus–FDG-PET strategy reduces the number of bronchoscopy examinations by approximately half has the least impact on cost savings. Second, the length of hospital stays in Japan is very long. The average stay in our hospital was 25.2 days for patients with benign diseases and 46.8 days for patients with malignant diseases. This is mainly because inpatients are only reimbursed for the cost of hospitalization

and concurrent examinations beyond the first 57,000 yen each month. This is a unique, complicated policy of the national health-care systems in Japan.[47] Third, regardless of the chest CT findings, diagnostic procedures for staging are ordered at the first outpatient visit for patients in whom lung cancer is suspected, partially because of a long waiting period for the diagnostic examinations. This means that patients with benign disease also undergo skeletal scintigraphy, brain MRI or CT, and abdominal CT or ultrasound. There is a tendency for the physician to order numbers of examinations in proportion to the probability of malignancy in the pulmonary nodule. These issues are very problematic in regard to cost-effectiveness analysis, and solving them is a challenge for nuclear medicine specialists and radiologists, as well as for general practitioners and economists.

Life expectancy gain and expected marginal costs vary widely with the prevalence of NSCLC. It is noteworthy that prevalence is a key variable in understanding the cost-effectiveness of our strategy. Our results revealed that as the prevalence of NSCLC increases, the expected marginal costs decrease and they entered the red at the threshold (cutoff) point of approximately 40%, while life expectancy gain increased. The deficit is presumably due to the three causes mentioned above. For the time being, possible measures to reduce the deficit include shortening hospital stay and performing additional staging investigations only when there is no evidence of mediastinal node involvement on chest CT. On the other hand, the whole-body FDG-PET system has the potential to detect distant metastatic foci. If whole-body surveys by FDG are employed to detect distant metastasis in NSCLC patients, it might be possible to perform fewer staging investigations.[3,4]

Chest CT was not incorporated into the current strategy for the diagnosis of lung cancer because of its low specificity (57.9%). Chest CT sensitivity for the diagnosis of lung cancer, however, is very high (99.7%). Mass screening for lung cancer by spiral CT has just recently been introduced nationwide in Japan, taking full advantage of the ability of spiral CT to detect smaller pulmonary nodules, those < 1.0 cm in diameter.[52,53] This new screening system is promising for earlier detection of lung cancer, while the clinical efficacy of mass screening using chest radiographs (photoscopic examination) is regarded as inadequate in terms of the survival of the screened population. Nevertheless, the new system will provide nuclear medicine specialists with another challenge, that of diagnosing smaller lesions by means of FDG-PET in the foreseeable future.

In conclusion, the chest CT plus chest FDG-PET strategy is unlikely to be cost-effective in patients with NSCLC in Japan. However, patient life expectancy gain would increase as a result of improved staging of NSCLC. The life expectancy gain would be 0.607 years (7.3 months) per patient and the cost increment would be 218,000 yen/yr/patient if the FDG-PET cost were 100,000 yen (around $700 US) per study. Last but not least, our results were obtained in a small group of patients in a single hospital in Japan, and we only speculate that the above-mentioned conclusions are true of the rest of Japan. We emphasize that these preliminary results should be confirmed by further studies for local environments.

References

1 Gambhir SS, Hoh CK, Phelps ME, et al. Decision tree sensitivity analysis for cost-effectiveness of FDG-PET in the staging and management of non-small-cell lung carcinoma. J Nucl Med 1996; 37:1428–1436

2 Weber W, Bulow H, Romer W, et al. FDG-PET in solitary pulmonary nodules: a German cost-effectiveness analysis [abstract]. J Nucl Med 1997; 38(suppl):245p

3 Gambhir SS, Shepherd J, Phelps ME, et al. A theoretical decision analysis model for the cost effectiveness of newly emerging coincidence imaging (CI) technology in the presurgicaal staging of non-small cell lung carcinoma (NSCLC) [abstract]. J Nucl Med 1997; 38(suppl):245p

4 Steinert HC, von Schulthess GK, Weder W. Effectiveness of whole-body FDG PET in staging of non-small-cell lung cancer (NSCLC) [abstract]. J Nucl Med 1998; 39(suppl):80p

5 Kubota K, Yamada S, Fukuda H, et al. Cost effectiveness analysis of FDG-PET in the differential diagnosis and staging of lung cancer in Japan. Kaku Igaku (Jpn J Nucl Med) 1997; 34:329–336

6 Ell PJ. Challenges for nuclear medicine in the 1990s. Nucl Med Commun 1992; 13:65–75

7 Kosuda S, Ichihara K, Watanabe M, et al. Decision tree sensitivity analysis for cost-effectiveness of chest FDG-PET in patients with a pulmonary tumor (non-small cell carcinoma). Kaku Igaku (Jpn J Nucl Med) 1998; 35:395–404

8 Weinstein MC, Fineberg HV. Clinical decision analysis. Philadelphia, PA: WB Saunders, 1980

9 Pauker S, Kassirer J. The threshold approach to clinical decision making. N Engl J Med 1980; 302:1109–1117

10 Luce B, Simpson K. Methods of cost-effectiveness analysis: areas of consensus and debate. Clin Therap 1995; 17:109–125

11 Kubota K, Matsuzawa T, Fujiwara T, et al. Differential diagnosis of lung tumor with positron emission tomography: a prospective study. J Nucl Med 1990; 31:1927–1932

12 Jacobs MP, Mantil JC, Peterson CD, et al. FDG PET imaging of the chest. J Nucl Med 1992; 33(suppl):975–976

13 Knopp MV, Bishoff H, Oberdorfer F, et al. Positron emission tomography of the thorax: the current clinical status. Radiology 1992; 32:290–295

14 Slosman DO, Spiliopoulos A, Couson F, et al. Satellite PET and lung cancer: a prospective study in surgical patients. Nucl Med Commun 1993; 14:955–961

15 Scott WJ, Schwabe JL, Gupta NC, et al. Positron emission tomography of lung tumors and mediastinal lymph nodes using [18F]fluoroglucose: the members of the PET-lung tumor study group. Ann Thorac Surg 1994; 58:698–703

16 Duhaylongsod FG, Lowe VJ, Patz EJ Jr, et al. Detection of primary and recurrent lung cancer by means of F-18 fluoro-

deoxyglucose positron emission tomography. J Thorac Cardiovasc Surg 1995; 110:130–139
17 Hubner KF, Buonocore E, Singh SK, et al. Characterization of chest masses by FDG positron emission tomography. Clin Nucl Med 1995; 20:293–298
18 Sazon DA, Santiago SM, Soo Hoo GW, et al. Fluorodeoxyglucose-positron emission tomography in the detection and staging of lung cancer. Am J Respir Crit Care Med 1996; 153:417–421
19 Weber W, Romer W, Ziegler S, et al. F-18-FDG PET in the evaluation of small solitary pulmonary nodules [abstract]. J Nucl Med 1996; 37(suppl):111p
20 Bury T, Dowlati A, Paulus P, et al. Evaluation of the solitary pulmonary nodule by positron emission tomography imaging. Eur Respir J 1996; 9:410–414
21 Gross B, Glazer G, Orringer M, et al. Bronchogenic carcinoma metastatic to normal-sized lymph nodes: frequency and significance. Radiology 1988; 166:71–74
22 Webb W, Gatsonis C, Zerhouni E, et al. CT and MR imaging in staging non-small cell bronchogenic carcinoma: report of the Radiologic Diagnostic Oncology Group. Radiology 1991; 178:705–713
23 McLoud TC, Bourgouin PM, Greenberg RW, et al. Bronchogenic carcinoma: analysis of staging in the mediastinum with CT by correlative lymph node mapping and sampling. Radiology 1992; 182:319–323
24 Seely JM, Mayo JR, Miller RR, et al. T1 lung cancer: prevalence of mediastinal nodal metastasis and diagnostic accuracy of CT. Radiology 1993; 186:129–132
25 White P, Adams H, Crane M, et al. Preoperative staging of carcinoma of the bronchus: can computed tomographic scanning reliably identify stage tumors? Thorax 1994; 49:951–957
26 Primack S, Lee K, Logan P. Bronchogenic carcinoma: utility of CT in the evaluation of patients with suspected lesions. Radiology 1994; 193:795–800
27 Dillemans B, Deneffe G, Verschakelen J, et al. Value of computed tomography and mediastinoscopy in preoperative evaluation of mediastinal nodes in non-small cell lung cancer. Eur J Cardiothorac Surg 1994; 8:37–42
28 Yokoi K, Okuyama A, Mori K. Mediastinal lymph node metastasis from lung cancer: evaluation with 201 Tl-SPECT; comparison with CT. Radiology 1994; 192:813–817
29 Wahl RL, Quint L, Greenough R, et al. Staging of mediastinal non-small cell lung cancer with FDG PET, CT, and fusion images: preliminary prospective evaluation. Radiology 1994; 191:371–377
30 Madar I, Hoh C, Figlin R, et al. Cost-effective staging of non-small-cell lung carcinoma by whole-body PET-FDG imaging [abstract]. J Nucl Med 1995; 36(suppl):57p
31 Valk P, Pounds T, Hopkins D, et al. Staging of lung cancer by whole-body PET-FDG imaging [abstract]. J Nucl Med 1995; 36(suppl):95p
32 Williams D, Paircolero P, Davis C, et al. Survival of patients surgically treated for stage I lung cancer. J Thorac Cardiovasc Surg 1981; 82:70–76
33 Evans E. Resection of bronchial carcinoma in the elderly. Thorax 1973; 28:86–88
34 Ginsberg R, Hill I, Eagan R, et al. Modern thirty-day operative mortality for surgical resection in lung cancer. J Thorac Cardiovasc Surg 1983; 86:654–658
35 Black WC, Armstrong P, Daniel T. Cost-effectiveness of chest CT in T1N0M0 lung cancer. Radiology 1988; 167:373–378
36 Moroff S, Pauker S. What to do when the patient outlives the literature, or DEALE-ing with a full deck. Med Decis Making 1983; 3:313–338
37 Cummings S, Illington G, Richard R. Managing solitary pulmonary nodules: the choice of strategy in a "close call." Am Rev Respir Dis 1986; 134:453–460
38 Hartman G, Hattery R, Witten D, et al. Mortality during excretory urography: Mayo Clinic experience. AJR Am J Roentgenol 1982; 139:914–922
39 McClennan B. Low-osmolality contrast media: premises and promises. Radiology 1987; 162:1–8
40 Beck J, Kassirer J, Pauker S. A convenient approximation of life expectancy (the "DEALE"): I. Validation of the method. Am J Med 1982; 73:883–888
41 Beck J, Pauker S, Gottlieb J. A convenient approximation of life expectancy (the "DEALE"): II. Use in medical decision-making. Am J Med 1982; 73:889–897
42 Kitagawa T. Radiotherapy. In: Ishikawa S, ed. Clinical lung cancer [in Japanese]. Tokyo, Japan: Kohdansha, 1983; 189–229
43 Proto AV, Thomas SR. Pulmonary nodules studied by computed tomography. Radiology 1985; 156:149–153
44 Zerhouni EA, Stitik FP, Siegelman SS, et al. CT of the pulmonary nodule: a cooperative study. Radiology 1986; 160:319–327
45 Siegelman SS, Khouri NF, Leo FP, et al. Solitary pulmonary nodules: CT assessment. Radiology 1986; 160:307–312
46 Huston J 3d, Muhm JR. Solitary pulmonary nodules: evaluation with a CT reference phantom. Radiology 1989; 170:653–656
47 Sasaki Y. Assessment of cost-effective nuclear medicine practice in Japan. Acad Radiol 1996; 3:S106–S108
48 Motoyama A, Kono M, Adachi S, et al. Secondary screening for lung cancer by helical CT [in Japanese]. Jpn J Lung Cancer 1995; 35:883–890
49 Yamanda T, Miyazawa M, Kondo R, et al. Analysis of small peripheral pulmonary tumors treated by thoracoscopic excisional biopsy (wedge resection) on a suspicion of primary lung cancer [in Japanese]. Jpn J Lung Cancer 1999; 39:137–143
50 Nomori H, Horio H, Fuyuno G, et al. Analysis of reasons for biopsy in small pulmonary nodules diagnosed by thoracoscopic and open-lung biopsy [in Japanese]. Jpn J Lung Cancer 1999; 39:35–41
51 Wahl RL. Positron emission tomography: applications in oncology. In: Henkin RB, et al, ed. Nuclear medicine. St. Louis, MO: Mosby, 1996; 1524–1545
52 Ito S, Koyama S, Tusaka M, et al. Fundamental study for lung-cancer screening by helical CT: first report; evaluation of radiation dose and image quality using a phantom. Nippon Igaku Hoshasen Gakkai Zasshi (Nippon Acta Radiol) 1996; 56:731–35
53 Sone S, Takashima S, Li F, et al. Mass screening for lung cancer with mobile spiral computed tomography scanner. Lancet 1998; 351:1242–1245