

RESEARCH ARTICLE

Economic Evaluation of Prostate Cancer Screening Test as a National Cancer Screening Program in South Korea

Sangjin Shin¹, Youn Hee Kim^{1,2}, Jin Sub Hwang¹, Yoon Jae Lee^{1,4}, Sang Moo Lee^{1,3}, Jeonghoon Ahn^{1*}

Abstract

Background: Prostate cancer is rapidly increasing in Korea and professional societies have requested adding prostate specific antigen (PSA) testing to the National Cancer Screening Program (NCSP), but this started a controversy in Korea and neutral evidence on this issue is required more than ever. The purpose of this study was to provide economic evidence to the decision makers of the NCSP. **Materials and Methods:** A cost-utility analysis was performed on the adoption of PSA screening program among men aged 50-74-years in Korea from the healthcare system perspective. Several data sources were used for the cost-utility analysis, including general health screening data, the Korea Central Cancer Registry, national insurance claims data, and cause of mortality from the National Statistical Office. To solicit the utility index of prostate cancer, a face-to-face interview for typical men aged 40 to 69 was conducted using a Time-Trade Off method. **Results:** As a result, the increase of effectiveness was estimated to be very low, when adopting PSA screening, and the incremental cost effectiveness ratio (ICER) was analyzed as about 94 million KRW. Sensitivity analyses were performed on the incidence rate, screening rate, cancer stage distribution, utility index, and treatment costs but the results were consistent with the base analysis. **Conclusions:** Under Korean circumstances with a relatively low incidence rate of prostate cancer, PSA screening is not cost-effective. Therefore, we conclude that adopting national prostate cancer screening would not be beneficial until further evidence is provided in the future.

Keywords: Prostatic neoplasms - early detection of cancer - cost-benefit analysis

Asian Pac J Cancer Prev, **15** (8), 3383-3389

Introduction

Prostate cancer is the second most commonly diagnosed cancer in men worldwide as well as the sixth highest cause of death among malignancies (Jemal et al., 2011). In Korea, commonly diagnosed cancers in men include lung cancer, colon cancer, liver cancer, and prostate cancer in order of decreasing incidence. In particular, the incidence of prostate cancer is rapidly increasing each year from 8.4/100,000 men in 1999 to 15.7 men in 2005, and to 25.3/100,000 men in 2010 (Jung et al., 2013a).

Due to the increasing incidence rate of prostate cancer in Korea, as indicated in these figures, the needs for early diagnosis and active treatment of this cancer have been emphasized by the urologists and the inclusion of prostate cancer screening in the national cancer screening program (NCSP) has been discussed. However, this recommendation has also raised some questions and no social consensus has been reached yet regarding this matter in Korea. In other countries, too, national screening plans for prostate cancer bring about debates. The biggest issue

is whether introduction of a national screening program for prostate cancer will ultimately contribute to improvement in health outcomes, that is, prolonged life. Prostate specific antigen (PSA) test is a marker currently used for early detection of prostate cancer. PSA is a common strategy for prostate cancer screening and it was popularized in the 1990s in the United States (Shteynshlyuger and Andriole, 2011).

To have a screening for a certain disease incorporated in the national health screening program, feasibility screening tests are necessary, including the national burden of the particular disease, valid screening method, expected improvement in clinical outcomes through disease screening, and whether the method is affordable for the country. Of these, this study aims to focus on the last one; whether the method is affordable for the country, in other words, the cost effectiveness of the incorporation of prostate cancer screening in the NCSP.

These cost-effectiveness studies have already been carried out in many countries. In Sweden, it was reported that the costs of local prostate cancer diagnosis through the NCSP was feasible. However, in the relevant study,

¹National Evidence-based Healthcare Collaborating Agency, ²Institute of Health and Environment, Seoul National University, ³Lee's Institute of Health Technology, Seoul, ⁴Department of Oriental Gynecology, Bundang CHA Medical Center, CHA University, Kyunggi-Do, Korea *For correspondence: jahn@neca.re.kr

the analysis did not include the information regarding quality of life of cancer patients as well as their mortality rate (Holmberg et al., 1998). Perez-Niddam et al. (1999) reviewed the economic feasibility of prostate cancer screening as part of the NCSP in France from the perspective of insurers. They reported that cost-effectiveness was reviewed for various screening strategies for men with subjective clinical symptoms and for men without but the result was not in favor of recommendations for introduction of the national prostate cancer screening program. In Japan, the cost of introduction of the national prostate cancer screening program was estimated. The estimation indicated that the costs per case of screening and specificity of the screening test would have a significant impact on the program's economic feasibility (Kobayashi et al., 2007).

There are some restrictions in applying these previous studies conducted in the other countries to the current status in Korea, primarily due to a significant difference between nations and ethnic groups in terms of clinical characteristics of prostate cancer as already indicated in many of the previous studies. The difference in incidence of prostate cancer between regions with high and low prevalence of the disease is as much as 25 times (Jemal et al., 2011). The United States shows a huge difference in the incidence of prostate cancer per 100,000 men between races; 146.3 in Caucasian men versus 231.9 in African American men. Mortality is 23.6 men among Caucasians versus 56.3 men among African Americans. On the other hand, both the incidence and mortality are considerably lower among Asian Americans (Jemal et al., 2011). As seen in these examples, it is difficult to have the other countries' study results directly applied to Korean society. For this reason, this study was designed to evaluate economic feasibility of incorporation of prostate cancer screening in the NCSP in Korea's circumstances.

In an effort to fully realize this objective, this study was based on Korean actual data, despite the limitations in available data sources in Korea at the moment, in the assessment of cost-effectiveness of the national prostate cancer screening program. As mentioned earlier, results from this study are expected to be utilized as a lead to resolving the conflicts surrounding introduction of the national prostate cancer screening program in Korea.

Materials and Methods

Materials

In this study, largely 4 types of secondary data sources were utilized. Firstly, general health screening data (2000-2010) from a university hospital in Korea were used (demographic variables, interview records, and lab data including PSA test results). As PSA scores may vary due to the development of test methods, only the data from the patients who were screened since year of 2000 were included in this study.

Secondly, the Korean Central Cancer Registry (KCCR) (~2008) was utilized for prostate cancer screening status and distribution of disease stages. The data from the patients who had PSA tests through general health screening as mentioned earlier were compared with data

from the KCCR to confirm prostate cancer screening status. Pathological diagnosis, Surveillance, Epidemiology and End Results (SEER) stage, and presence of other cancers were also verified.

Thirdly, Health Insurance Review & Assessment Service (HIRA) claims data (2005-2009) were used as well to estimate treatment costs by stage of prostate cancer. For this, the entire data claimed as prostate cancer (ICD-10 code: C61.0) were analyzed. Additionally, the hospital screening data and the cause of mortality data from the National Statistical Office (NSO) were also compared for the sensitivity analysis of prostate cancer screening status and distributions of disease stages.

Lastly, to confirm prostate cancer mortality, a database was constructed to connect the cause of mortality data from the NSO (~2009), the first general hospital screening data, and the second KCCR. The cause of mortality data from the NSO among the general public who had health screenings was divided by year into death due to prostate cancer, death due to other cancer, and death due to reasons other than cancer.

This study protocol was approved by the Institutional Review Board of National Evidence-based Healthcare Collaborating Agency (IRB No. NECAIRB10-009-1).

Methods for economic evaluation

Korean men aged 50 to 74 were included in this study for the assessment of cost effectiveness of the national prostate cancer screening program through PSA tests. Accuracy of PSA tests in Korea were calculated and cost effectiveness analyzed from the perspective of public health care system. The final effectiveness of this study was QALY; productivity cost caused by prostate cancer morbidity and early death was not to be included in this study due to concerns over dual calculations.

A decision tree was constructed to compare the health effect and costs between the introduction of the national prostate cancer screening program and the retention of the current private screening system. The time horizon was 5 years (Figure 1). Based on the transition probabilities, cost, and effectiveness value estimated as following, incremental cost effectiveness of the national prostate cancer screening program was analyzed from the perspective of public health care system.

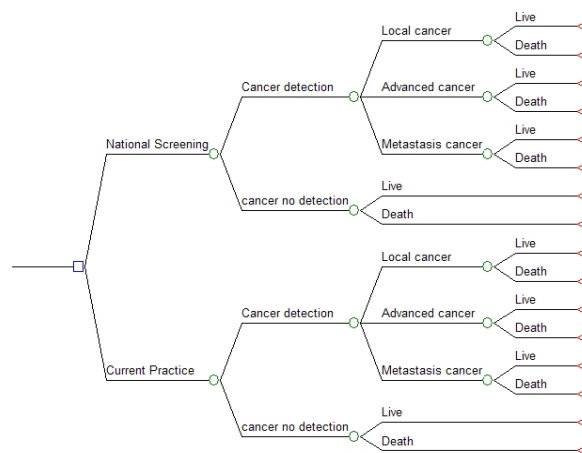


Figure 1. Decision Tree

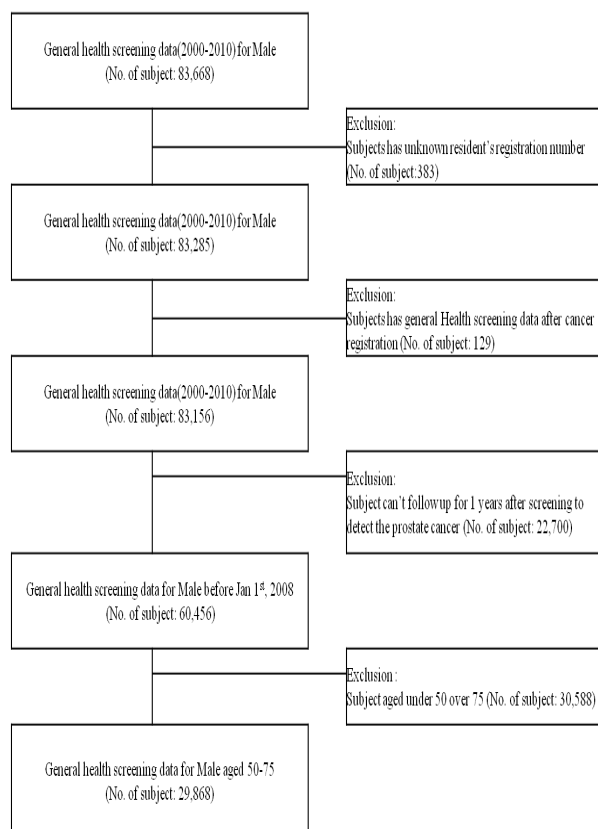


Figure 2. Flow Chart for Estimating Transition Probability

Estimation of transition probabilities

Primary transition probabilities needed in this study were the incidence rate of prostate cancer, distributions of prostate cancer stages, and mortality rate by screening status. To estimate these probabilities, the data sources were structured as in Figure 2.

For the incidence rate of prostate cancer, prostate cancer incidence rates in men aged 50 to 74 in the 2008 KCCR annual report was used. Introduction of the national prostate cancer screening program is expected to enable early diagnosis of prostate cancer, which, in turn, will affect the distributions of prostate cancer stages at the time of onset. To verify this assumption, the SEER disease stages from the KCCR and the TNM classification of malignant tumors (TNM) codes of the HIRA claims data were analyzed together.

The main effect of introduction of the national prostate cancer screening program was thought to be cancer diagnosis at relatively earlier stage. Therefore, differences in disease stage distributions between the screening group and the current practice group were investigated in patients diagnosed with prostate cancer. As for disease stage distributions in patients diagnosed with prostate cancer through screening, both the HIRA TNM disease stage codes and the SEER disease stage codes were confirmed in patients registered as prostate cancer at the KCCR within one year after hospital general screening.

Estimation of cost

In this study, cost items included prostate cancer screening costs, treatment costs by stage of cancer, and

direct non-medical costs (travel costs, patient's time costs, and care costs). Treatment costs for prostate cancer were estimated from HIRA claims data and out of pocket payment also included (NHICP, 2009). In the travel costs and patient's time costs during the medical institution visits after the diagnosis of prostate, the travel costs and patient's time costs particularly for screening were not separately included in this study since the additional travel costs and time costs for screening were deemed insignificant as screenings are generally performed simultaneously for a number of cancers.

Care costs were included in the analysis on the assumption that when patients were hospitalized for the treatment of prostate cancer, their guardians or paid care givers were there to help the patients. To calculate direct non-medical costs, data from a Korea National Health and Nutrition Examination Survey (KNHNES) and a survey report on labor conditions by employment type were used (Ministry of employment and labor, 2011). All cost was corrected to 2010 value using the annual consumer price index of Korean Statistical Information, Service (KOSIS).

Estimation of utility

Health utility in Korean patients with prostate cancer by disease stage were directly surveyed from 160 Korean men aged 40 to 69 (Kim et al., 2013). The survey subject was selected through allocations by age and by region. Face-to-face questionnaires were used to measure utility based on Time-Trade Off (TTO) and Visual Analog Scale (VAS) in which health scenarios with descriptions of major clinical symptoms of local, locally advanced, and metastatic prostate cancer were applied. The health scenarios were developed through a number of consultations with methodologist in quality of life surveys as well as urologists.

Results

Transition probabilities

Incidence rate: the incidence rate of prostate cancer based on the number of male population as of 2010 was estimated to be approximately 0.09%; 4,612/5,424,584 men aged 50 to 74 in total. In this study, consistent prostate cancer incidences were assumed for both the national prostate cancer screening program and the current private screening system, because this study was focused on the assessment of stage shift effect; expected effect of cancer diagnosis at a relatively earlier stage due to prostate cancer screening (Table 1).

Prostate cancer stage: as for the current practice group, specific codes were used among the prostate cancer claims data of male patients aged 50 to 74. Based on the SEER codes entered at the time of disease registration at the KCCR, the distributions of prostate cancer stages were as follows: local cancer in 81.72%, locally advanced cancer in 16.13%, and metastatic cancer in 2.15%. Based on the TNM codes used at the time the claims were made to the HIRA, the distributions were as follows: local cancer in 73.91%, locally advanced cancer in 21.74%, and metastatic cancer in 4.35%. These disease stage distributions included only those for whom the disease

Table 1. Input Parameters

Parameters			Base value	Sensitivity analysis	Sources*
Transition probabilities					
Incidence rate(men aged 50 to 74)			0.085%	-	2008 KCCR Annual Report
Stage					
National screening	SEER	Local	81.72%	-	Linkage general screening data(2005-2008) with KCCR(2005-2008)
		Local-advanced	16.13%	-	
		Advanced	2.15%	-	
Current practice	TNM	Local	-	73.91%	Linkage general screening data(2005-2008) with HIRA (2005-2008) HIRA claims data
		Local-advanced	-	21.74%	
		Advanced	-	4.35%	
Current practice	TNM	Local	69.20%	-	HIRA claims data
		Local-advanced	17.28%	-	
		Advanced	13.52%	-	
Current practice	SEER	Local	-	65.96%	Jung et al., 2013b
		Local-advanced	-	23.08%	
		Advanced	-	10.95%	
Cancer specific mortality					
Cancer specific mortality		Local	0.46%	0.70%	Jung et al., 2013b
		Local-advanced	2.04%	0.88%	
		Advanced	18.18%	16.20%	
Cancer non-specific mortality					
Utility, Mean (SD)			8.80%	-	NSO Life table, 2010
Prostate cancer (1 st year)					
Prostate cancer (1 st year)		Local	0.727(0.142)	0.744(0.122)	Kim et al., 2013
		Local-advanced	0.545(0.144)	0.579(0.117)	
		Advanced	0.321(0.151)	0.365(0.121)	
Prostate cancer (2 nd -5 th year)		Local	0.653(0.135)	0.683(0.125)	
		Local-advanced	0.485(0.470)	0.494(0.125)	
		Advanced	0.149(0.153)	0.225(0.126)	
Common					
Cost (unit: KRW)			0.942	-	KNHANES, 2005
Screening cost					
Prostate specific antigen test			15,000	-	KUA survey**
Biopsy test			38,540	-	
Pathologic test			20,260	-	
Review			3,430	-	
Non-medical cost					
Transportation (round trip)	Inpatient		21,034	-	KNHANES, 2005
		Outpatient	9,968	-	
Time cost for treatment	Inpatient (per day)		104,268	-	Ministry of Employment and Labor, 2010
		Outpatient (per visit)	44,197	-	
Caregiver cost (per day)			50,000	-	Caregiver association, 2005
Treatment cost including out of pocket					
1 st year		Local	9,544,991	7,905,871	HIRA claims data NHIC, 2010
		Local-advanced	11,430,055	10,159,360	
		Advanced	11,080,629	8,572,553	
2 nd -5 th year		Local	3,669,105	2,363,509	
		Local-advanced	4,835,583	3,409,538	
		Advanced	7,654,700	4,325,159	
Treatment cost, Mean(SD)					
1 st year		Local	-	6,386,452(2,247,339)	KUA survey**
		Local-advanced	-	10,275,777(5,687,288)	
		Advanced	-	11,028,204(11,981,692)	
2 nd year		Local	-	334,492(330,372)	
		Local-advanced	-	2,991,853(3,841,871)	
		Advanced	-	7,535,924(6,692,252)	
3 rd year		Local	-	244,914(273,704)	
		Local-advanced	-	3,109,717(5,136,027)	
		Advanced	-	8,119,882(7,440,251)	
4 th year		Local	-	482,883(1,544,965)	
		Local-advanced	-	1,587,676(2,413,810)	
		Advanced	-	6,656,405(6,076,118)	
5 th year		Local	-	284,565(365,634)	
		Local-advanced	-	2,873,228(5,365,695)	
		Advanced	-	14,452,996(22,231,463)	

*See the details in material and method; **Estimated by chart review by Korean Urological Association

stage could be confirmed; among 203 patients registered at the KCCR within 1 year after prostate cancer screening, those with missing disease stage data were excluded.

Meanwhile, disease stage distributions in prostate cancer patients in the current practice without introduction of the national screening program were calculated based

on TNM codes of claims data of the entire prostate cancer patients. In this case, the distributions were as follows; local cancer in 69.20%, locally advanced cancer in 17.28%, and metastatic cancer in 13.52% (Table 1).

Mortality rate: the probability of mortality of prostate

cancer was 0.46% in local cancer, 2.04% in locally advanced cancer, and 18.18% in metastatic cancer. In addition, the total mortality rate in men aged 50 to 74 was also estimated where the probabilities of mortality due to other reasons were also considered. The general mortality rate in men aged 50 to 74 was calculated from the entire male population (5,828,294) aged 50 to 74 as of 2009 by using the life table released by the NSO (Table 1).

Cost

Screening cost: for PSA test cost, the entire PSA test cost was applied for the screening group, whereas biopsy and pathological costs and pathological review costs were also applied to the group where cancer was diagnosed. In the group where cancer was not diagnosed, biopsy, pathologic test, and review costs were also applied for patients who were applicable to PSA cut-off value or above. In the screening group, PSA test costs and additional test costs were allocated for the cancer group and only PSA test cost was allocated for the non-cancer group. In the current practice group, PSA test costs and additional test costs were allocated only for the cancer patient group (Table 1).

Prostate cancer costs: the treatment costs calculated based on the HIRA claims data as well as the patient chart review conducted in collaboration with the Korean Urological Association is presented in Table 1. The treatment costs of prostate cancer at the stage of locally advanced cancer and metastatic cancer was estimated to be higher in the patient chart review than in the HIRA claims data. The travel costs, patient's time costs and care costs also included into total cost.

Utility estimation: the quality of life after the diagnosis of local prostate cancer was estimated to be 0.727 for the first year and 0.653 for the second year. Approximately 10% of the responders said that the quality of life in the second year following the diagnosis was better than in the first year, whereas more than 90% of the responders held the opposite view: worsened quality of life in the second year following the diagnosis. Older patients tended to view the quality of life in the second year after local cancer diagnosis as worse. In terms of locally advanced cancer, the quality of life after the diagnosis of locally advanced prostate cancer was estimated to be 0.545 for the first year and 0.485 for the second year, indicating a lower quality of life in the second year. In terms of metastatic cancer, the quality of life after the diagnosis of metastatic prostate cancer was estimated to be 0.321 for the first year and 0.149 for the second year. Results from the Time Trade-Off (TTO) based analysis and VAS based analysis did not differ largely, except that the values of the second year following metastatic cancer diagnosis was somewhat different.

Table 2. Cost-effectiveness Results

	Cost	Incremental cost	QALYs	Incremental QALYs	ICER
Current practice	7,247,535		3.93558		
National screening	7,261,002	13,467	3.93572	0.00014	94,035,213

Cost-effectiveness analysis: cost-effectiveness was analyzed based on the transition probability, utility index, and cost data estimated from the perspective of public health care system. The results indicated that QALY was anticipated to increase when the prostate cancer screening was incorporated in the national health care service program as compared to when the present voluntary screening system was maintained. However, the incremental effectiveness was very low and due to it, the incremental cost-effectiveness ratio (ICER) is beyond the socially acceptable level (Ahn et al., 2010) (Table 2). Therefore, the introduction of the national prostate cancer screening system is not thought to be cost effective for now.

Sensitivity analyses: the sensitivity results are presented in Table 3. In this cost-effectiveness analysis, the incidence rate of prostate cancer was a factor with the biggest impact on the cost effectiveness of the national prostate cancer screening program. Although the incidence of prostate cancer in Korean men are rapidly rising these days, the absolute value of this incidence rate is still lower than those of other diseases at present. However, this economic evaluation on prostate cancer may change if this rapidly increasing incidence rate of this disease continues down the road. With this possibility taken into account, a threshold analysis was conducted in this study, and the result indicated that the national screening program could be cost effective when the incidence rate of prostate cancer is higher than 0.243%.

Secondly, sensitivity analysis was conducted for prostate cancer stage distributions for the introduction of national screening system and for the retention of the current system. Basic analysis was based on the SEER disease stages of the KCCR while sensitivity analysis was based on the TNM codes of the HIRA claims data. Furthermore, sensitivity analysis also conducted based on previous study (Jung et al., 2013b) with using prostate cancer stage distribution in current practice.

In addition, in the basic analysis, 100% cancer screening rate was assumed in the event of the introduction of national prostate cancer screening system. However, the actual national cancer screening rates for other cancers are around 50% (Kim et al., 2011). Therefore, the results were analyzed at 50% screening rate in this study.

Table 3. Sensitivity Analysis Results

	Cost	Incremental Cost	Incremental QALYs	ICER
Base analysis				
Current practice	7,247,535		3.93558	
National screening	7,261,002	13,467	3.93572	0.00014 94,035,213
Stage distribution (TNM) of national screening				
Current practice	7,247,535		3.93558	
National screening	7,261,662	14,128	3.93565	0.00007 201,224,736
Stage distribution (SEER) of current practice				
Current practice	7,248,257		3.93567	
National screening	7,261,002	12,745	3.93572	0.00005 274,815,024
Screening rate (50%)				
Current practice	7,247,535		3.93558	
National screening	7,261,914	14,379	3.93559	0.00001 1,273,122,765
Cancer treatment cost (Urological Association)				
Current practice	7,238,353		3.93558	
National screening	7,250,038	11,685	3.93572	0.00014 81,588,412
Utility index(VAS)				
Current practice	7,247,535		3.93569	
National screening	7,261,002	13,467	3.93582	0.00013 103,352,564

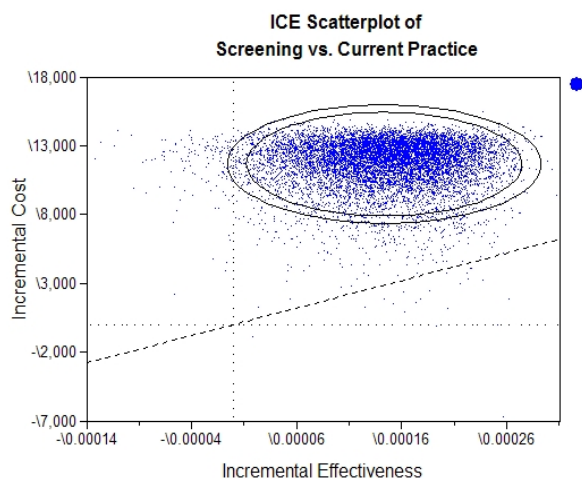


Figure 3. Probabilistic Sensitivity Analyses

Additional costs are anticipated to be generated when there are concurrent diseases apart from prostate cancer. In this case, the relatively higher treatment costs may affect the study results. Due to this reason, the analysis was performed based on treatment costs where the patients with concurrent diseases with relatively higher treatment costs, besides prostate cancer, were excluded in the calculation.

Probabilistic sensitivity was analyzed for the incidence rate of prostate cancer (Beta distribution), treatment costs (Gamma distribution), and utility index (Beta distribution). The results are presented in Figure 3.

Results from the deterministic sensitivity analysis and the probabilistic sensitivity analysis for factors affecting the cost effectiveness analysis indicated that, compared to the present voluntary screening, the incorporation of prostate cancer screening in the national cancer screening program was not cost effective.

Discussion

Prostate cancer screening based PSA test has been widely used and its effectiveness is well accepted. However, among the western countries including the United States and Europe, there is no country that has officially introduced the national prostate cancer screening system. With the rising incidence of prostate cancer among Korean men, some experts in this field insist that the PSA test should be added to the national cancer screening program. However, no consensus was achieved. Economic evaluation for cancer screening programs is of increasing interest in the healthcare sector. Such evaluation would allow health-care resources to be allocated more efficiently. However, economic studies on PSA screening are still far from sufficient, especially in Korea. Many additional studies are needed to improve our knowledge of the economic impact of this service (Imamura and Yasunaga, 2008). Under this circumstance, economic efficiency of the national prostate cancer screening system based on PSA was assessed in Korean men aged 50 to 74 using actual data obtained in this country. The cost effectiveness analysis indicated that the ICER was approximately 94 million KRW. Sensitivity was analyzed in a multilateral manner for the incidence rate of prostate

cancer, screening rate, distribution of disease stage, utility index of prostate cancer, and treatment cost of the disease. Nevertheless, the results did not significantly differ from that of the basic analysis.

These results were similar to the previous results proposed by Krahn et al. (1994). Krahn et al. (1994) conducted a decision analysis comparing PSA screening strategies with a strategy of not screening. Most notably screening programs produced only a small gain in average life expectancy for men aged 50-70 years. Therefore, they concluded that PSA screening could not be considered to be economically attractive.

The incidence rate of prostate cancer appears to be the most important factor to the cost effectiveness analysis model applied in this study followed by the screening rate. Although there is a concern over the recent rapid increase in the prostate cancer incidence compared to other cancers in Korea, the absolute value of the incidence rate is still too low to conclude that introduction of the national screening system for this cancer is cost effective at this point, and therefore, this is thought to be of lower priority relative to other public health care agenda. Another analysis was carried out in this study to find out the level of prostate cancer incidence with which the national prostate cancer screening program will achieve a higher probability of cost effectiveness, based on the assumption that 20 million KRW per 1 QALY as suggested in the previous studies as a criterion of cost effectiveness (Ahn et al., 2010). With the assumption of 100% screening rate and the maximized decrease of prostate cancer mortality rate due to the cancer screening, it was found that the national prostate cancer screening plan would be an alternative option with a sufficiently high probability of cost effectiveness when the incidence rate of prostate cancer in men aged 50 to 74 is increased from the present level (85 of 100,000 men per year) to 223.5 of 100,000 men annually.

In addition, the analysis also indicated that these results could not be expected until the incidence reach approximately 593.8/100,000 men on the assumption of 50% cancer screening rate, which is a goal of the Ministry of Health and Welfare for 2012, and the maximum decrease of mortalities of prostate cancer due to prostate cancer screening.

Although the incidence of prostate cancer has been gradually increasing in recent years (Jung et al., 2013a), the number of deaths from prostate cancer in Korea is still lower than that of the US and Europe. Both a high incidence and a high mortality rate are required to perform cancer screening (Hamashima and Yoshida, 2000). To estimate the time point when the introduction of the national prostate cancer screening program attains a higher probability of feasible cost-effectiveness, the fluctuations of prostate cancer incidences up to 2030 were predicted through the Auto Regressive Integrated Moving Average (ARIMA) using prostate cancer incidences based on the KCCR data and the cumulative population data from the NSO from 1999 through to 2008. Based on comparisons between the predicted incidence and the thresholds of prostate cancer, the relevant incidence rate is expected to reach around 2030 on the assumption that the screening rate is approximately 50% or by around 2018 on the

assumption that the screening rate is 100%.

In addition, screening rate is one of the variables that may affect cost effectiveness of the national prostate cancer screening program. Therefore, a decision should be made with the screening rate taken into account since the screening effect according to the earlier mentioned increases in incidences may vary depending on the screening rate.

To evaluate cost effectiveness of the national prostate cancer screening program in the situation in Korea, secondary data sources available in the country were used for analysis. However, the study had several limitations due to its data sources. Firstly, the effect of prostate cancer screening was estimated based on the data from only one hospital. Due to this reason, caution should be exercised during interpretations to avoid erroneous generalization.

Secondly, a stage shift model was applied in this study, that is, it was assumed that introduction of the national screening system would enable earlier detection of prostate cancer with better prognosis. However, there were so many missing data in the SEER codes of the KCCR and the TNM codes of the HIRA claims data. Since there was no previous study that included the data of disease stages of patients who had PSA tests in Korea, the above data sources were applied in this study, with the limitation of the data sources specified. Disease stage distributions calculated as above were reviewed by advisory urologists and acknowledged as valid despite the limitation caused by numerous missing data

Nevertheless, the relevant data had to be used in this study despite the limitations caused by missing values due to the lack of other actual data available from which distributions of prostate cancer by stage could be confirmed.

Thirdly, as mentioned earlier, the study was aimed to use actual data in Korean men if possible, since the previous investigations indicated that epidemiology of prostate cancer shows differences between races. Since the available data were very limited, it was not possible to construct the cost effectiveness analytic model in a more precise manner. For instance, parameters such as the shift of prostate cancer stages, screening frequency or interval could not be reflected in this study.

Despite these limitations, this study is highly likely to be of use as basic data for decision making by the Korean government with regard to the national cancer screening program since no other data are available at present to help determine cost effectiveness of the national prostate cancer screening program.

In conclusion, under Korean circumstances with low incidence rate of prostate cancer, best available local data were used to evaluate whether national prostate cancer screening program is a cost-effective for the prevention of prostate cancer in Korea setting from a healthcare system perspective. The present economic evaluation indicates that PSA national screening is not cost-effective. Therefore, we conclude that adopting a national prostate cancer screening would not be beneficial until further evidence is provided in the future.

Acknowledgements

This work was supported by grants from National R&D program for Cancer control (No. 1020430) and completed while all the authors were working in the NECA. We would like to thank the Korean Urological Association (KUA) for clinical advice on building the model. However, the authors are responsible for all the contents and errors and this study does not necessarily represent the view of KUA.

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