Cost–utility analysis of screening for colorectal precancerous lesions and cancer in Beijing: A case–control study

ABSTRACT

Objective: To provide an objective cost–utility evaluation of a colorectal cancer screening program in a hypothetical general population.

Materials and Methods: A cost–utility analysis was conducted comparing screened individuals with the general population. Patients were evaluated as part of the screening program which conducted colorectal cancer risk assessments and performed colonoscopies from October 2012 to May 2013. Data were compared to a hypothetical group of the same size, consisting of the general population in which no cancer screening had been conducted. The cost and utility data have been published previously.

Results: The average cost per quality-adjusted life year (QALY) of colorectal cancer screening population was 84,092 CNY, while the average cost per QALY of the general population was 122,530 CNY. The colorectal cancer screening program saved 43,530 CNY per additional QALY.

Conclusion: The colorectal cancer screening program could improve health-related quality of life and reduce medical expenditure.

KEY WORDS: Colorectal cancer, colorectal precancerous lesion, cost–utility, quality-adjusted life year

INTRODUCTION

High mortality (16.0/million) due to cancer in urban China has led to a number of programs being implemented to increase prevention.[1] As an example, the Cancer Screening Program in Urban China (CanSPUC) has been implemented in 14 provinces to provide screening for lung, breast, colorectal, oesophageal, gastric, and liver cancers.[2,3] Colorectal cancer is ranked as the 3rd most common cancer in women and 4th in men.[4] Its high incidence makes colorectal cancer prevention highly significant. Since cost–utility analysis can help governments to make decisions on providing the most cost-effective screening, we conducted a case–control study to evaluate the cost–utility of colorectal cancer screening in urban China.[5]

Cost–utility analysis is one of the most important tools in health economics. A systematic review by Aaron summarized the results of cancer-related cost–utility analyses of prevention, treatment, and control conducted from 1998 through 2013.[6] The review indicated that the median incremental cost-effectiveness ratio of colorectal cancer secondary prevention (including population screening and appropriate management) is approximately $14,000 (in 2014 USD). A large number of other cost-effectiveness analyses were conducted, such as the study by Zhai et al. which calculated the cost of screening one patient with a colorectal precancerous lesion to be 2612.88 CNY, while the cost of screening one colorectal cancer patient is 39,193.13 CNY.[7] CanSPUC also published a cost-effectiveness review of the analyses in 2013.[8] However, to date, there are no reports of cost–utility analyses of colorectal cancer in China. By conducting an assessment of quality of life in 2014, we aimed to utilize the available cost and health utility data to address the absence of colorectal cancer cost–utility analyses in China.

MATERIALS AND METHODS

Sample selection
We conducted a screening program which included colorectal cancer risk assessments and colonoscopy screening. Cancer risk assessments were based on the stratified cluster sampling method. Nineteen
community-health-service centers from six urban districts in Beijing (Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai, and Shijingshan) administered assessment questionnaires between October 2012 and May 2013. An individual was selected to receive the questionnaire if he/she met the following criteria: (1) a resident living in Beijing for more than 3 years and (2) age between 40 and 69 years old (based on the onset age data of cancer registration system, CanSPUC included residents in this age). Patients with cancers or serious organ dysfunction were excluded from the target population. We subsequently recommended the participants who have received positive results in colorectal cancer risk assessment to undergo colonoscopy screening, which was conducted at a 3A hospital (the highest level of the hospital hierarchy in China).

Patients included in the screening population who tested positive were designated as the screened group. In addition to the patients with confirmed cancer, and in consideration of the natural history model of colorectal cancer, we detected potential patients who had precancerous lesions at the time of testing which may become cancers in the future. We therefore divided the screened group into confirmed patients and potential patients. Furthermore, we used the Union for International Cancer Control-American Joint Committee on Cancer colorectal tumor-node-metastasis (TNM) staging system to further subdivide the patients into those with precancerous lesions and the four groups corresponding to the four stages of cancer.

We compared the screened group to the general population with the same background, but without cancer screening. This hypothetical general population group was designed to contain a similar total number of confirmed and potential patients as the screened group. Since patients in the general group have not received screening, any incidence of cancer would have been detected and diagnosed as in normal patients; therefore, the number of confirmed patients in the general group was calculated using the colorectal cancer incidence in Beijing’s residents older than 40 years of age. We classified the patients’ cancer stages by statistical data regarding colorectal cancer in Beijing residents.

Sample selection process and the calculations performed are depicted in Figure 1.

Data collection
We trained investigators from community health service centers before beginning field work. Interviewees were recruited from the communities, and each individual was asked to complete the cancer risk assessments. When cancer risk assessments were completed, they were verified by investigators to prevent any blank or incomplete answers. The assessments were subsequently sent to the project office in Beijing and submitted to an additional verification of data consistency. CanSPUC verified the submitted data and sent the assessments with positive results back to the communities. Community health service staff notified interviewees of positive results and recommended colonoscopy screening appointments at 3A hospitals included in CanSPUC to patients. The colonoscopy screenings were implemented and reported by experienced specialists.

Outcome calculations and data analyses
EpiData 3.1 (Denmark), Statistical package for social science (SPSS) 19.0 (Chicago, IL, USA) were used for double data entry, quality check, calculations, and analyses. The screening cost estimation was published in the previous CanSPUC research project.[10] The cost included direct costs (the cost of cancer risk assessment questionnaire survey and cost of clinical screening), indirect costs (transportation cost of residents’ participation in the screening), and treatment costs. According to the previous cost analysis of the colorectal screening program in Beijing, we analyzed the cost–utility and compared the screened group with the hypothetical general group.

We have collected health utility data from a previously completed CanSPUC research project. As continuous collection of data regarding an individual’s health state is impossible, individual health utility value can only be determined at specific time points. We applied the linear method to address the discontinuous utility value and used the area under the curve to calculate the quality-adjusted life year (QALY) values.[9–11]

Cost–utility analysis research commonly uses cost–utility ratio (CUR) and incremental CUR (ICUR) to present the results. We compared the CUR of screened group with that of the hypothetical group and determined the cost to achieve gains expressed per QALY in each group. The following calculation was used to estimate which group was more effective and exhibited greater gains in QALYs:

\[
ICUR = \frac{\Delta Cost}{\Delta QALYs} = \frac{Cost_{\text{screened group}} - Cost_{\text{general group}}}{QALYs_{\text{screened group}} - QALYs_{\text{general group}}}
\]

The differences in discount rates, which are influenced by multiple factors, are very large between different countries. The characteristics of national economy and different views on short- and long-term health outcomes are factors that affect the discount rate. Developing countries may prefer a higher discount rate, resulting in health investments which are likely to deal with the current and short-term health problems.[11] Based on the NICE report, we have used 3.5% as the discount rate for cost and health outcomes.[12] The calculation approach was to multiply the cost and QALYs of the n year by \(\frac{1}{1.035^n}\) to obtain the discounted cost and QALYs.[13] In addition, we performed a sensitivity analysis of ICUR by different discount rates.

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The first author holds the certificate of Protecting Human Research Participants from the National Institutes of Health. We obtained informed consent forms from all interviewees.

Ethics approval
We obtained approval for this portion of the CanSPUC from the Ethics and Confidentiality Committee of the National Cancer Center of China.

RESULTS

Study sample
In the cancer risk assessment, 12,953 residents joined the preliminary screening and 2487 residents were found to exhibit high risk of colorectal cancer, with the positive rate of cancer risk assessment calculated as 19.2%. Out of the patients who exhibited high risk, 1055 made appointments...
for colonoscopy, but only 375 completed their colonoscopy procedure. The compliance with colonoscopy was 35.5%, which was much higher than 15.3% reported within a recent population-based screening program in Mainland China. A total of 71 precancerous lesions and 9 colorectal cancer patients were detected on assessment, reflecting a detection rate for colorectal precancerous lesion of 54.62/million (71/12,953) and a detection rate for colorectal cancer of 6.92/million (9/12,953).

Cost analysis of colorectal cancer screening, diagnosis, and treatment

Based on the results of our previous research, the total cost of colorectal cancer screening, diagnosis, and treatment of 12,953 residents was 1.0741 million CNY, while the total cost of the same number in the general population group was 1.2028 million CNY. Since the previous cost analysis was calculated in 2012 and the quality of life assessment was implemented in 2013, we discounted the costs from 2012 to 2013. Final calculated cost in the screened group was 1.1117 million CNY, and the cost in the general group was 1.2449 million CNY.

Utility analysis of colorectal cancer screening

As shown in the previous section, screening detected 9 patients with colorectal cancer and 71 patients with colorectal precancerous lesions. Based on a systematic review of natural history models of colorectal cancer, the canceration rate from precancerous lesion to colorectal cancer was 4.4%. Therefore, we estimate that 3.12 patients with precancerous lesion patients would progress to colorectal cancer if they were to receive no treatment. As reported in related studies, the rate of early, medium, and late stages detected on screening were calculated as 72%, 17%, and 11%, respectively. The statistics data regarding colorectal cancer Stages I, II, III, and IV in Beijing colorectal cancer patients without screening project exhibited rates of 13%, 22%, 37%, and 28%. According to Health Report of Population in Beijing, colorectal cancer incidence of Beijing’s above 40 years old residents is 492.5/1million.

Using Duke’s stage research and the proposed transformation between Duke’s stages to the TNM staging system, the expected survival times of patients in Stages I-II, III, and IV were 34.6, 20.9, and 11.3 months. According to the previously completed health utility value study, the median health utility values of Stages I, II, III, and IV of colorectal cancer patients’ quality of life were 0.7830, 0.9375, 0.8690, and 0.7830, respectively. After discounting, we calculated the QALYs for the four stages of colorectal cancer (as areas under the curves) to be 1.11, 1.33, 0.79, and 0.39, respectively, as shown in Figure 2. Therefore, the total QALYs of the screened group were 12.63 and that of the general group were 9.73, with the detailed calculations presented in Table 1.

Cost-utility analysis

The total cost of colorectal cancer screening program was 1.1117 million CNY, with a total of 13.22 QALYs gained from the program. Therefore, the CUR was calculated as 84,092 CNY/QALY, which corresponded to an average cost per QALY of 84,092 CNY. Without the screening, the cost of disease management in the general group was 1.2449 million CNY with 10.16 QALYs gained. Therefore, the CUR was 122,530 CNY/QALY, indicating an average cost per QALY of 122,530 CNY. Therefore, the ICUR was calculated as:

Figure 2: Quality-adjusted life years of patients with different stages of colorectal cancer

Table 1: Cost-utility analysis of the colorectal cancer screening program

| Stages                      | Total population | Confirmed cases | Potential cases | QALYs | Total QALYs |
|-----------------------------|------------------|-----------------|-----------------|-------|-------------|
| Screening population (screened group) | 12,953           | 9.00            | 3.12            | 13.22 |
| Stage I                     | -                | 6.48            | 2.25            | 9.69  |
| Stage II                    | -                | 1.53            | 0.53            | 2.02  |
| Stage III                   | -                | 0.50            | 0.17            | 0.53  |
| Stage IV                    | -                | 0.50            | 0.17            | 0.53  |
| Hypothetical population (general group) | 12,953           | 6.38            | 5.74            | 10.16 |
| Stage I                     | -                | 0.83            | 0.75            | 1.11  |
| Stage II                    | -                | 1.40            | 1.26            | 2.66  |
| Stage III                   | -                | 2.36            | 2.13            | 3.54  |
| Stage IV                    | -                | 1.79            | 1.61            | 3.38  |

*Proportions of colorectal cancer patients screened at different stages patients are 72% (Stage I), 17% (Stage II), 5.5% (Stage III) and 5.5% (Stage IV). *Statistics data of colorectal cancer patients at different stages colorectal cancer patients of in Beijing are 13% (Stage I), 22% (Stage II), 37% (Stage III) and 28% (Stage IV). *Colorectal cancer incidence of Beijing’s above 40 years old residents is 492.51 million. *In hypothetical population, the number of confirmed cases=number of population×incidence. *The canceration rate from precancerous lesion to colorectal cancer was 4.4%. In screening population, the number of potential cases=the number of precancerous lesion patients×the canceration rate. *Total QALYs=QALYs×(confirmed cases+potential cases). QALYs=Quality-adjusted life years
The results of calculation were as follows: $\Delta\text{Cost} = -133,200$ CNY, $\Delta\text{QALYs} = 3.06$, and ICUR = $-43.53$. Compared to the general group, the colorectal cancer screening program saved 133,200 CNY and gained 3.06 QALYs. In other words, compared to the general population group, the colorectal cancer screening program saved 43,530 CNY per additional QALY.

**Sensitivity analysis**

Based on related research, we used 5% as the discount rate to adjust the CUR and ICUR values, with the results presented in Table 2.[22]

In this sensitivity analysis, the different discount rates affected the costs and QALYs; however, the trends in CUR and ICUR values were same as in the original analysis. Therefore, the individuals in the screened group fared better than the general group.

**DISCUSSION**

Our research addresses the absence of a cost–utility evaluation of colorectal cancer screening in Beijing. Compared to the population which received no screening, the colorectal cancer screening program has saved 43,530 CNY per each additional QALY. The results of the sensitivity analysis also demonstrated that the screening program has the advantages of reducing the health expenditure and improving the quality of life. This research calculated an average cost per QALY of colorectal cancer screening program to be 84,092 CNY. Sun et al. evaluated 10 years (1991–2001) of data regarding colorectal cancer detection and found that the average cost per DALY of early diagnosis was 6,179.76 CNY.[21] The small difference in the average cost observed, in addition to the differences in calculations of QALYs and DALYs, may reflect the discount and inflation in China. Notably, this past evaluation has also demonstrated that screening for colorectal cancer was clinically effective.

The survival time data, published in 2001, may result in calculations of QALYs that do not match those found in current medical conditions. Recent publications, however, report the 5-year survival rates of Stages I, II, III, and IV of colorectal cancer to be 88.2, 64.7, 48.5, and 37.0%, demonstrating a difference in survival time for early, middle, and late stages of colorectal cancer.[24] While portions of the data used in this research have a number of limitations, future updates to the data in the future will make a significant positive impact of colorectal cancer screening more obvious. Despite significant improvements in medical technology over the past years, early colorectal cancer screening continues to have a positive effect on extending survival and improving QALYs.

In our utility analysis, we have included canceration of precancerous lesions to clinically relevant cancer but have not considered the transformation from healthy people to those harboring precancerous lesions. However, since the screening population would receive follow-up colorectal cancer screening in time, any individuals developing precancerous lesions would be detected earlier in the screened group compared to the general population.

We have used the results of a single health utility investigation in our study. Collection of serial follow-up health data ranging from diagnosis to death would allow for a more precise calculation of QALYs.

The sample size was only 12,953 in this study; a larger population would inform the decision to extend the colorectal cancer screening program to a larger scale. In such an evaluation, the advantages in cost-saving and improvements of quality of life would be more obvious, supporting the assertion that a screening program would greatly reduce the expenditure on disease management and reduce the patients’ pain.

**CONCLUSION**

The colorectal cancer screening program had a positive effect on cancer prevention, and can improve health-related quality of life and reduce medical expenditures.
Consent to publish
All authors have approved this manuscript for submission and claim that none of the material in the paper has been published or is under consideration for publication elsewhere.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. National Health Commission of the People's Republic of China. China Health and Family Planning Statistical Yearbook. Beijing: Peking Union Medical College Press; 2017.
2. Dai M, Shi J, Li N. Design and prospective target of the cancer screening program in Urban China. Chin J Prev Med 2013;47:179-82.
3. Qiu WQ, Shi JF, Guo LW, Mao AY, Huang HY, Hu GY, et al. Medical expenditure for liver cancer in urban China: A 10-year multicenter retrospective survey (2002-2011). J Cancer Res Ther 2018;14:163-70.
4. Zheng RS, Sun KX, Zhang SW, Zeng HM, Zou XN, Chen R, et al. Report of cancer epidemiology in China, 2015. Zhonghua Zhong Liu Za Zhi 2019;41:19-28.
5. Weinstein MC, Torrance G, McGuire A. QALYs: The basics. Value Health 2009;12 Suppl 1:S5-9.
6. Winn AN, Ekwueme DU, Guy GP Jr., Neumann PJ. Cost-utility analysis of cancer prevention, treatment, and control: A systematic review. Am J Prev Med 2016;50:241-8.
7. Zhai AJ, Chen H, Wang GQ, Wang YD, Zhao J. Cost-effectiveness of opportunistic screening for colorectal cancer in community population. Chin Gen Pract 2015;18:4184-6.
8. Mao AY, Dong P, Yan XL, Hu GY, Chen QK, Qiu WQ. Cost analysis of the colorectal neoplasm screen program in Beijing. Chin J Prev Med 2015;49:387-91.
9. Billingham LJ, Abrams KR, Jones DR. Methods for the analysis of quality-of-life and survival data in health technology assessment. Health Technol Assess 1999;3:1-52.
10. Manca A, Hawkins N, Sculpher MJ. Estimating mean QALYs in trial-based cost-effectiveness analysis: The importance of controlling for baseline utility. Health Econ 2005;14:847-96.
11. Shanshan K, Yunbo C. QALYs calculation in trial-based cost utility analysis. Chinese Health Econ 2015;34:16-8.
12. Institute for Health and Care Excellence. Guide to the Methods of Technology Appraisal. PMG9. Institute for Health and Care Excellence; 2013. Available from: https://www.nice.org.uk/process/pmg9. [Last accessed on 2019 Mar 01].
13. Severens JL, Milne R. Discounting health outcomes in economic evaluation: The ongoing debate. Value Health 2004;7:397-401.
14. Chen HD, Li N, Ren JS, Shi JF, Zhang YM, Zou SM, et al. Compliance rate of screening colonoscopy and its associated factors among high-risk populations of colorectal cancer in urban China. Chin J Prev Med 2018;52:231-7.
15. Li ZF, Huang HY, Shi JF, Guo CG, Zou SM, Liu CC, et al. A systematic review of worldwide natural history models of colorectal cancer: Classification, transition rate and a recommendation for developing Chinese population-specific model. Zhonghua Xiu Xue Wai I科 Zhi 2017;38:253-60.
16. Shen YZ, Qian J, He F, Cao PX, Ma HQ, Shen GF, et al. An analysis on the result of screening, early detection and treatment for colorectal cancer from 2007 to 2008 in Haining city, Zhejiang Province. China Cancer 2009;18:728-30.
17. Hu GY, Mao AY, Dong P, Yan XL, Qiu WQ. Discovery approach and economic burden of six kinds of common cancers patients in Beijing. Cancer Res Prev Treat 2015;42:171-6.
18. Beijing Municipal Government. Annual Report on Health and Population Health in Beijing, 2015. Beijing: People's Health Publishing House; 2016.
19. Guo FR. Multiple analysis of prognosis for colorectal cancer. Chin J Health Stat 2001;18:24-5.
20. Qing SH. Clinical and pathological staging system of colorectal cancer and its clinical significance. World Chin J Digestol 2003;11:1760-3.
21. Yao YF. The TNM stage of colorectal cancer. Chin J Front Med Sci (Elec Ver) 2011;3:8-10.
22. Guan HJ, Xu F, Liu GE. Discussing quality-adjusted life year calculation method based on EQ-5D instrument. Chin Health Econo 2015;34:5-8.
23. Sun CJ, Yao Q, Xu JG, Yu BM. Evaluating 10 years work of early detecting colorectal cancer in symptom clients in community. Chin Cancer 2002;11:652-4.
24. Kalcan S, Sisik A, Basak F, Hashabecce M, Kiliç A, Kosmaz K, et al. Evaluating factors affecting survival in colon and rectum cancer: A prospective cohort study with 161 patients. J Cancer Res Ther 2018;14:416-20.