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ORIGINAL CONTRIBUTIONS

Cost-effectiveness of Bariatric Surgery for People with Morbid Obesity in South Korea

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Abstract

Objective This study aimed to evaluate the cost-effectiveness of bariatric surgery (BS) compared to non-surgical treatment (NST) in Korean people with morbid obesity according to comorbidities and body mass index (BMI) severity.

Methods The target cohort was people with morbid obesity, defined as BMI of ≥ 35 kg/m^2, or obese people with BMI of 30–34.9 kg/m^2 having obesity-related comorbidities. A decision-tree model for 1-year obesity treatment and Markov model for the rest of life were used. In the decision-tree model, the comorbidity remission rate and BMI change after 1-year treatment were decided based on a prospective clinical trial. In the Markov model, the transition probabilities were calculated considering the BMI level and age. The starting age of 20 years, a cycle length of 1 year, a time horizon of 80 years, and a 5% discount rate were applied for the base case from the healthcare system perspective.

Results In the base case, BS improved quality-adjusted life years (QALYs) and was the cost-effective option in total cohort (incremental cost-effectiveness ratio of BS vs. NST was 674 USD/QALY). It was shown to be cost-effective in all subgroup analyses based on BMI level. In particular, BS was a dominant alternative for the subgroup with basal BMI of 35.0–37.4 kg/m^2. Various sensitivity analyses showed the robustness of results indicating the cost-effectiveness of BS.

Conclusion BS at BMI of > 30 kg/m^2 was more effective than NST for a reduction in BMI and remission of obesity-related comorbidities and was cost-effective in Korea.

Keywords Cost-utility analysis · Morbid obesity · Bariatric surgery

Introduction

As the number of obese people increases worldwide, obesity-related health problems are soaring. Obesity is a risk factor for chronic diseases, such as hypertension, diabetes, and cardiovascular diseases, and it was also reported to increase the risk of mortality independently [1–4]. Therefore, obesity is now classified as a disease to be managed with high priority from the perspective of global public health.

Asians tend to have low body mass index (BMI) and a lower prevalence of obesity compared to Westerners. However, they have a higher proportion of body fat [5, 6] and higher prevalence and mortality rate of obesity-related chronic diseases than Westerners [7]. Therefore, Asian countries set the BMI threshold for obesity at a lower BMI than Western countries (BMI cut-off point for obesity is 30 kg/m^2 for West, 25 kg/m^2 for Asia) and have tried to strengthen the management of obesity [8].

Although the overall increase in obesity prevalence is stagnant in Asia, morbid obesity, defined by BMI > 35 kg/m^2, is increasing, particularly among young people due to westernized diets and the lack of outdoor activities [9, 10]. In a recent research in a Korean population, the mortality risk was reportedly increased by 1.18–1.71 times in morbid obesity cases than in non-obese controls [11]. Prevention and proper treatment of obesity are crucial considering the severity of obesity-related chronic diseases, and morbid obesity should be treated

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more urgently. In addition, social support for the treatment of obesity should be provided more adequately to the people in unstable socioeconomic conditions, given the high incidence rate of obesity in the group [12, 13].

Bariatric surgery (BS) is an effective treatment for morbid obesity, whereas non-surgical treatment (NST) with altered diet, exercise, or medications showed insufficient efficacy with short-term effects [14, 15]. BS has already been established as a general treatment for obesity in the West [16, 17] and its benefits in terms of cost-effectiveness have been evaluated in many researches [18, 19]. In comparison, there is a lack of clinical and economic assessment data for BS in Asia [20]. Interests and discussions on the need of BS to treat obesity have been growing in Asia [21], and research on and evaluation of the clinical usefulness and economic feasibility of BS are urgently required in the region.

The cost-effectiveness of BS has been evaluated in 2013 based on a retrospective trial in a Korean population, and the results showed acceptable cost-effectiveness in morbidly obese individuals. However, the study presented only the results of total subjects and did not assess the cost-effectiveness in the context of specific comorbidities and BMI statuses, which directly impact mortality and medical expenditure [22]. This study was conducted to evaluate the cost-effectiveness of BS and compare it with that of NST in Korean people with morbid obesity or obesity at BMI 30–34.9 kg/m^2 with comorbidity according to their comorbidities and BMI severity.

Methods

Target Analysis Cohort and Setting

This study used individual patient data from a prospective clinical trial [23]. The target cohort included morbidly obese people with basal BMI ≥ 35 kg/m^2. People with BMI of 30–34.9 kg/m^2 were also included if they had obesity-related comorbidities, such as hypertension, diabetes, and hyperlipidemia. BS comprised Roux-en-Y gastric bypass and sleeve gastrectomy, and NST included regular hospital outpatient visits for obesity treatment via medications, diet, or exercise support. A cycle length of 1 year, a time horizon of 80 years, and a discount rate of 5% were applied for base case analysis from the healthcare system perspective.

Model Structure and Estimation

The decision-tree model for 1-year obesity treatment (BS vs. NST) and the Markov model for the rest of the lifetime were used (Fig. 1). The decision-tree model reflected the changes in the BMI level and comorbidity remission rates for 1 year of obesity treatment. The analysis was moved to the Markov model according to the changed BMI level and comorbidity status of the individuals after 1 year of treatment. In the Markov model, five health statuses—no comorbidity, mild/moderate comorbidity (hypertension and/or diabetes and/or hyperlipidemia), severe comorbidity (coronary artery disease and/or stroke), death due to cardiovascular disease (CVD), and death due to any other reasons—were assumed to reflect changes in the comorbidity status according to the changed BMI level and aging over the time horizon.

Clinical Data and Utility

The clinical data and utility weight used in this study were collected through a prospective multicenter clinical trial conducted in 13 university hospitals in Korea from August 2016 to October 2018 [23]. The initial proportion of comorbidity before obesity treatment, the comorbidity remission rate, and the changed BMI level after 1 year of obesity treatment were obtained from the clinical trial results. Quality of life was investigated using patient questionnaires of the EuroQol-5 dimension (EQ-5D) 3 level in the clinical trial. The utility weight according to the BMI level was calculated by applying Korean tariff and was adjusted for age, sex, treatment group (BS or NST), and comorbidity status by the generalized estimation equation. The utility weight of severe comorbidity was obtained by multiplying the utility weights of mild/moderate comorbidity by 0.854, the ratio obtained from the Korea National Health and Nutrition Examination Survey (KNHNES, 2007–2015) because people with severe comorbidity were not included in the clinical data. The KNHNES is a national survey implemented by the Korea Centers for Disease Control (KCDC) to evaluate the health and nutritional status of Koreans [24].

Model Structure and Transition Probability

It was assumed that the BMI level at 1 year after obesity treatment was maintained lifetime according to a previous article which reported the long-term clinical results of BS vs. NST in Swedish people with morbid obesity [25]. The transition of comorbidity only allowed movement to a more severe status in the Markov model. For example, people with severe comorbidity could not move to no comorbidity and mild/moderate comorbidity statuses. The transition probabilities among health statuses by the BMI level were assumed using the incidence rates of comorbidity in the reference group (18.5–24.0 kg/m^2 BMI) in each age group. Hazard ratio for transition probability according to BMI of ≥ 25.0 kg/m^2 were assumed based on a re-analysis of the database used for the research by Song et al. [25] and by Park et al. [11]. The incidence rate of comorbidity in the reference group (BMI of 18.5–24.9 kg/m^2) was obtained from the representative Korean data based on the National Health Insurance

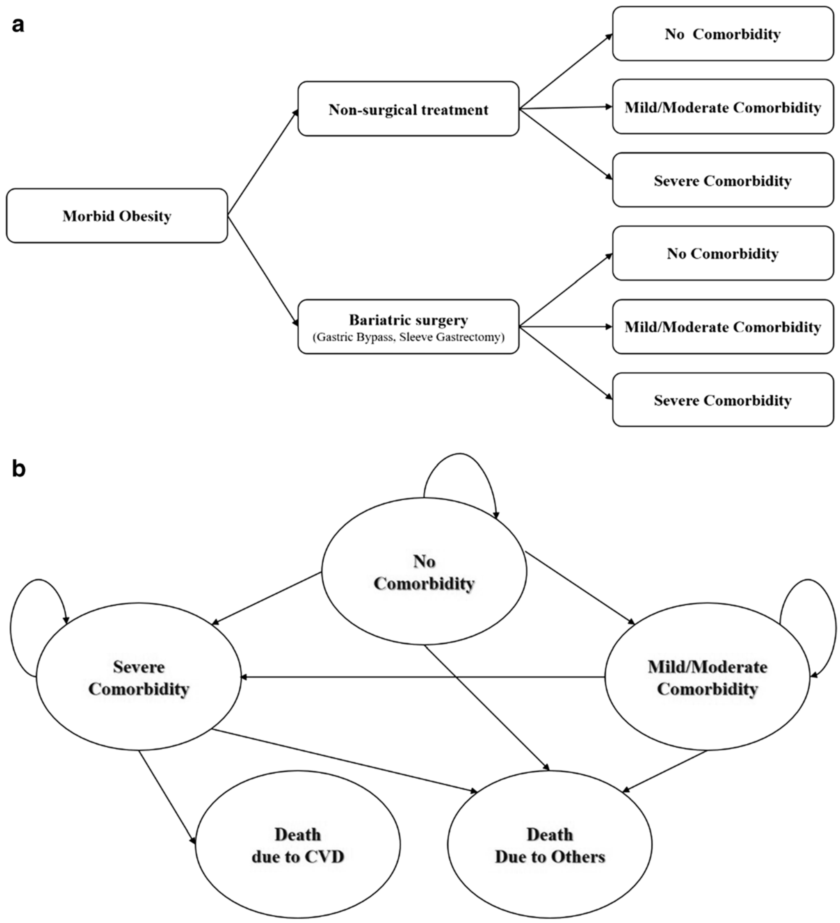

Fig. 1 Structure of the model. **a** Decision tree; 1st year. **b** Markov model; after 1st year

Service-Health Screening cohort (NHIS-HEALS, 2002–2013) [26] and KNHAES data. The NHIS-HEALS comprises a random sample of 10% of subjects aged 40–79 years who underwent health screening between 2002 and 2003, and the subjects were followed up for 10 years [27]. The hazard ratio of moderate or severe comorbidity by the BMI level was drawn from the NHIS-HEALS database [11]. The transition probability of death due to other causes was obtained from Korean Death Statistics (2016) [28] excluding the people with cardiovascular disease (CVD). The transition probability of death due to CVD was obtained by multiplying death due to other causes by 1.81 based on a previous research [29]. The hazard ratio of death according to the BMI level was assumed based on the analysis of the NHIS-HEALS cohort data, and it was applied to the transition probability to reflect the difference of death according to the BML level.

Costs

The costs in the first and following years were the medical expenses associated with the obesity treatment and obesity-related comorbidity treatment, respectively. The first-year cost was assumed by micro-costing simulations. The costs for resource use were assumed based on unit cost provided by the Health Insurance Review and Assessment Service (HIRA) [30] and frequency assumption based on clinical trial data and expert advices. In the Markov model, the cost of health status was calculated based on the unit cost and proportion of each comorbidity (e.g., hypertension, diabetes, and hyperlipidemia), which was derived from data analysis of the Korean HIRA-National Patients Sample database (HIRA-NPS, 2010–2014). HIRA-NPS was composed of an annual random sample of 3% ($n = \sim 1{,}400{,}000$) of the entire population that visited clinics or hospitals [31].

Statistics and Sensitivity Analysis

The results of this study were presented by the incremental cost-effectiveness ratio (ICER) of BS compared with NST in people with morbid obesity or obesity at BMI 30–34.9 kg/m^2 with comorbidity. The uncertainty was evaluated through deterministic sensitivity analysis and probabilistic sensitivity analysis. In the deterministic sensitivity analysis, change of input values for various variables, such as the comorbidity remission rate at 1 year after obesity treatment, utility weight, surgery cost, starting age, time horizon, and discount rate, was considered. In the probabilistic sensitivity analysis, 1000 micro-simulations were performed based on the assumptions of parameter distribution for utility, transition probabilities, and cost.

Results

Characteristics of Target Analysis Cohort, Effectiveness, and Cost

Characteristics of the target cohort are presented in Table 1. The proportions of BMI 30–34.9 kg/m^2 and ≥ 35 kg/m^2 were 50% and 50%, respectively. People with mild/moderate comorbidity accounted for 81.4% of included individuals. At 1 year after the obesity treatment, 65.6% of people who underwent BS and 14.5% people who underwent NST had a BMI of < 30 kg/m^2. The remission rate (change from mild/moderate comorbidity status to no comorbidity status) was 43.9% with BS and 9.5% with NST.

The input data, such as utility weights, cost, and transition probabilities for this model, are summarized in Table 2. The utility weight tended to significantly decrease as BMI levels increased. However, the utility weights for no comorbidity and mild/moderate comorbidity were not statistically significant, and the same utility weight was applied. The first-year cost for BS was approximately 6.7 times higher than that of NST (BS, 7780 USD; NST, 1160 USD). The costs after the first year were approximately 1400 USD for mild/moderate comorbidity and approximately 2000 USD for severe comorbidity.

Base Case Analysis

In the base case analysis, people who underwent BS spent 235 USD more and gained 0.348 quality-adjusted life years (QALY) more for a lifetime. BS was a cost-effective alternative with an ICER of 674 USD/QALY to NST (Table 3).

Sensitivity Analysis

In the results of the deterministic sensitivity analysis, the ICER was affected by the discount rate, comorbidity remission in the first year after obesity treatment, surgery cost, starting age, time horizon, and utility weight, in that order. When the discount rate was set at 7.5%, the ICER was the highest at 9012 USD/QALY. A discount rate of 0–3%, 25% increase in the remission rate of mild/moderate comorbidity in BS, and 25% decrease in the surgery cost showed cost-saving results with higher QALYs (Fig. 2).

The BMI level before obesity treatment was divided into five groups: 30.0–32.4 kg/m^2, 32.5–34.9 kg/m^2, 35.0–37.4 kg/m^2, 37.5–39.9 kg/m^2, and ≥ 40.0 kg/m^2, and then, sub-group analyses were performed (Table 3). Consequently, BS was a cost-effective alternative in all subgroups. In particular, BS was a dominant alternative at basal BMI of 35.0–37.4 kg/m^2.

Probabilistic sensitivity analysis revealed that BS was a cost-effective alternative under the willingness to pay threshold of 32,000 USD/QALY [32] with higher than 90% probability (Fig. 3).

Discussion

This study evaluated the cost-effectiveness of BS in people with morbid obesity or obesity at BMI 30–34.9 kg/m^2 with comorbidity using a prospective clinical trial conducted in South Korea. The ICERs in base and deterministic sensitivity analyses were all less than 10,000 USD/QALY, confirming that BS was a cost-effective alternative to NST for the target people. In particular, this study presented more elaborated ICERs by applying different incidence rates of comorbidity and mortality rate according to the level of BMI.

ICERs were mostly affected by the efficacy of BMI reduction and comorbidity remission after 1 year of obesity treatment in the prospective clinical study. The proportion of people with reduced BMI of < 30 kg/m^2 after 1 year was 65.6% in BS, which was much higher than 14.5% reported for NST. The results in terms of BMI reduction with BS in this study were in agreement with those of previous studies on Westerners [33, 34] or Asians [35, 36]. BS was also effective in reducing BMI and increasing remission rate associated with comorbidities, and the rate of remission was 34.4% higher in BS than in NST (43.9% for BS, 9.5% for NST). In a British study, which involved 33,718 highly obese people who underwent an operation for obesity treatment, the rates of comorbidity remission were 23–96% after BS; the remission rates were 78% for diabetes, 69% for hypertension, and 60% for hyperlipidemia when people received Roux-en-Y gastric bypass [37]. In a meta-analysis, the remission rates were reported to be 66.7% for diabetes, 38.2% for hypertension, and 60.4% for hyperlipidemia [38]. Compared with these studies, the remission rates assumed for this study were lower, and this may be attributed to the short observational period of 1 year to normalize chronic diseases in the clinical trial used for the source data in this study. The subgroup analysis conducted by dividing BMI levels by 2.5 kg/m^2 also showed that BMI reduction and remission rates had a very crucial impact on the outcome of cost-effectiveness. BS was the most effective option in the subgroup of 35.0–37.4 kg/m^2 at the basal BMI level. In this subgroup, the differences in terms of the proportion of patients with post-treatment BMI < 30 kg/m^2 and the remission rate between BS and non-surgical groups were 97.5% and 46.2%, respectively, which were the highest differences among subgroups. The high surgery cost was thought to be compensated by the savings of future costs that could have incurred in comorbidity management.

Table 1 Clinical outcome assumption

Mean ± SD	Bariatric surgery	Non-surgical treatment
Basal status		
BMI level (kg/m^2)		
Total patients	36.0 ± 5.1	
BMI distribution (%)		
30.0–32.4 kg/m^2	28.0	
32.5–34.9 kg/m^2	22.0	
35.0–37.4 kg/m^2	20.8	
37.5–39.9 kg/m^2	11.0	
≥ 40 kg/m^2	18.2	
Comorbidity distribution (%)		
No comorbidity (NC)	18.6	
Mild/moderate comorbidity (MC)	81.4	
Severe comorbidity (SC)	0	
Post treatment (at the end of 1st year)		
BMI distribution (%)		
18.5–24.9 kg/m^2	35.9	0.5
25.0–29.9 kg/m^2	29.7	14.0
30.0–39.9 kg/m^2	28.1	72.0
≥ 40 kg/m^2	6.3	13.5
BMI level (kg/m^2)		
Total patients	28.6 ± 6.6	34.3 ± 4.4
Basal BMI, 30.0–32.4 kg/m^2	23.0 ± 1.7	30.4 ± 1.7
Basal BMI, 32.5–34.9 kg/m^2	25.7 ± 2.1	32.9 ± 1.7
Basal BMI, 35.0–37.4 kg/m^2	25.3 ± 2.4	35.6 ± 2.1
Basal BMI, 37.5–39.9 kg/m^2	29.0 ± 5.6	37.8 ± 2.1
Basal BMI, ≥ 40 kg/m^2	34.1 ± 7.0	42.3 ± 3.2
Proportion of BMI < 25 kg/m^2 (%)		
Total patients	34.4	0.5
Basal BMI, 30.0–32.4 kg/m^2	90.9	1.6
Basal BMI, 32.5–34.9 kg/m^2	16.7	0.0
Basal BMI, 35.0–37.4 kg/m^2	46.7	0.0
Basal BMI, 37.5–39.9 kg/m^2	33.3	0.0
Basal BMI, ≥ 40 kg/m^2	4.3	0.0
Proportion of BMI < 30 kg/m^2 (%)		
Total patients	64.1	14.5
Basal BMI, 30.0–32.4 kg/m^2	100.0	39.7
Basal BMI, 32.5–34.9 kg/m^2	100.0	5.8
Basal BMI, 35.0–37.4 kg/m^2	100.0	2.5
Basal BMI, 37.5–39.9 kg/m^2	55.6	0.0
Basal BMI, ≥ 40 kg/m^2	17.4	0.0
Comorbidity remission rate (MC→NC) (%)		
Total patients	43.9	9.5
Basal BMI, 30.0–32.4 kg/m^2	44.4	14.6
Basal BMI, 32.5–34.9 kg/m^2	33.3	6.8
Basal BMI, 35.0–37.4 kg/m^2	46.2	0.0
Basal BMI, 37.5–39.9 kg/m^2	28.6	0.0
Basal BMI, ≥ 40 kg/m^2	50.0	23.8

SD standard deviation, *BMI* body mass index

Table 2 Input data for the study model

Parameters		Base case	SE[a]	Distribution	Alpha	Beta	Sources
Analysis setting							
Start age (year)		20	3.425	Log-normal			[23]
Time horizon (year)		80	8.000	Normal			
Utility weights							
NC, MC							
BMI 18.5–24.9 kg/m^2		0.962	0.096	Beta	2.808	0.110	[23]
BMI 25.0–29.9 kg/m^2		0.911	0.091	Beta	8.009	0.784	
BMI 30.0–39.9 kg/m^2		0.851	0.085	Beta	14.079	2.471	
BMI ≥ 40 kg/m^2		0.778	0.078	Beta	21.452	6.132	
SC							
BMI 18.5–24.9 kg/m^2		0.822	0.082	Beta	16.979	3.677	[23] and KNHANES database
BMI 25.0–29.9 kg/m^2		0.778	0.078	Beta	21.422	6.112	
BMI 30.0–39.9 kg/m^2		0.727	0.073	Beta	26.607	10.008	
BMI ≥ 40 kg/m^2		0.664	0.066	Beta	32.905	16.627	
Costs							
1st year							
NST		1160	116.0	Gamma	0.1	11.6	Expert advice and HIRA
BS[b]		7780	778.0	Gamma	0.1	77.8	
BS[b], re-operation		14,935	1493.5	Gamma	0.1	149.4	
BS[b], death		7780	778.0	Gamma	0.1	77.8	
After 1st year							
NST	MC	1435	143.5	Gamma	0.1	14.4	HIRA-NPS
	SC	1967	196.7	Gamma	0.1	19.7	
BS[b]	MC	1424	142.4	Gamma	0.1	14.2	
	SC	1949	194.9	Gamma	0.1	19.5	
Transition probability							
To MC for patients with BMI 18.5–24.9 kg/m^2							
20–29 years		0.00327					[25][c] and KNHANES database
30–39 years		0.00409					
40–49 years		0.01285					
50–59 years		0.02634					
60–69 years		0.03534					
70–79 years		0.04389					
≥ 80 years		0.04455					
To SC for patients with BMI 18.5–24.9 kg/m^2							
20–29 years		0.00052					[25] [c] and KNHANES database
30–39 years		0.00052					
40–49 years		0.00405					
50–59 years		0.00669					
60–69 years		0.01298					
70–79 years		0.01736					
≥ 80 years		0.10448					
Hazard ratio for transition probability according to BMI level							
To MC							[25][c]
BMI 25.0–29.9 kg/m^2		1.440	0.007	Normal			
BMI 30.0–39.9 kg/m^2		1.900	0.023	Normal			
BMI ≥ 40 kg/m^2		3.660	0.349	Normal			
To SC							
BMI 25.0–29.9 kg/m^2		1.350	0.008	Normal			
BMI 30.0–39.9 kg/m^2		1.610	0.024	Normal			

Table 2 (continued)

Parameters	Base case	SE[a]	Distribution	Alpha	Beta	Sources
BMI ≥ 40 kg/m^2	2.230	0.302	Normal			
Probability for death due to other cause						
20–29 years	0.00037					Statistics Korea
30–39 years	0.00064					
40–49 years	0.00138					
50–59 years	0.00309					
60–69 years	0.00648					
70–79 years	0.01881					
≥ 80 years	0.06847					
Hazard ratio for death probability						
BMI 18.5–24.9 kg/m^2	Ref.					[11] [c]
BMI 25.0–29.9 kg/m^2	0.840	0.012	Normal			
BMI 30.0–39.9 kg/m^2	1.000	0.034	Normal			
BMI ≥ 40 kg/m^2	2.270	0.230	Normal			

SE standard error, *NST* non-surgical treatment, *BS* bariatric surgery, *BMI* body mass index, *NC* no comorbidity, *MC* mild/moderate comorbidity, *SC* severe comorbidity, *KNHANES* Korea National Health and Nutrition Examination Survey, *HIRA* Health Insurance Review and Assessment Service, *HIRA-NPS* Health Insurance Review and Assessment Service-National Patients Sample database, *NHIS-Heals* National Health Insurance Service-Health Screening Cohort

[a] 10% of base value

[b] Comprised Roux-en-Y gastric bypass (32.8%) and sleeve gastrectomy (67.2%)

[c] Based on a re-analysis of the database used for the previous researches ([11, 25])

The utility weights did not significantly affect ICERs in the deterministic sensitivity analysis; however, the utility values assumed in this study could be meaningful because they were analyzed based on real patient data from the clinical trial. These data were derived from patient responses to the 3-level EQ-5D questionnaire that was acquired at the baseline and post-treatment visits with 12-week intervals until 48 weeks. The utility values decreased with increasing BMI levels, and a similar trend was observed in several previous studies [39–41]. In a research on the relation between the quality of life and BMI level in the general population aged 45 or more in the UK [39], the absolute values of utility weights tended to be lower than those reported in this study; 0.803 for BMI 18.5–< 25.0 kg/m^2, 0.780 for BMI 25.0–< 30.0 kg/m^2, 0.704 for BMI 30.0–< 35.0 kg/m^2, 0.682 for BMI 35.0–< 40.0 kg/m^2, and 0.621 for BMI > 40.0 kg/m^2. In general, utility weights are affected by the social and economic factors of the subject, and the absolute values may vary by country. However, the differences in utilities between subgroups were similar in the two studies. The dropped utility weights in this study were − 0.051, − 0.111, and − 0.184 in the increasing order of BMI subgroup with reference of BMI 18.5–< 25.0 kg/m^2 group, and they were − 0.023, − 0.099, − 0.121, and − 0.182 in the UK study. Thus, the utility weights used in this study appeared to be valid in comparing the tendency of the decrease of utility values with increasing BMI level.

The cost-effectiveness of BS in morbidly obese people in Korea has been published by Song et al. based on retrospective data in 2013 [22], and this study is the second evaluation based on prospective clinical trial. The base ICER in this study was slightly lower than 1771 USD/QALY of the first evaluation. The difference might be caused by the following reasons; First, changes in comorbidities could not be applied to the model in the previous study due to the limitation of data because the source data was a retrospective chart review study, but this study overcame these factors and reflected changes in comorbidities in the assessment. Second, the previous study included only the individuals with BMI 30–40 kg/m^2 and assumed a fixed post-treatment BMI level after 1 year of treatment as 25–30 kg/m^2 for BS and 30–40 kg/m^2 for NST. This study included people with BMI ≥ 30 kg/m^2 without any upper limits and assumed post-treatment BMI distribution as analyzed as the source data of clinical trial. In addition, the transition probability and mortality were also assumed differently according to the BMI level in this study. Lastly, BS is now covered by insurance in Korea, which has led to a slight cost reduction for BS.

BS has been considered cost-effective in the West as the ICERs of BS were about 1506–36,570 USD/QALY, which were all lower than their accepted willingness to pay threshold [18, 19]. ICERs inevitably differ according to the country as socio-economical and public health environments are

Table 3 Cost-utility in base case and subgroup analysis

Based on BMI	Intervention	Cost (USD)	ΔCost (USD)	QALYs	ΔQALYs	ICER (USD/QALY)
Total	NST	22,701		16.421		
	BS	22,936	235	16.770	0.348	674
30.0–32.4 kg/m^2	NST	21,001		17.322		
	BS	21,784	784	17.939	0.617	1271
32.5–34.9 kg/m^2	NST	24,172		16.939		
	BS	25,399	1227	17.307	0.368	3338
35.0–37.4 kg/m^2	NST	23,304		16.941		
	BS	21,665	− 1639	17.451	0.510	Dominating
37.5–39.9 kg/m^2	NST	23,837		16.285		
	BS	25,342	1505	16.751	0.466	3230
≥ 40.0 kg/m^2	NST	21,491		15.059		
	BS	23,086	1595	15.682	0.623	2561

NST non-surgical treatment, *BS* bariatric surgery, *QALYs* quality-adjusted life years, *ICER* incremental cost-effectiveness ratio

different, and therefore, the threshold value of willingness to pay can be a basis for determining cost-effectiveness. In Asia, cost-effectiveness of BS has rarely been assessed for individuals with morbid obesity. Tang et al. (2016) presented the cost-effectiveness ratio by treatment options for individuals with type 2 diabetes and BMI ≥ 28 kg/m^2. The medical treatment costs per QALY were 1589 USD for medical treatment, 1028 USD for laparoscopic sleeve gastrectomy, and 1198 USD for laparoscopic Roux-en-Y gastric bypass. Thus, surgery showed the lowest medical cost per QALY, but ICERs were not presented [42].

On the basis of the deterministic sensitivity analyses, discount rate, remission rate of comorbidity, surgery cost, and starting age at the time of entering the model affected ICERs relatively more than other factors. However, all ICERs from the deterministic sensitivity analysis were less than 10,000 USD/QALY, which is lower than the threshold of willingness to pay in South Korea (approximately 32,000 USD/QALY [32]). The results of probabilistic sensitivity analysis also showed > 90% cost-effectiveness at the willingness to pay threshold, and these results supported the cost-effectiveness of BS.

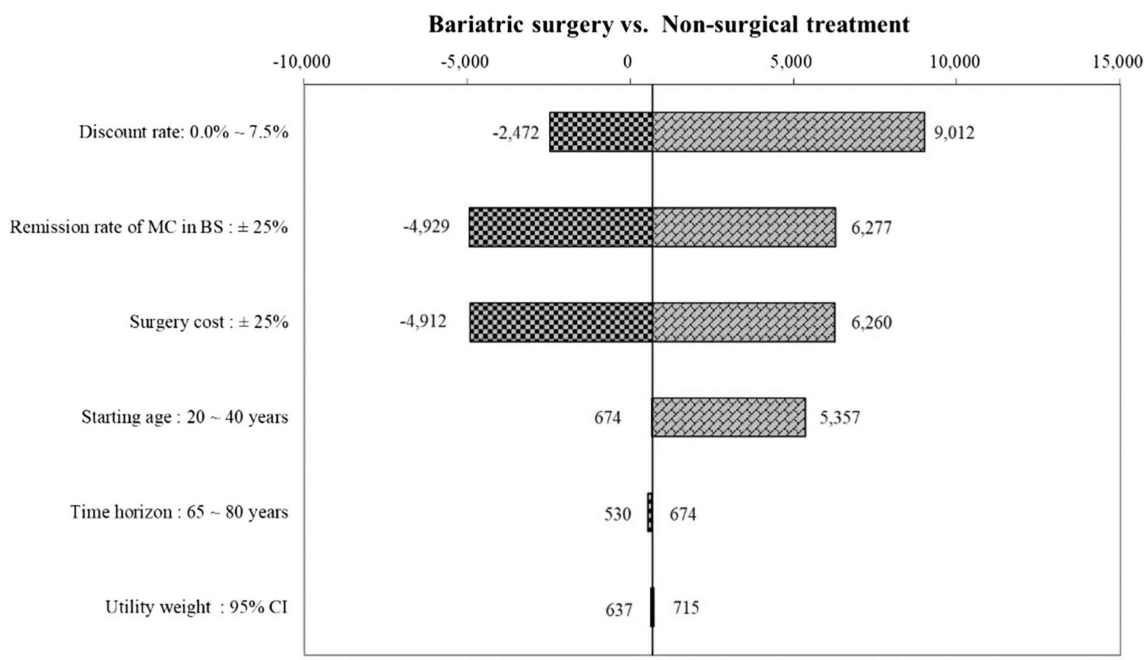

Fig. 2 Tornado diagram of bariatric surgery versus non-surgical treatment. *MC* mild/moderate comorbidity, *BS* bariatric surgery, *CI* confidence interval

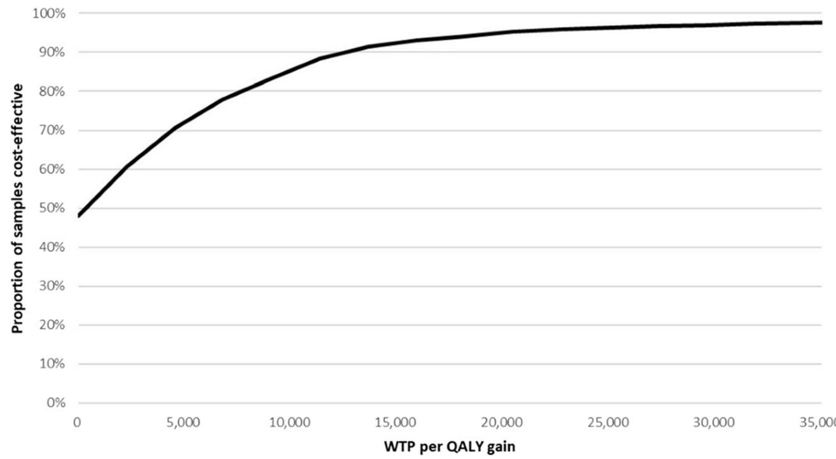

Fig. 3 Acceptability curves of bariatric surgery. *WTP* willingness to pay, *QALY* quality-adjusted life year

This study had limitations as follows. First, the follow-up period of the clinical trial which was the main reference for clinical efficacy assumption in this study was limited to 1 year. Thus, the severity of comorbidity and mortality data were not sourced from the trial and were assumed based on the real-world data instead. Second, it was assumed that the BMI level at the end of the first-year treatment was maintained for a lifetime. However, this weakness may not affect the results significantly as the results of deterministic sensitivity showed stable ICERs on this assumption. Third, the same probabilities of transferring to severe comorbidity were applied regardless of previous comorbidity status. A patient in mild comorbidity status is more likely to move to severe comorbidity than a patient in non-comorbidity status, and therefore, this assumption of the same probability was considered to make the base ICER conservative. Fourth, even though the treatment costs for the non-surgical group generally last more than a year, they were assumed to last only a year in this study. This is also thought to be a conservative assumption as ICERs may be more favored for BS if the non-surgical costs of beyond 1 year were added.

Despite these limitations, this study effectively showed the cost-effectiveness of BS over non-surgery in both total subjects and subgroups according to the base BMI level using real-world data, such as base distribution of comorbidity, remission rate of comorbidity and detailed BMI distribution at the end of 1 year of treatment, and utility weights derived from clinical study participants. In addition, individuals with a basal BMI of 30–34.9 kg/m^2 who would not be considered morbidly obese in the West were included if they had obesity-related comorbidities, such as hypertension, diabetes, and hyperlipidemia, like Asian countries, including Korea, have stricter criteria for defining morbid obesity. NST also has a marginal effect on resolving obesity in the subgroup of BMI of 30–35 kg/m^2, and the efficacy difference between BS and NST could be lower than estimated. However, BS showed significantly better effect in individuals in the clinical trial, and the ICERs for the subgroup having basal BMI of 30–35 kg/m^2 were also shown to be cost-effective. These results could be useful in establishing standards and guidelines for future studies on BS in other countries.

Conclusions

To our knowledge, this study is the first study in Korea to evaluate the cost-effectiveness of BS in morbid obesity or obesity at BMI 30–34.9 kg/m^2 with comorbidity using data from a prospective clinical trial. BS was more effective than NST for people with BMI of ≥ 30 kg/m^2 as it offered a better reduction in BMI and remission of obesity-related comorbidities and was cost-effective considering the lifetime. In particular, surgical treatment was a dominant alternative for people with basal BMI of 35.0–37.5 kg/m^2.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval The study was approved by the IRB of the Kyungpook National University (KNU 2016–0007). In addition, prospective clinical trials for the source data in this study were approved by the Institutional Review Board (IRB) of their respective centers (the approval number of IRB at principal investigator center: INHAUH 2016-06-015).

Informed Consent The NHIS-HEALS database was retrospectively established in an anonymous format, and the informed consent requirement for this study was waived, and informed consent was obtained from all individual participants included in the prospective clinical trial used for source data in this study.

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