의학석사 학위논문

Impact of obesity on total hospital costs in patients who underwent colorectal cancer surgery

대장암으로 수술 받은 환자에서 비만이 진료비에 미치는 영향

2018 년 2 월

서울대학교 대학원

의학과 외과학 전공

권 윤 혜

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비만이 진료비에 미치는 영향

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권 윤 혜

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A thesis of the Master's Degree

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Impact of obesity on total hospital costs in patients who underwent colorectal cancer surgery

February 2018

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Abstract

Introduction: The prevalence of obesity is increasing at a rapid rate. Obesity is associated with greater use of healthcare resources and obese patients have higher costs compared with other standardized body mass groups. Obesity is well-known cause of many systemic diseases and related to the development of colorectal cancer. However, only few studies examined the impact of obesity in colorectal cancer patients. This study aimed to determine whether obesity increases hospital costs in patients who underwent colorectal cancer surgery.

Methods: We retrospectively collected hospital billings for patients who underwent surgery for stage I-III colorectal cancer and analyzed the association between obesity and hospital cost. Obesity was assessed by preoperative body mass index (BMI) and computed tomography-assessed adipose tissue area. Primary outcome was hospital costs assessed by direct hospital billing during hospitalization.

Results: A total of 656 patients were analyzed in the study. Mean BMI was 23.92 ± 2.912 kg/m2, mean total adipose tissue (TAT) area was 249.57 ± 92.82 cm2 and mean visceral adipose tissue (VAT) area was 101.50 ± 56.57 cm2. The mean cost during index admission was 6,442,162.52 ± 2,480,435.78 ₩. We defined obese as the value over the cutoff value.

In multivariate analysis by each obesity indices, obese patients defined by TAT area was significantly associated with higher total medical cost (p=0.046) and in multivariate analysis for subdivided medical cost according to TAT area, the higher operation/consultation cost significantly associated with obesity (p=0.003).

Conclusions: Increased total adipose tissue area but not BMI was associated with higher medical costs (p=0.046) in colorectal cancer patients, especially associated with the higher operation/consultation cost (p=0.003).

Keywords: Obesity, BMI, adipose tissue, hospital cost, surgical cost, colorectal cancer
Student number: 2016-21923

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List of abbreviations

BMI	Body mass index
ASA	American Society of Anesthesiologists
LOS	Length of stay
ICU	Intensive care unit
CT	Computed tomography
TAT	Total adipose tissue
VAT	Visceral adipose tissue
SAT	Subcutaneous adipose tissue
WHO	World Health Organization
HU	Housefield units
SD	Standard deviation
ROC	Receiver operation characteristic
AUC	Area under the curve

Introduction

In worldwide, obesity is increasing at a rapid rate and the global increase in body mass index (BMI) has not slowed down [1, 2]. In the United States, the prevalence of obesity increased dramatically during the last few decades with over one-third (35.7%) of the population having a BMI ≥30 kg/m2 [3, 4]. Results from the National Health and Nutrition Examination Survey revealed that the prevalence of obesity in the United States population has increased from 14.5% in 1976–80 to 32.2% in 2003–4.

Obesity is associated with greater use of healthcare resources and patients with obesity have higher costs compared with other standardized body mass groups [5-7]. The total cost of obesity is impossible to determine accurately, however, the costs of obesity-related disorders in the US are estimated to be between $US 52 and $US 95 billion annually [8-10].

Obesity is well-known cause of many systemic diseases, including diabetes mellitus, hypertension, cardiovascular diseases, musculoskeletal disorders and metabolic syndrome as well as associated with an increased risk of postoperative complications [11, 12]. According to a recent report, obesity and visceral obesity are closely related to the development of colorectal cancer [13-15]. Because the rapid growth of the obese population shows no signs of slowing down, it can be expected that the number of obese patients who require colorectal cancer surgery will only continue to increase.

There are only few studies have examined the impact of body mass on resource utilization in the colorectal cancer patients, therefore, we designed this study to measure the impact of obesity on both hospital costs and clinical outcomes after colorectal cancer surgery in obese patients and compare with those in the normal weight patients.

Materials and methods

Study Design and Population

We retrospectively reviewed the electronic medical records of patients who underwent curative operation performed by single surgeon for stage I–III colorectal cancer at Seoul National University Hospital between October 2004 and December 2008. Curative resection included a complete resection of the tumor– proximally, distally and circumferentially, as confirmed by a lack of tumor cells at the resection margin, conventional lymph node dissection and no remaining macroscopic evidence of disease. Demographics and clinical characteristics were collected, including age, sex, comorbidities, height and weight at the time of surgery, American Society of Anesthesiologists (ASA) physical status. The intraoperative and postoperative findings including duration of anesthesia and operation, estimated amount of intraoperative blood loss, number of surgical gauze used during operation, transfusion requirement, postoperative length of stay (LOS), postoperative intensive care unit (ICU) stay, 30–day mortality and complications were also obtained through electronic medical records review. Anesthesia time was calculated as the time between placing the patient on the operating table and end transfer the patient to the recovery room. Operative time was calculated as the time between the first incision and wound closure. The recorded cancer characteristics were tumor size, presence of multiple tumors, final pathologic stage according to TNM 7th edition and lymph node positivity.

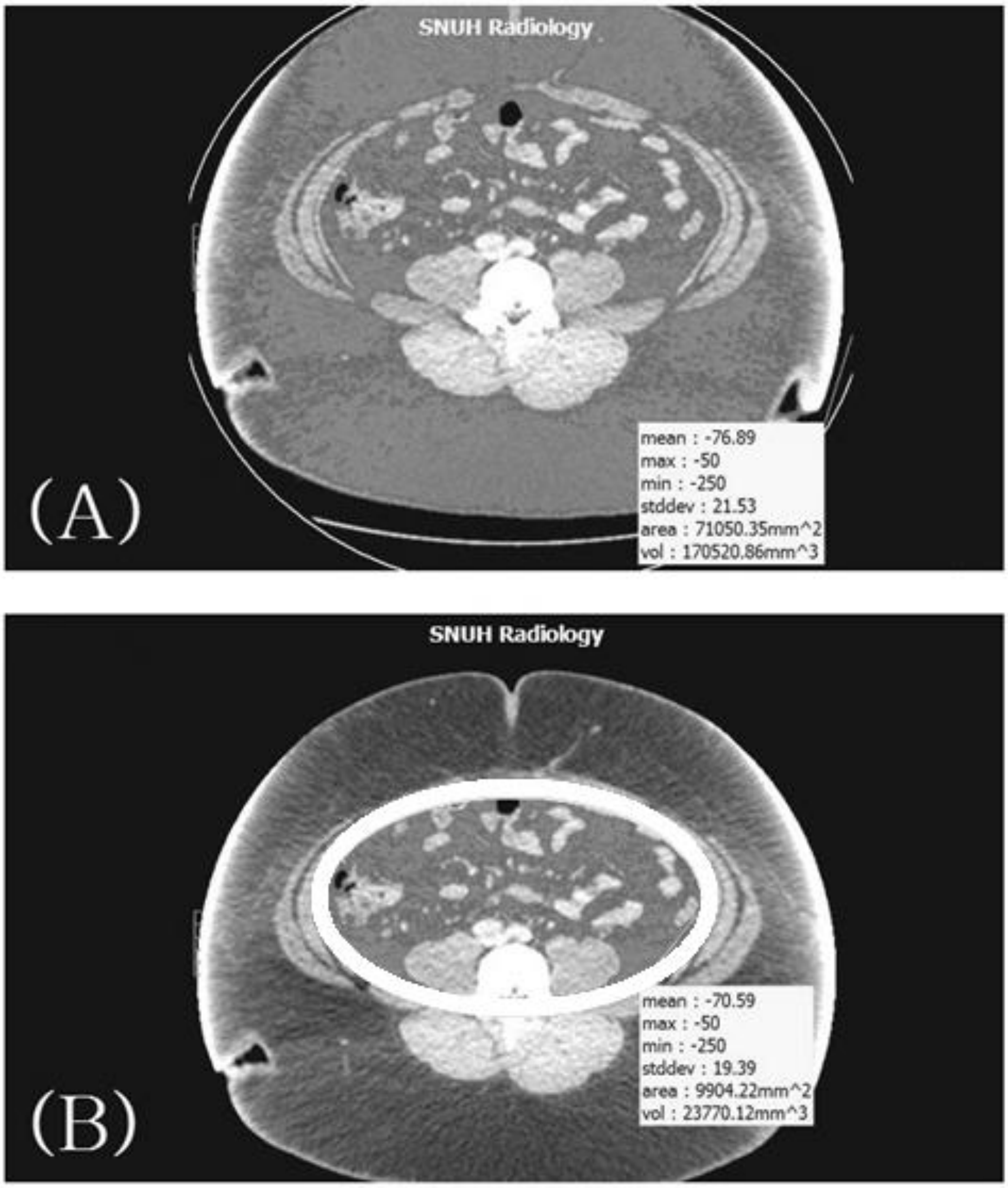
Definition and Measurements

All patients underwent preoperative abdominal computed tomography (CT) for staging work−up. Obesity was assessed by preoperative body mass index (BMI), CT−assessed total adipose tissue (TAT), visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) areas. BMI was calculated from measured weight and height and according to the modified World Health Organization (WHO) criteria from the Asia-Pacific guideline, categorized as follows: normal (<23 kg/m2), overweight (23-24.9 kg/m2) and obese (≥25 kg/m2). The adipose tissue area was measured at the level of the umbilicus, using abdominal CT scanner, as previously described (Figure 1) [16, 17]. We used a commercial software (Rapidia 2.8; INFINITT, Seoul, Korea) to measure the pixels density between −250 and −50 Hounsfield units (HU) which defines the fat compartment. We defined VAT area as an intra−abdominal adipose tissue area confined by the parietal peritoneum, excluding the paraspinal muscles and the vertebral column. SAT areas were defined as adipose tissue areas external to the abdomen and back muscles. The sum of VAT and SAT areas were defined as TAT area.

The primary outcome was hospital costs assessed by direct hospital billing during hospitalization. Secondary outcome included duration of operation, length of hospital stay and ICU stay, 30−day mortality and morbidity. Total hospital costs including surgery, anesthesia, laboratory, radiology, hospital room, medication, surgical supplies and blood associated with index admission for colorectal cancer surgery were collected from hospital billing data. All costs originally measured in Korean Won(₩).

Figure 1. Calculation of adipose tissue area by multi−detector CT scan

The measurement was performed at the level of umbilicus. Adipose tissue areas were indicated by Hounsfield scale between −250 and −50 Hounsfield units, which is an attenuation values specific for fatty tissues. (A) Green color indicates total adipose tissue area, both subcutaneous and visceral. (B) Green color inside the circle indicates the visceral adipose tissue area.



Ethics Statement

The Institutional Review Board of Seoul National University Hospital approved the study protocol (IRB number H−1605−049−760), and the study was conducted in accord with the Helsinki Declaration. Informed consent was waived by the board.

Statistical analysis

All continuous variables are expressed as the mean ±standard deviation (SD). Analysis of categorical variables was performed with Pearson's $\chi 2$−test or Fisher's exact test and the chi−squared test. Continuous variables were compared using Student's t test and the Mann-Whitney U test. SPSS, version 19.0 (SPSS Inc., Chicago, IL, USA) was used for all analyses. Results were considered statistically significant when the P value was 0.05 or less.

Results

Baseline characteristics of the study population

Total of 656 stage I–III colorectal cancer patients were included in this study. Table 1 details the baseline characteristics of the patients. BMI, TAT and VAT data were available in all patients. Mean BMI was 23.92 ± 2.91 kg/m2 (range, 16.8 –39.5 kg/m2), mean TAT area was 249.57 ± 92.82 cm2 (range 14.35– 604.90 cm2) and mean VAT area was 101.50 ± 56.57 cm2 (range 6.71– 284.68 cm2). Overall, there were 430 (65.5%) men and 226 (34.5%) women with a mean age of 62.13 ± 10.87 years (range, 25–93 years). There were 157 (23.9%) patients diagnosed as diabetes, 277 (42.2%) patients with hypertension and 28 (4.3%) patients with cerebral vascular disease. 97 (14.8%) patients were current smoker.

Table 1. Clinical characteristics of the patients

Clinical characteristics (N=656)	
Age, years (Mean±SD)	62.13±10.87
Gender, n (%)	
Female	226
Male	430
Body mass index, kg/m2 (Mean±SD)	23.92±2.912
Total adipose tissue area, cm2 (Mean±SD)	249.57 ± 92.82
Visceral adipose tissue area, cm2 (Mean±SD)	101.50 ± 56.57
ASA Class, n (%)	
I	250
II	347
III	44
IV	1
Comorbidity, n (%)	
Diabetes	157
Hypertension	277
Cerebral vascular disease	28
Heart disease	48
Current smoker, n (%)	97
Location of tumor, n (%)	
Right colon	147
Left colon	236
Rectum	254
Multiple tumors	19
Laboratory data at operation (Mean±SD)	
Hemoglobin (g/dL)	12.93±2.04
Platelet ($\times 10^3$ /μℓ)	256.46±74.13
Glucose (mg/dL)	135.83±152.81
Cholesterol (mg/dL)	169.24±34.69
Aspartate transaminase (IU/L)	21.21±10.84
Alanine transaminase (IU/L)	19.58±14.39
Albumin (g/dL)	3.93±0.44
Blood urea nitrogen (mg/dL)	13.34±4.96
Creatinine (mg/dL)	1.01±0.24
Carcinoembryonic Antigen (ng/mL)	47.15±197.33

Intraoperative findings and Postoperative outcomes

The mean operative time was 95.60 ± 40.373 minutes (range, 30−365 min) and the mean anesthesia time was 129.36 ± 42.401 minutes (range, 65−390 min). Mean intraoperative blood loss was 156.45 ± 128.302 cc (range, 100−1200 cc) and mean number of surgical gauze used during operation was 51.73 ± 14.312 (range, 20−150). Intraoperative findings are summarized in Table 2.

The mean hospital stay was 11.68 ± 4.924 days (range, 6−75 days) and mean postoperative stay was 7.51 ± 3.133 days (range, 0−43 days). 30−day postoperative complications included 44 ileus (6.7%), 7 postoperative bleeding (1.1%), 2 anastomosis site leakage (0.3%), 53 emergency room visit after discharge (8.1%) and 11 reoperation (1.7%). There were two deaths within 30 days. One patient had sudden cardiac arrest on operative day and the other patient died from pulmonary thromboembolism at postoperative 2 weeks. The mean cost during index admission was 6,442,162.52 ± 2,480,435.78 ₩ (range, 2,910,775.00−42,127,302.00₩). Postoperative outcomes are summarized in Table 3.

Table 2. Intraoperative findings

Clinical characteristics (N=656)	
Operative time, min (Mean±SD)	95.60 ± 40.373
Anesthesia time, min (Mean±SD)	129.36 ± 42.401
Blood loss, cc (Mean±SD)	156.45 ± 128.302
Surgical gauze used, n (Mean±SD)	51.73 ± 14.312
Transfusion, n (%)	16 (2.43)

Table 3. Postoperative outcomes

Clinical characteristics (N=656)	
Intensive care unit stay, n (%)	26 (3.96)
Total hospital stay, day (Mean±SD)	11.68 ± 4.924
Postoperative hospital stay, day (Mean±SD)	7.51 ± 3.133
Complications, n (%)	85 (13.1)
Ileus	44 (6.7)
Wound complication	21 (3.2)
Bleeding	7 (1.07)
Anastomosis leakage	2 (0.30)
30-day Reoperation	11 (1.68)
30-day ER visit	53 (8.08)
30-day mortality	2 (0.30)
AJCC 7th stage, n (%)	
O	15 (2.29)
I	124 (18.90)
II	250 (38.11)
III	267 (40.70)
T stage, n (%)	
1	61 (9.91)
2	102 (15.55)
3	444 (67.68)
4	49 (7.47)
Node positivity, n (%)	264 (40.24)
Total medical cost, ₩ (Mean±SD)	6,442,162.52 ± 2,480,435.78
Anesthesia	337,584.90 ± 87,491.37
Laboratory test	892,511.53 ± 469,478.60
Operation/consultation	1,824,793.03 ± 531,066.86
Radiology test	403,075.90 ± 479,193.59
Room	1,652,897.00 ± 1,253,555.76
Medication	502,039.85 ± 536,938.82
Surgical supplies	801,667.52 ± 395,079.35
Blood	27,592.79 ± 178,360.16

Clinical characteristics according to obesity indices and total medical cost

In the first, we created a prediction model for total medical cost according to obesity indices: BMI, TAT and VAT (Table 4). As previously mentioned, all costs originally measured in Korean Won(₩). Receiver operation characteristic (ROC) curve was drawn and the optimal cutoff value and area under the curve (AUC) of three obesity indices for total medical cost were calculated. We defined obese as the value over the cutoff value and not obese as the value under the cutoff value. For example, optimal cutoff value for BMI is 25 kg/m2, therefore, BMI over 25 kg/m2 is obese BMI. Table 5 details demographics of the patients through this method.

Since there was no standard value for the medical cost, we divided total medical cost into two groups: low cost (<mean medical cost−1standard deviation(SD), 8,922,598₩) and high cost (≥mean medical cost+1SD, 8,922,598₩). Table 6 details demographics of the patients by total medical cost groups.

Table 4. Prediction model for total medical cost according to obesity indices

	TAT	VAT	BMI
Optimal cutoff value	312.66 cm2	109.61 cm2	25 kg/m2
Area Under the Curve	0.561	0.541	0.53
Confidence Interval	0.454–0.669	0.435–0.648	0.436–0.624
P–value	< 0.001	< 0.001	< 0.001
Sensitivity (%)	39.50	63.20	45.80
Specificity (%)	77.60	52.20	68.80
Positive Predictive value (%)	5.00	4.60	5.90
Negative Predictive value (%)	89.30	91.80	89.60

Table 5. Clinical characteristics of the patients according to obesity indices

	TAT (cutoff value=31266)			VAT (cutoff value=10961)			BMI (cutoff value=25)		
	Obese	Non-obese	P-value	Obese	Non-obese	P-value	Obese	Non-obese	P-value
Patient number	456	141		305	292		432	224	
Gender, n (%)			< 0.001			< 0.001			0.955
Male	322 (70.6)	75 (53.2)		180 (59.0)	217 (74.3)		284 (65.7)	146 (65.2)	
Female	134 (29.4)	66 (46.8)		125 (41.0)	75 (25.7)		148 (34.3)	78 (34.8)	
Age, years (Mean±SD)	61.9 ± 11.2	63.7 ± 8.7	0.044	61.4 ± 11.7	63.3 ± 9.5	0.028	62.1 ± 11.6	62.2 ± 9.3	0.824
AJCC 7th stage, n (%)			0.561			0.006			0.408
1	11 (2.4)	3 (2.1)		7 (2.3)	7 (2.4)		10 (2.3)	5 (2.2)	
2	81 (17.8)	32 (22.7)		41 (13.4)	72 (24.7)		75 (17.4)	49 (21.9)	
3	177 (38.8)	55 (39.0)		125 (41.0)	107 (36.6)		173 (40.0)	77 (34.4)	
4	187 (41.0)	51 (36.2)		132 (43.3)	106 (36.3)		174 (40.3)	93 (41.5)	
Tumor Location, n (%)			0.386			0.327			0.03
Right colon	108 (23.7)	26 (18.4)		75 (24.6)	59 (20.2)		110 (25.5)	37 (16.5)	
Left colon	336 (73.7)	110 (78.0)		220 (72.1)	226 (77.4)		309 (71.5)	181 (80.8)	
Multiple	12 (2.6)	5 (3.5)		10 (3.3)	7 (2.4)		13 (3.0)	6 (2.7)	
Current smoker, n (%)	74 (16.3)	15 (10.7)	0.138	44 (14.4)	45 (15.6)	0.783	62 (14.7)	35 (15.8)	0.796
Drinking, n (%)	157 (34.4)	37 (26.4)	0.096	76 (24.9)	118 (40.5)	< 0.001	122 (28.8)	85 (38.1)	0.02
Education, n (%)			0.043			0.667			0.045

< Primary school	91 (21.0)	41 (31.1)		68 (23.8)	64 (22.9)		86 (21.0)	56 (26.3)	
< High school	207 (47.7)	51 (38.6)		134 (46.9)	124 (44.3)		200 (48.9)	82 (38.5)	
> University	136 (31.3)	40 (30.3)		84 (29.4)	92 (32.9)		123 (30.1)	75 (35.2)	
Admission route, n (%)			0.545			0.088			0.061
via Outpatient clinic	413 (91.6)	132 (93.6)		271 (90.0)	274 (94.2)		384 (89.9)	210 (94.6)	
via Emergency room	38 (8.4)	9 (6.4)		30 (10.0)	17 (5.8)		43 (10.1)	12 (5.4)	
Hypertension, n (%)	180 (39.5)	78 (55.3)	0.001	97 (31.8)	161 (55.1)	< 0.001	156 (36.1)	121 (54.0)	< 0.001
Diabetes, n (%)	97 (21.3)	47 (33.3)	0.005	59 (19.3)	85 (29.1)	0.007	92 (21.3)	65 (29.0)	0.036
ASA class, n (%)			0.254			0.009			0.414
1	182 (40.6)	45 (33.1)		134 (45.1)	93 (32.4)		174 (40.8)	76 (35.2)	
2	234 (52.2)	84 (61.8)		143 (48.1)	175 (61.0)		221 (51.9)	126 (58.3)	
3	31 (6.9)	7 (5.1)		19 (6.4)	19 (6.6)		30 (7.0)	14 (6.5)	
4	1 (0.2)	0 (0.0)		1 (0.3)	0 (0.0)		1 (0.2)	0 (0.0)	
Laboratory data at operation (Mean±SD)									
Hemoglobin (g/dL)	12.8 ± 2.1	13.3 ± 1.9	0.012	12.5 ± 2.0	13.4 ± 2.0	< 0.001	12.6 ± 2.0	13.6 ± 1.9	< 0.001
Platelet (×10^3 /㎕)	255.8 ± 72.9	256.1 ± 65.4	0.966	259.4 ± 73.1	252.2 ± 68.9	0.218	259.8 ± 76.4	250.1 ± 69.3	0.114
Glucose (mg/dL)	108.8 ± 31.3	115.4 ± 41.6	0.09	107.0 ± 32.6	113.9 ± 35.3	0.015	108.1 ± 31.4	113.9 ± 37.3	0.05
Cholesterol (mg/dL)	168.4 ± 34.4	173.8 ± 35.2	0.107	166.3 ± 34.3	173.2 ± 34.7	0.014	166.6 ± 34.1	174.4 ± 35.2	0.006
Aspartate transaminase (IU/L)	20.4 ± 9.1	24.0 ± 15.6	0.011	20.2 ± 10.9	22.4 ± 11.1	0.016	20.7 ± 10.1	22.3 ± 12.1	0.09

Alanine transaminase (IU/L)	18.4 ± 13.4	24.0 ± 17.4	0.001	16.8 ± 11.6	22.8 ± 16.7	< 0.001	17.9 ± 14.1	22.7 ± 14.5	< 0.001
Albumin (g/dL)	3.9 ± 0.4	4.0 ± 0.4	0.002	3.8 ± 0.4	4.0 ± 0.4	< 0.001	3.9 ± 0.5	4.0 ± 0.4	< 0.001
Blood urea nitrogen (mg/dL)	13.4 ± 5.2	13.2 ± 4.3	0.673	13.2 ± 5.0	13.6 ± 4.9	0.309	13.1 ± 5.3	13.7 ± 4.3	0.146
Creatinine (mg/dL)	1.0 ± 0.3	1.0 ± 0.2	0.014	1.0 ± 0.2	1.0 ± 0.2	0.026	1.0 ± 0.3	1.0 ± 0.2	0.526
Carcinoembryonic Antigen (ng/mL)	5.1 ± 8.5	10.6 ± 42.7	0.133	5.7 ± 9.3	7.2 ± 30.2	0.411	8.2 ± 43.3	7.2 ± 30.8	0.745
Anesthesia time, min (Mean±SD)	128.0 ± 43.3	134.5 ± 39.6	0.112	127.4 ± 45.9	131.7 ± 38.7	0.222	126.2 ± 42.4	135.4 ± 41.7	0.008
Operative time, min (Mean±SD)	94.5 ± 41.4	100.0 ± 37.6	0.155	94.3 ± 44.0	97.3 ± 36.7	0.371	92.9 ± 40.5	100.8 ± 39.7	0.016
Surgical gauze used, n (Mean±SD)	51.1 ± 13.9	54.3 ± 16.4	0.036	51.4 ± 15.8	52.2 ± 13.2	0.485	50.6 ± 13.8	54.0 ± 15.1	0.004
Blood loss, cc (Mean±SD)	123.2 ± 145.9	131.3 ± 139.7	0.56	123.1 ± 147.9	127.2 ± 140.9	0.735	127.9 ± 148.4	124.5 ± 135.4	0.771
Postoperative hospital stay, day (Mean±SD)	7.4 ± 2.4	7.7 ± 4.1	0.335	7.5 ± 2.4	7.4 ± 3.3	0.888	7.4 ± 2.8	7.7 ± 3.7	0.296
Complications, n (%)	59 (12.9)	21 (15.0)	0.571	42 (13.8)	38 (13.0)	0.811	54 (12.2)	32 (15.1)	0.323
Ileus	30 (6.6)	9 (6.4)	1.000	19 (6.3)	20 (6.8)	0.869	29 (6.5)	15 (34.1)	0.868
Wound complication	11 (2.4)	9 (6.4)	0.030	9 (3.0)	11 (3.8)	0.653	12 (2.7)	9 (4.2)	0.344
Bleeding	5 (1.1)	2 (1.4)	0.669	5 (1.6)	2 (0.7)	0.451	5 (1.1)	2 (0.9)	1.000
Anastomosis leakage	1 (0.2)	1 (0.7)	0.414	1 (0.3)	1 (0.3)	1.000	1 (0.2)	1 (0.5)	0.542
30-day Reoperation	5 (1.1)	4 (2.9)	0.225	5 (1.6)	4 (1.4)	1.000	7 (1.6)	4 (1.9)	0.753
30-day ER visit	34 (7.4)	12 (8.6)	0.717	23 (7.6)	23 (7.8)	1.000	34 (7.7)	19 (9.0)	0.545
30-day mortality	2 (0.4)	0 (0.0)	1.000	2 (0.7)	0 (0.0)	0.499	2 (0.5)	0 (0.0)	1.000

Total medical cost, ₩ (Mean±SD)	6,241,739.1 ± 1,838,874.5	6,647,526.4 ± 2,273,726.0	0.055	6,243,312.8 ± 1,943,392.1	6,436,040.6 ± 1,967,427.3	0.229	6,337,083.1 ± 2,508,018.0	6,644,815.7 ± 2,419,003.7	0.132
Anesthesia	333,737.4 ± 80,310.8	349,733.3 ± 101,557.9	0.088	331,942.4 ± 84,341.3	343,336.4 ± 87,428.6	0.106	332657.7 ± 82950.7	347,087.3 ± 95,116.3	0.055
Laboratory	867,702.1 ± 309,522.3	893,036.3 ± 397,200.3	0.488	868,959.1 ± 315,586.4	878,622.5 ± 349,062.4	0.723	899,625.6 ± 516,488.3	878,791.5 ± 362,669.3	0.549
Operation/consultation	1,771,786.1 ± 437,185.3	1,912,018.6 ± 472,515.6	0.001	1,772,357.0 ± 452,721.5	1,838,904.8 ± 444,024.6	0.07	1,810,246.7 ± 552,818.9	1,852,846.7 ± 486,342.2	0.311
Radiology	388,300.0 ± 366,171.3	413,803.1 ± 487,875.4	0.567	392,950.7 ± 368,096.4	395,757.1 ± 427,606.6	0.932	405,765.2 ± 498,585.8	397,889.3 ± 440,417.9	0.836
Room	1,610,810.5 ± 1,252,042.5	1,709,023.6 ± 1,183,542.0	0.41	1,580,442.8 ± 1,307,696.9	1,689,955.0 ± 1,155,829.3	0.278	1,559,045.5 ± 937,522.0	1,833,896.4 ± 1,693,165.4	0.025
Medication	476,762.9 ± 277,399.5	475,331.4 ± 279,045.5	0.957	503,676.0 ± 317,422.9	447,960.3 ± 225,677.0	0.013	521,432.8 ± 632,504.1	464,639.1 ± 267,326.6	0.108
Surgical supplies	771,731.1 ± 375,768.3	853,894.5 ± 378,099.8	0.024	774,823.4 ± 386,630.6	808,176.0 ± 367,864.4	0.281	785,082.3 ± 411,376.3	833,653.2 ± 360,313.3	0.12
Blood	20,909.0 ± 69,298.3	40,685.6 ± 349,114.3	0.505	18,161.3 ± 48,025.7	33,328.6 ± 252,513.0	0.314	23,227.2 ± 70,634.6	36,012.1 ± 289,290.2	0.515

Table 6. Clinical characteristics of the patients by total medical cost groups

	Low cost (n=608)	High cost (n=48)	P-value
Gender, n (%)			1.000
Female	399 (65.6)	31 (64.6)	
Male	209 (34.4)	17 (35.4)	
Age, years (Mean±SD)	61.8 ± 10.7	66.0 ± 12.3	0.011
AJCC 7th stage, n (%)			0.726
0	14 (2.3)	1 (2.1)	
1	115 (18.9)	9 (18.8)	
2	235 (38.7)	15 (31.2)	
3	244 (40.1)	23 (47.9)	
Tumor Location, n (%)			< 0.001
Right colon	140 (23.0)	7 (14.6)	
Left colon	455 (74.8)	35 (72.9)	
Multiple	13 (2.1)	6 (12.5)	
Current smoker, n (%)	92 (15.3)	5 (11.1)	0.584
Drinking, n (%)	197 (32.7)	10 (22.2)	0.197
Education, n (%)			0.097
< Primary school	132 (22.8)	10 (22.7)	
< High school	268 (46.4)	14 (31.8)	
> University	178 (30.8)	20 (45.5)	
Admission route, n (%)			< 0.001
via Outpatient clinic	565 (93.9)	29 (61.7)	
via Emergency room	37 (6.1)	18 (38.3)	
Hypertension, n (%)	252 (41.4)	25 (52.1)	0.199
Diabetes, n (%)	137 (22.5)	20 (41.7)	0.005
ASA class, n (%)			< 0.001
1	237 (39.6)	13 (29.5)	
2	326 (54.5)	21 (47.7)	
3	34 (5.7)	10 (22.7)	
4	1 (0.2)	0 (0.0)	
Laboratory data at operation (Mean±SD)			
Hemoglobin (g/dL)	13.0 ± 2.0	12.0 ± 2.2	0.002
Platelet ($\times 10^3$ /$\mu\ell$)	253.3 ± 70.7	297.0 ± 101.5	0.005
Glucose (mg/dL)	109.1 ± 32.4	121.9 ± 44.2	0.055
Cholesterol (mg/dL)	170.4 ± 33.6	155.0 ± 44.7	0.024
Aspartate transaminase (IU/L)	21.1 ± 10.4	22.4 ± 15.5	0.588
Alanine transaminase (IU/L)	19.6 ± 13.5	19.8 ± 23.3	0.958
Albumin (g/dL)	3.9 ± 0.4	3.7 ± 0.5	< 0.001
Blood urea nitrogen (mg/dL)	13.3 ± 4.7	14.1 ± 7.9	0.477
Creatinine (mg/dL)	1.0 ± 0.2	1.1 ± 0.4	0.276

Carcinoembryonic Antigen (ng/mL)	6.1 ± 20.3	30.4 ± 125.7	0.197
Anesthesia time, min (Mean±SD)	127.2 ± 40.2	156.5 ± 58.3	0.001
Operative time, min (Mean±SD)	93.5 ± 38.1	122.5 ± 56.4	0.001
Surgical gauze used, n (Mean±SD)	51.1 ± 13.2	59.2 ± 23.6	0.024
Blood loss, cc (Mean±SD)	120.5 ± 134.1	205.4 ± 223.2	0.012
Postoperative hospital stay, day (Mean±SD)	7.1 ± 1.9	12.5 ± 8.0	< 0.001
30-day Readmission, day (Mean±SD)	0.2 ± 1.6	0.1 ± 1.0	0.867
Postoperative complications, n (%)	82 (13.5)	4 (8.3)	0.380
Ileus	43 (7.1)	1 (2.1)	0.241
Wound complication	19 (3.1)	2 (4.2)	0.661
Bleeding	7 (1.2)	0 (0.0)	1.000
Anastomosis leakage	2 (0.3)	0 (0.0)	1.000
30-day Reoperation	10 (1.6)	1 (2.1)	0.569
30-day ER visit	51 (8.4)	2 (4.2)	0.415
Total medical cost, ₩ (Mean±SD)			
Anesthesia	331,440.9 ± 75,152.2	415,408.5 ± 164,507.0	0.001
Laboratory	826,772.8 ± 239,846.9	1,725,202.5 ± 1250876.6	< 0.001
Operation/consultation	1,778,165.4 ± 413,146.6	2,415,409.9 ± 1,158,285.8	< 0.001
Radiology	339,611.3 ± 321,629.5	1,206,961.3 ± 1,073,331.6	< 0.001
Room	1,467,666.4 ± 693,390.1	3,999,150.7 ± 3,102,273.5	< 0.001
Medication	444,018.2 ± 197,690.6	1,236,981.0 ± 1,708,194.6	0.002
Surgical supplies	776,848.3 ± 364,392.0	1,116,044.7 ± 592,875.4	< 0.001
Blood	15,732.3 ± 57,749.9	177,825.8 ± 612,699.4	0.073
BMI as continuous variable, kg/m2 (Mean±SD)	23.8 ± 2.9	24.1 ± 3.8	0.616
VAT as continuous variable, cm2 (Mean±SD)	109.47 ± 50.48	117.70 ± 63.03	0.436
SAT as continuous variable, cm2 (Mean±SD)	137.96 ± 59.31	152.03 ± 77.12	0.277
TAT as continuous variable, cm2 (Mean±SD)	248.43 ± 91.96	263.29 ± 102.74	0.297

Logistic regression analysis for total medical cost

The prognostic factors associated with total medical cost groups presented in Table 7. In univariate analysis, age, tumor location, admission route, ASA class and TAT area was significantly associated with an increased total medical cost. However, in multivariate analysis by each obesity indices after adjusting for confounders, no association was found with total medical cost (Table 8).

We also attempt to analyze the total medical cost in continuous value. In univariate analysis, factors significantly associated with an increased total medical cost were exactly matched with the results of analysis with cost groups (Table 9). In multivariate analysis by each obesity indices after adjusting for confounders, obese patients defined by TAT area was significantly associated with higher total medical cost (p=0.046) (Table 10).

Table 7. Univariate logistic regression analysis for total medical cost groups

	OR	LCI	HCI	P value
Gender	1.05	0.56	1.91	0.8838
Age	1.04	1.01	1.07	0.0111
T stage	1.37	0.9	2.2	0.1627
N stage	1.23	0.83	1.79	0.2921
AJCC 7th stage	1.14	0.79	1.68	0.4908
Tumor location	2.7	1.34	5.66	0.0069
Smoking	0.69	0.23	1.64	0.4471
Drinking	0.59	0.27	1.17	0.1492
Education	1.32	0.87	2.05	0.1998
Admission route	9.48	4.77	18.57	0.000
ASA class	2.04	1.24	3.36	0.0049
Obese by TAT	2.24	1.11	4.39	0.02
Obese by VAT	1.86	0.96	3.76	0.0732
Obese by BMI	1.7	0.93	3.07	0.0789

† *OR, odd ratio*

‡ *LCI, low bounds of the confidence intervals*

§ *HCL, high bounds of the confidence intervals*

Table 8. Multivariate logistic regression analysis for total medical cost groups

	OR	LCI	HCI	P value
Obese by TAT area	1.37	0.53	3.32	0.4938
Obese by VAT area	2.02	0.86	5.02	0.1151
Obese by BMI area	1.77	0.82	3.79	0.14

* *Adjusted for Age, T stage, Tumor location, Drinking, Education, Admission route, ASA class*

† *OR, odd ratio*

‡ *LCI, low bounds of the confidence intervals*

§ *HCL, high bounds of the confidence intervals*

Table 9. Univariate linear regression analysis for total medical cost in continuous value

	Standard Beta	Standard Beta SE	P value
Gender	−0.02	0.04	0.579
Age	0.13	0.04	0.002
T stage	0	0.04	0.933
N stage	0.01	0.04	0.752
AJCC 7th stage	−0.01	0.04	0.808
Tumor location	0.3	0.04	< 0.001
Smoking	−0.02	0.04	0.575
Drinking	0	0.04	0.909
Education	0.07	0.04	0.112
Admission route	0.27	0.04	< 0.001
ASA class	0.15	0.04	< 0.001
Obese by TAT area	0.09	0.04	0.044
Obese by VAT area	0.06	0.04	0.134
Obese by BMI area	0.07	0.04	0.122

† *SE, standard error*

Table 10. Multivariate linear regression analysis for total medical cost in continuous value

	Standard Beta	Standard Beta SE	P value
Obese by TAT area	0.08	0.04	0.046
Obese by VAT area	0.05	0.04	0.232
Obese by BMI area	0.03	0.04	0.465

* *Adjusted for Age, Tumor location, Education, Admission route, ASA class*

† *SE, standard error*

Multivariate linear regression analysis for subdivided medical cost according to TAT area

TAT area was significantly associated with total medical cost (p=0.046) in multivariate analysis. Therefore, subgroup analysis was performed with detailed medical cost subdivided into 8 independent components: Anesthesia, laboratory test, operation/consultation, radiology test, room, medication, surgical supplies and blood (Table 11). The operation/consultation cost includes charges for consultation, physical examination and an operation. In multivariate analysis for subdivided medical cost according to TAT area, higher total medical cost, notably the higher operation/consultation cost was significantly associated with obesity (p=0.046, p=0.003, respectively).

Comprehensive prediction model for total medical cost

We created a comprehensive prediction model for total medical cost with TAT area and other risk factors with AUC. Each model is comprised of the combination of risk factors and AUC value is increasing as the TAT area component is added (Table 12). Therefore, we can confirm that TAT area affects the total medical cost by this prediction model.

Table 11. Multivariate linear regression analysis for subdivided medical cost according to TAT area

	Standard Beta	Standard Beta SE	P value
Total medical cost	0.08	0.04	0.046
Anesthesia	0.05	0.04	0.212
Laboratory test	0.02	0.04	0.66
Operation/consultation	0.11	0.04	0.003
Radiology test	0.02	0.04	0.605
Room	0.12	0.04	0.38
Medication	0	0.04	0.936
Surgical supplies	0.06	0.03	0.084
Blood	0.05	0.04	0.247

** Adjusted for Age, Tumor location, Education, Admission route, ASA class*

*** SE, standard error*

Table 12. Comprehensive prediction model for total medical cost

	Model A	Model B	Model C
Area under the curve	0.635	0.796	0.813

**Model A: Adjusted for Age, Tumor location*

†Model B: Model A plus Education, Admission route, ASA class

‡Model C: Model B plus Obesity by TAT area

Discussion

Obesity is one of the fastest growing and most prevalent major comorbidities that surgeons encounter. Most of the surgeons would have experienced difficulties in surgery with obese patients beginning with preoperative risk evaluation associated with comorbid diseases. The annual medical burden of obesity has increased from 6.5 percent to 9.1 percent based on the National Health Expenditure Accounts estimate [6] and Mason, R.J and colleagues analyzed that annual national hospital expenditures for the surgical procedures is an estimated $160 million higher in obese patients [18]. Obese patients utilized significantly more hospital resources than non-obese patients. However, the literature on the effect of obesity on outcomes following general and colorectal surgery is less clear cut. Interestingly, several studies on morbidity following general and colorectal procedures have failed to show any effect of obesity on outcomes [19-23]. Radical prostatectomy has been shown to be more expensive in obese patients [24, 25] and operating costs were higher for morbidly obese patients undergoing total hip arthroplasty [19]. Kremers, H.M et al. have reported that obesity is associated with longer hospital stays and costs in large cohort who underwent total knee arthroplasty.

The effect of obesity on costs was associated with higher hospitalization costs through obesity-related comorbid conditions [26]. There are only a few reports on the effect of BMI on costs of surgical procedures. It was reported that morbidly obese patients produced higher costs after cardiac surgery, as they required longer intensive care unit stays [27]. By contrast, one recent study including over 6000 patients who underwent surgery for various reasons found no difference in the incidence and severity of complications [23]. In our data, obese patients had significantly higher incidence of diabetes and hypertension, furthermore, longer anesthesia time and operative time and a higher number of surgical gauze use were identified. Hawn et al. reported longer operative times for a variety of general surgical procedures, including mastectomy, cholecystectomy and colectomy, in obese than in non-obese patients [28]. Length of stay is often a major determinant in overall inpatient medical costs [29, 30]. In literature, increased length of stay was associated with obesity, however, on the contrary in this study there was no association between obesity and length of stay. In our hospital, Enhanced recovery after surgery (ERAS) protocols is applied to most patients undergoing colorectal surgery since 2004. It might serve as an important factor affecting the length of hospital stay.

We analyzed the clinical characteristics and postoperative outcomes of colorectal cancer patients according to the obesity indices. Tapper, R., et al. reported that colorectal surgery for obese patients cost 36 % more to treat than that for patients of normal weight [8]. Conversely, there are several studies which failed to show any effect of obesity on morbidity [19-23]. Although there are WHO cut-off points for obesity, the WHO expert consultation concluded that Asians generally have a higher percentage of body fat than white people, additional cut-off points for Asian population were identified in 2004 [31]. In this study, we defined obesity with the cutoff value calculated with our data using ROC curve and AUC of three obesity indices and the cutoff value for BMI was same as Asian-Pacific BMI classification: 25kg/m2. Contrary to our hypothesis that obese patients would have a higher chance of ICU admissions and longer ICU stay, there was no differences compared to normal weight patients in this study. Neither, there were no differences in 30-day complications or overall mortality. We presumed it could be related to insufficient number of obese patients.

In the results from our study, TAT area was significantly associated with total medical cost. In multivariate analysis, the operation/consultation cost significantly associated with TAT (p=0.046, p=0.003, respectively). The operation/consultation cost includes charges for preoperative and postoperative consultations, physical examination and an operation, and higher operation/consultation cost implying agreement with the literature that obese patients utilized significantly more hospital resources [18]. The surgical supplies was not statistically significant but showed some influence on higher cost (p=0.084).

Our study has inherent limitations of a retrospectively designed study. Time required for each operative steps were not recorded routinely and only total operative time could be obtained through medical records review. Total operative time consist of each operative steps, usually start with placing the patient on the operating table and end with transfer the patient to the recovery room. Further studies are needed to find the association between main procedures time and obesity of the patients. In the same context of limitations of retrospective design, intraoperative blood loss was not measured accurately. The results of intraoperative blood loss did not show difference in the obese group is inconsistent with previous data which showed association between obesity and increased intraoperative blood loss. At our hospital, intraoperative blood loss is roughly counted by anesthesiologist with the scale drawn on the suction bottle therefore small units are not identifiable. We tried to reflect the actual amount of blood loss by the number of surgical gauze used during operation. Although, number of surgical gauze used is not actual amount blood loss, we assumed that is closer to the actual amount than estimated blood loss counted by suction bottle.

There are several other limitations. First, this study was conducted by a single experienced surgeon at a large volume center including obese patients, which might limit to apply the result of this study generally. Second, no laparoscopic surgery were included. Previously Bensalah.et al reported that no increase in complication rate in heavy patients for several minimally invasive laparoscopic procedure [32]. Our study included only open surgery, therefore we could not evaluate the outcome of laparoscopic surgery for obese patients including conversion to open rate. Third, the degree of obesity was lower. In our data, patient with highest BMI was 39.5 kg/m2 and there were no super obese patients which is defined as BMI over 40 kg/m2.

In conclusion, based on the present study, we found that increased TAT area but not BMI was associated with higher hospital costs (p=0.046) in colorectal cancer patients, especially associated with the higher operation/consultation cost which includes charges for consultation, physical examination and an operation (p=0.003).

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국문 초록

서론: 전세계적으로 비만의 유병률은 빠른 속도로 증가하고 있으며 비만 환자는 표준 체중을 가진 집단과 비교하여 더 많은 의료 자원 사용 및 더 큰 의료비용과 연관이 있는 것으로 밝혀져 있다. 비만은 많은 전신 질환의 잘 알려진 원인이며 대장암의 발병과 관련이 있지만, 대장암 환자에서 비만이 미치는 영향을 조사한 연구는 많지 않다. 이 연구의 목적은 대장암으로 수술을 받은 환자에서 비만이 진료비용 증가에 영향을 주는지에 대해 알아보는 것이다.

방법: 2004 년 10 월부터 2008 년 12 월까지 1-3 기 대장암으로 수술 받은 환자를 대상으로 병원 청구자료와 의무기록을 수집하여 후향적으로 비만과 진료비 간의 상관 관계를 분석하였다. 대상 환자들의 비만을 평가하기 위한 척도로 수술 전 신체질량 지수와 컴퓨터 단층 촬영을 통해 계산된 지방 조직 면적이 사용되었다.

결과: 총 656 명의 환자가 이 연구에서 분석되었고, 환자들의 평균 신체질량지수는 23.92 ± 2.912 kg / m2, 평균 총 지방 조직 면적은 249.57 ± 92.82 cm2 였으며 평균 내장 지방 조직 면적은 101.50 ± 56.57 cm2 이었다. 입원기간에 대해 청구된 평균 진료비용은 6,442,162.52 ± 2,480,435.78₩ 이었다. 우리는 절단값보다 높은 신체질량 지수 또는 지방 조직 면적을 보인 경우를 비만으로 정의했다. 각 비만 지표별 다변량 분석을 한 결과 총 지방 조직 면적 기준에 따른 비만 환자는 유의하게 높은 총 진료비 (p = 0.046)를 지불한 것으로 나타났다. 진료비를 세분화 하여 분석했을 때, 총 지방 조직 면적 기준에 따라 진료비 중 특히 수술료 및 검진료가 총 지방 조직 면적과 유의한 연관성을 보였다 (p=0.003).

결론: 총 지방조직 면적이 넓은 대장암 환자는 높은 진료비와 연관이 있었으나 (p=0.046), 신체질량지수는 진료비와 연관이 없었다. 특히, 진료비 중 수술료 및 검진료가 넓은 총 지방조직 면적과 연관을 보였다 (p=0.003).

주요어 : 비만, 신체질량지수, 지방, 병원비, 진료비, 대장암
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