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Body Mass Index (BMI) as a Prognostic Factor Influencing Outcomes of Gastric Cancer Resection Including Curative Gastrectomy

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Abstract

Background/Aim: This study evaluated the influence of the body mass index (BMI) on outcomes of gastric cancer resection, with a specific focus on curative gastrectomy.

Patients and Methods: A total of 756 patients who underwent gastric cancer resection, including 372 cases of curative gastrectomy, were analyzed. The impact of BMI on overall, systemic, and surgical complications, as well as on relaparotomy, perioperative mortality, and 5-year survival was examined.

Results: Underweight (BMI <18.5 kg/m^2), and obesity (BMI ≥30 kg/m^2) were identified as independent risk factors for overall complications (p<0.0001, and p<0.0001), systemic complications (p<0.0001, and p=0.001), and surgical complications (p<0.0001, and p=0.023) in all gastric cancer resections. Similar trends were observed for curative gastrectomy, where underweight and obese patients demonstrated more overall complications (p<0.0001, and p<0.0001), systemic complications (p<0.001, and p=0.0001), and surgical complications (p<0.0001, and p=0.0032). No differences in 5-year survival were observed among BMI categories in 372 cases of curative gastrectomy. However, being underweight was associated with a poorer 5-year survival in all 756 cases of gastric cancer resection (odds ratio=0.45, 95% confidence interval= 0.27-0.73, p=0.0016).

Conclusion: BMI significantly influences the outcomes of gastric cancer resection, with underweight and obese patients demonstrating higher complication rates. Underweight status is also linked to poorer long-term survival in the broader gastric cancer population but not in curative resection cases.

Keywords: Gastric cancer resection, prognostic factor, obesity, BMI.

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Introduction

There were nearly 1 million new cases of gastric cancer in 2022, and approximately 660,000 deaths, making it the fifth most common cancer worldwide in terms of both incidence and mortality. Alongside Eastern Asia, incidence rates of gastric cancer are the highest in Eastern Europe (1). In Poland, nearly 5,000 deaths from gastric cancer were reported annually in 2021, with a 5-year survival rate of 30% for patients (2, 3). It is well established that early diagnosis significantly improves the prognosis for gastric cancer patients. The standard treatment includes curative resection combined with routine pre- and postoperative chemotherapy and immunotherapy. Despite the administration of multimodal therapy, treatment results are still unsatisfactory, and new ways to improve survival for these patients are investigated (4-10).

In our recent study, we evaluated the influence of quite a large number of prognostic factors such as sex, age, tumor location, type of gastric cancer according to Lauren classification, stage of gastric cancer according to the TNM classification of the American Joint Committee on Cancer/Union for International Cancer Control (AJCC/UICC), type of gastrectomy, resection type, number of retrieved lymph nodes, and resection of an additional organ on outcomes of gastric cancer resection (4). However, obesity and its complications are among the most important public health challenges worldwide. By 2035, over 4 billion people are projected to be affected by overweight and obesity, compared to 2.6 billion in 2020. This represents an increase in prevalence from 38% of the global population in 2020 to over 50% by 2035. In Poland, according to data from the Central Statistical Office in 2019, 56.6% of people over 15 years of age were overweight (BMI ≥25 kg/m^2), and 18.5% of these people were obese (BMI ≥30 kg/m^2). According to estimates from the NCD Risk Factor Collaboration and Lobstein *et al.*, in Poland, between 2025 and 2035, 25-25.9% of women and 30.3-35% of men aged 20 and older are expected to be obese (11-13). For this reason, we expanded the analysis of prognostic factors determining the prognosis for patients with gastric cancer resection. In the present study, we examined the influence of being overweight (BMI 25-29.9 kg/m^2) and suffering from obesity (BMI ≥30 kg/m^2) on outcomes of gastric cancer resection. In addition, we also evaluated the impact of being underweight (BMI <18.5 kg/m^2) on overall, systemic, and surgical complications as well as on relaparotomy, perioperative mortality, and 5-year survival. Furthermore, we evaluated the effect of BMI separately for all cases of gastrectomy and for cases of curative gastrectomy.

Patients and Methods

Patient cohort. We gathered 784 patients who had gastric cancer resections at the First Department of Surgery, Jagiellonian University Medical College in Krakow in the years 2007-2017. From the patient database, we collected information about their weight and height in 756 cases. As a result, 756 of 784 patients with gastric cancer resection were finally included in the study. Their clinicopathologic features and surgical characteristics were gathered. For the histologic evaluation of tumors, the Lauren classification was used (14). The gastric cancer stages were assessed according to the 8th edition of the TNM staging system by the American Joint Committee on Cancer/Union for International Cancer Control (AJCC/UICC) (15).

Gastric cancer resection and treatment were carried out according to the Polish Consensus on Gastric Cancer Diagnosis and Treatment - Update 2022 (16). However, conventional laparotomy was performed in all patients included in the study. Of the 756 cases, 372 involved curative gastrectomy. Multimodal treatment, including routine administration of pre- and postoperative chemotherapeutic regimens (5-fluorouracil, leucovorin, cisplatin, oxaliplatin, irinotecan, etoposide, doxorubicin and docetaxel).

BMI as a prognostic factor. Body mass index (BMI) measures the ratio of height to weight to estimate body fat. BMI is calculated by dividing weight in kilograms (kg) by the square of height in meters (m^2). According to most sources, BMI is categorized into four main weight groups: underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2),

overweight (25-29.9 kg/m^2), and obese (≥30 kg/m^2). In this study, all patients were classified into these BMI categories. Additionally, the BMI categories were analyzed separately for patients who underwent curative gastrectomy (11-13, 17, 18).

Follow-up. A routine follow-up every 3-6 months was used for all patients, if necessary, in shorter intervals. After discharge, information on the dates of death was obtained from the census registry office. All treatment outcome parameters were recorded in the patient database. Some patients experienced more than one systemic or surgical complication; in some cases, both systemic and surgical complications occurred in the same patient. Perioperative death was defined as any death occurring during the hospital stay following gastrectomy. We analyzed the impact of BMI on overall complications, systemic complications, surgical complications, relaparotomy, perioperative mortality, as well 5-year survival for all cases of gastric cancer resection and separately for cases of curative gastrectomy.

Statistical methods. To analyze the relationship between groups of patients with different BMI categories (BMI <18.5 kg/m^2, BMI 18.5-24.9 kg/m^2, BMI 25-29.9 kg/m^2, and BMI ≥30 kg/m^2) and the outcomes of treatment a multivariate logistic regression model was applied. The analysis included all patients who underwent gastric cancer resection (756 patients) and, separately, those who underwent curative gastric cancer resection (372 patients). In the logistic regression model, both treatment outcomes and predictors were presented in binary form. A p-value of ≤0.05 was considered statistically significant.

The statistical calculations were performed using the STATISTICA v. 13 software (StatSoft Polska, Krakow, Poland) and StatsDirect v. 3.3.4 software (StatsDirect Ltd, Wirral, UK).

Results

Clinicopathologic features and surgical characteristics. The database of 756 patients included 502 (66.4%) males and 254 (33.6%) females. Among patients who underwent curative resection, there were 240 (65.5%) males and 132 (35.5%) females. Patients aged over 70 years accounted for 32.4% of all gastric cancer resection cases and 35.2% of the 372 patients who underwent curative resection. The most common tumor location in the whole cohort was in the upper third part of the stomach [246 patients (32.5%)], compared to the middle third part of the stomach [214 patients (28.3%)], and the lower third part of the stomach [162 patients (21.4%)]. In those who underwent curative resection, the upper third part of the stomach was the most common location of the tumor (31.8%). The proportions of intestinal and diffuse types, according to the Lauren classification, were comparable: 44.7% *versus* 42.6% in all gastric resections and 46.5% *versus* 41.7% in curative resections. The advancement of gastric cancer patients, based on the eighth edition of the TNM (AJCC/UICC) classification, is summarized in Table I. Among the 756 patients who underwent gastric cancer resection, distant metastasis (M0 stage) was not observed in 460 cases (60.8%). However, among the 372 patients who underwent curative gastric cancer resection, there was significantly less advancement in T stage, N stage, and M stage according to the TNM classification (Table I).

The most common type of surgery was total gastrectomy, performed in 564 (74.6%) of 756 patients. The incidence of total/subtotal distal/subtotal proximal gastrectomy was 564 (74.6%), 148 (19.6%) and 44 (5.8%), respectively. Among the curative resection cases, the proportion of total/subtotal distal/subtotal proximal gastrectomy was 252 (67.8%), 98 (26.3%), and 22 (5.9%), with total gastrectomy remaining the most common procedure in these patients. Notably, the proportion of subtotal distal gastrectomy was higher in curative resections 26.3% compared to all gastric resections (19.6%) (Table I).

In 626 (82.8%) cases of the 756 gastric cancer resections, and in 312 cases (83.9%) of the 372 curative gastrectomies, the number of retrieved lymph nodes was >15. The incidence of resection of an additional organ was higher in all gastric cancer resections (21.4%) compared

to curative gastrectomies – (16.7%). The spleen was the most commonly resected additional organ both in all gastric resections [78 (10.3%)] and in curative resections [20 (5.4%)]. In the entire cohort of patients who underwent gastric cancer resection, the proportion of curative gastrectomies to non-curative gastrectomies was 372 (49.2%) and 384 (50.8%), respectively (Table I).

Potential prognostic factor – BMI. The most common BMI category was normal weight (BMI 18.5-24.9 kg/m^2) both in all patients with gastric cancer resection – 291 (38.5%) of 765 cases, and those with curative gastrectomy - 154 (41.4%) of 372 cases. The incidence of the following categories of BMI in the 756 patients with gastric cancer resection, *i.e.*, underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5-24.9 kg/m^2), overweight (BMI 25-29.9 kg/m^2), and obese (BMI ≥30 kg/m^2) was 94 (12.4%), 291 (38.5%), 204 (27%), and 167 (22.1%), respectively. Similarly, among the 372 patients with curative resection, the BMI distribution was underweight (BMI <18.5 kg/m^2) in 28 cases (7.5%), normal weight (BMI 18.5-24.9 kg/m^2) in 154 cases (41.4%), overweight (BMI 25-29.9 kg/m^2) in 101 cases (27.2%), and obese (BMI ≥30 kg/m^2) in 89 cases (23.9%) (Table II).

Outcomes of treatment. The incidence of overall complications was 158 (20.9%) in all gastric cancer resection cases. Systemic complications occurred in 97 of 756 patients (12.8%), with the most common being respiratory failure 39 (5.2%), pneumonia 38 (5.0%), and renal failure 27 (3.6%). Surgical complications were observed in 93 patients (12.3%), with the most common being abdominal fluid collections [78 (10.3%)], wound infection [54 (7.1%)], intra-abdominal abscess – [32 (4.2%)], and anastomotic leak [31(4.1%)]. Relaparotomy and perioperative mortality occurred in 42 (5.6%), and 28 (3.7%) cases, respectively. The 5-year survival rate in all 765 cases of gastric cancer resection was 39.1%.

Compared to all gastric resection patients, the 372 cases of curative gastrectomy had a significantly lower incidence of overall complications (45, 12.1%), systemic

Table I. *Clinicopathologic and surgical characteristics of patients.*

Patient cohort	All gastric cancer resection (n=756)	Curative resection (n=372)
Clinicopathologic features	n (%)	n (%)
Sex		
Male	502 (66.4%)	240 (65.5%)
Female	254 (33.6%)	132 (35.5%)
Age, years		
≤70	511 (67.6%)	241 (64.8%)
>70	245 (32.4%)	131 (35.2%)
Location		
Upper	246 (32.5%)	118 (31.8%)
Middle	214 (28.3%)	111 (29.8%)
Lower	162 (21.4%	99 (26,6%)
Other	134 (17.7%)	44 (11.8%)
Lauren type		
Diffuse	322 (42.6%)	155 (41.7%)
Intestinal	339 (44.7%)	173 (46.5%)
Mixed	95 (12.7%)	44 (11.8%)
T stage (eight edition AJCC/UICC)		
T1a	38 (5.0%)	37 (9.9%)
T1b	45 (6.0%)	41 (11.0%)
T2	126 (16.7%)	102 (27.4%)
T3	187 (24.7%)	136 (36.6%)
T4a	114 (15.1%)	29 (7.8%)
T4b	246 (32.5%)	27 (7.3%)
N stage (eight edition AJCC/UICC)		
N0	116 (15.3%)	111 (29.8%)
N1	121 (16.0%)	107 (28.8%)
N2	135 (17.9%)	90 (24.2%)
N3a	94 (12.4%)	28 (7.5%)
N3b	290 (38.4%)	36 (9.7%)
M stage (eight edition AJCC/UICC)		
M0	460 (60.8%)	363 (97.6%)
M1	296 (39.2%)	9 (2.4%)
Surgical characteristics	n (%)	n (%)
Type of gastrectomy		
Total	564 (74.6%)	252 (67.8%)
Subtotal distal	148 (19.6%)	98 (26.3%)
Subtotal proximal	44 (5.8%)	22 (5.9%)
Number of retrieved lymph nodes		
≤15	130 (17.2%)	60 (16.1%)
>15	626 (82.8%)	312 (83.9%)
Resection of an additional organ		
None	594 (78.6%)	310 (83.3%)
Spleen	78 (10.3%)	20 (5.4%)
Bowel	22 (2.9%)	14 (3.8%)
Esophagus	17 (2.2%)	11 (2.9%)
Pancreas	6 (0.8%)	2 (0.5%)
Spleen, bowel	7 (0.9%)	3 (0.8%)
Spleen, pancreas	13 (1.7%)	3 (0.8%)
Other	19 (2.5%)	9 (2.4%)
Curative resection		
Yes	372 (49.2%)	
No	384 (50.8%)	

complications (19, 5.1%), and surgical complications (30, 8.1%). In the patients with curative resection, the most common systemic complication was pneumonia (13, 3.5%), while the most common surgical complication was abdominal fluid collections (22, 5.9%). The rates of relaparotomy (10 cases, 2.7%) and perioperative mortality (1 case, 0.3%) were significantly lower compared to all 756 cases of gastrectomy. Furthermore, the 5-year survival rate among patients who underwent curative gastric cancer resection was 76.9% (Table III).

Statistical analysis. To assess BMI as a potential prognostic factor for gastric cancer resection, we examined its influence on the outcomes of treatment separately for all patients who underwent gastric cancer resection (n=765) and for those who underwent curative gastric cancer resection (n=372), using a logistic regression model.

The impact of BMI on outcomes in gastric cancer resection. The multivariate analysis revealed both underweight (BMI <18.5 kg/m^2), and obesity (BMI ≥30 kg/m^2) as independent risk factors of overall complications. Underweight patients had an odds ratio (OR) of 4.23 [95% confidence interval (CI)=2.69-6.65, p<0.0001], while obese patients had an OR of 2.53 (95%CI=1.72-3.72, p<0.0001) (Table IV). Further analysis revealed that underweight (OR=3.9, 95%CI=2.35-6.45, p<0.0001) and obesity (OR=2.15, 95%CI=1.4-3.4, p=0.001) were significant risk factors for systemic complications. Similarly, underweight (OR=5.1, 95%CI=3.1-8.4, p<0.0001) and obesity (OR=1.74, 95%CI=1.08-2.8, p=0.023) were significant risk factors for surgical complications (Table IV).

Underweight was identified as an independent prognostic factor associated with a higher risk of relaparotomy (OR=12.33, 95%Cl=6.35-23.7, p<0.0001) and perioperative mortality (OR=18.4, 95%Cl=8.03-42.1, p<0.0001) (Table IV). In all gastric cancer resection cases, underweight patients were the only group with a statistically significant poorer chance of 5-year survival compared to other BMI categories, including normal weight (BMI 18.5-24.9 kg/m^2), overweight (BMI 25-29.9 kg/m^2), and obese (BMI ≥30 kg/m^2) (OR=0.45, 95%Cl=0.27-0.73, p=0.0016) (Table V).

Table II. *BMI distribution among patients.*

BMI (kg/m^2)	All gastric cancer resection (n=756)	Curative resection (n=372)
	n (%)	n (%)
<18.5	94 (12.4%)	28 (7.5%)
18.5-24.9	291 (38.5%)	154 (41.4%)
25.0-29.9	204 (27%)	101 (27.2%)
≥30	167 (22.1%)	89 (23.9%)

Table III. *Treatment outcomes.*

Parameter	All gastric cancer resection (n=756)	Curative resection (n=372)
	n (%)	n (%)
Overall complications	158 (20.9%)	45 (12.1%)
Systemic complications	97 (12.8%)	19 (5.1%)
Respiratory failure	39 (5.2%)	12 (3.2%)
Pneumonia	38 (5.0%)	13 (3.5%)
Renal failure	27 (3.6%)	6 (1.6%)
Cardiocirculatory failure	25 (3.3%)	5 (1.3%)
Sepsis	21 (2.8%)	5 (1.3%)
Urinary infection	20 (2.6%)	7 (1.9%)
Liver failure	6 (0.8%)	2 (0.5%)
Other	25 (3.3%)	10 (2.7%)
Surgical complications	93 (12.3%)	30 (8.1%)
Abdominal fluid collections	78 (10.3%)	22 (5.9%)
Wound infection	54 (7.1%)	14 (3.8%)
Intra-abdominal abscess	32 (4.2%)	10 (2.7%)
Anastomotic leak	31 (4.1%)	9 (2.4%)
Pancreatic fistula	30 (3.9%)	8 (2.1%)
Mechanical Ileus	12 (1.6%)	4 (1.1%)
Abdominal/gastrointestinal bleeding	5 (0.7%)	3 (0.8%)
Other	22 (2.9%)	9 (2.4%)
Relaparotomy	42 (5.6%)	10 (2.7%)
Perioperative mortality	28 (3.7%)	1 (0.3%)
5-year survival	300 (39.7%)	286 (76.9%)

The impact of BMI index on outcomes in curative gastric cancer resection cases. In the 372 patients with curative gastric cancer resection, being underweight and obese were independent risk factors of overall complications (OR=4.34, 95%Cl=2.75-6.66, p<0.0001; OR=3.02, 95%Cl= 1.56-3.9,

Table IV. *Logistic regression analysis for complications in gastric cancer resection (n=756).*

Prognostic factors	OR	95%CI	Coefficient	*p*-Value
Overall complications (Intercept)	n/a		–1.57	<0.0001
BMI <18.5	4.23	(2.69 to 6.65)	1.44	<0.0001
BMI 18.5-24.9	0.23	(0.15 to 0.37)	–0.44	0.079
BMI 25-29.9	0.63	(0.41 to 0.96)	–0.46	0.063
BMI ≥30	2.53	(1.72 to 3.72)	0.93	<0.0001
Systemic complications (Intercept)	n/a		–2.17	<0.0001
BMI <18.5	3.9	(2.35 to 6.45)	1.36	<0.0001
BMI 18.5-24.9	0.17	(0.09 to 0.33)	–0.75	0.675
BMI 25-29.9	0.82	(0.5 to 1.35)	–0.2	0.437
BMI ≥30	2.15	(1.4 to 3.4)	1.37	0.001
Surgical complications (Intercept)	n/a		–2.28	<0.0001
BMI <18.5	5.1	(3.1 to 8.4)	1.63	<0.0001
BMI 18.5-24.9	0.27	(0.15 to 0.48)	–0.31	0.876
BMI 25-29.9	0.57	(0.33 to 0.98)	–0.56	0.645
BMI ≥30	1.74	(1.08 to 2.8)	0.95	0.023
Relaparotomy (Intercept)	n/a		–14.97	<0.0001
BMI <18.5	12.3	(6.35 to 23.7)	2.5	<0.0001
BMI 18.5-24.9	0.15	(0.05 to 0.44)	–0.85	0.079
BMI 25-29.9	0.42	(0.18 to 1.05)	–0.83	0.063
BMI ≥30	0.81	(0.37to 1.82)	–0.19	0.639
Perioperative mortality (Intercept)	n/a		–15.4	<0.0001
BMI <18.5	18.4	(8.03 to 42.1)	3.91	<0.0001
BMI 18.5-24.9	0.25	(0.09 to 0.74)	–0.76	0.092
BMI 25-29.9	0.44	(0.15 to 1.28)	–0.82	0.133
BMI ≥30	0.12	(0.01 to 0.93)	–0.58	0.084

BMI (kg/m^2); OR: Odds ratio; CI: confidence interval.

Table V. *Logistic regression analysis for 5-year survival in gastric cancer resection (n=756).*

Prognostic factors	OR	95%CI	Coefficient	*p*-Value
(Intercept)	n/a		–9.22	<0.0001
BMI <18.5	0.45	(0.27 to 0,73)	–1.39	0.0016
BMI 18.5-24.9	1.08	(0.8 to 1.46)	0.08	0.596
BMI 25-29.9	1.09	(0.78 to 1.5)	0.08	0.609
BMI ≥30	1.25	(0.88 to 1.78)	0.23	0.201

BMI (kg/m^2); OR: Odds ratio; CI: confidence interval.

p<0.0001), systemic complications (OR=3.8, 95%Cl=2.37-6.4, *p*<0.0001; OR=2.25, 95%Cl=1.46-3.4, *p*=0.0001), and surgical complications (OR=4.92, 95%Cl=2.08-8.4, *p*<0.0001; OR=2.15, 95%Cl=1.7-2.9, *p*=0.0032) (Table VI). As demonstrated in the statistical analysis, the influence of BMI on overall complications, systemic complications, and surgical complications in patients undergoing curative gastrectomy was significant and comparable to that observed in all 756 cases of gastric cancer resection. However, in patients with curative gastric cancer resection, the rates of rela-parotomy and perioperative mortality were not statistically significantly different across the analyzed BMI categories (underweight, normal weight, overweight, and obese) (Table VI).

In contrast to the findings for all 756 gastric cancer resections, where underweight was found to be an

Table VI. *Logistic regression analysis for complications in curative resection (n=372).*

Prognostic factors	OR	95%CI	Coefficient	*p*-Value
Overall complications (Intercept)	n/a		–3.25	<0.0001
BMI <18.5	4.34	(2.75 to 6.66)	1.54	<0.0001
BMI 18.5-24.9	0.23	(0.15 to 0.37)	–0.66	0.089
BMI 25-29.9	0.63	(0.41 to 0.96)	–0.55	0.091
BMI ≥30	3.02	(1.56 to 3.9)	0.89	<0.0001
Systemic complications (Intercept)	n/a		–2.16	<0.0001
BMI <18.5	3.8	(2.37 to 6.4)	1.37	<0.0001
BMI 18.5-24.9	0.18	(0.09 to 0.35)	–0.75	0.957
BMI 25-29.9	0.83	(0.5 to 1.35)	–0.19	0.437
BMI ≥30	2.25	(1.46 to 3.4)	0.76	0.0001
Surgical complications (Intercept)	n/a		–17.02	<0.0001
BMI <18.5	4.92	(2.08 to 8.4)	2.52	<0.0001
BMI 18.5-24.9	0.16	(0.16 to 0.56)	–0.41	0.294
BMI 25-29.9	0.44	(0.23 to 0.99)	–0.58	0.386
BMI ≥30	2.15	(1.7 to 2.9)	0.55	0.003
Relaparotomy (Intercept)	n/a		–14.97	<0.0001
BMI <18.5	1.0	(0.81 to 1.39)	0.082	0.590
BMI 18.5-24.9	0.16	(0.05 to 0.54)	–0.84	0.078
BMI 25-29.9	0.43	(0.18 to 1.047)	–0.83	0.063
BMI ≥30	0.83	(0.33 to 1.91)	–0.19	0.639
Perioperative mortality (Intercept)	n/a		–12.7	<0.0001
BMI <18.5	0.44	(0.26 to 0.76)	0.81	0.289
BMI 18.5-24.9	0.24	(0.08 to 0.85)	–0.36	0.192
BMI 25-29.9	0.42	(0.13 to 1.28)	–0.81	0.263
BMI ≥30	0.13	(0.02 to 0.97)	–0.68	0.143

BMI (kg/m^2); OR: Odds ratio; CI: confidence interval.

Table VII. *Logistic regression analysis for 5-year survival in curative resection (n=372).*

Prognostic factors	OR	95%CI	Coefficient	*p*-Value
(Intercept)	n/a		–4.18	<0.0001
BMI <18.5	0.55	(0.27 to 0.74)	–0.79	0.162
BMI 18.5-24.9	1.08	(0.8 to 1.46)	0.082	0.590
BMI 25-29.9	1.09	(0.78 to 1.51)	0.08	0.609
BMI ≥30	1.25	(0.88 to 1.78)	0.23	0.201

BMI (kg/m^2); OR: Odds ratio; CI: confidence interval.

independent prognostic factor influencing 5-year survival (p=0.0016), the 5-year survival in patients undergoing curative gastrectomy did not differ statistically among the BMI categories (Table VII). To explore the probable reason for this discrepancy, we analyzed the incidence of distant metastasis (M1 stage, according to the TNM classification) in underweight patients (BMI <18.5 kg/m^2) for both all gastric cancer resections and curative gastrectomies. Among the 756 gastric cancer resection cases, 92 patients were categorized as underweight. Of these, 43 patients (46.7%) had no distant metastasis (M0 stage), while 49 patients (53.3%) had distant metastasis (M1 stage).

In the 372 cases of curative gastrectomy, 28 patients were categorized as underweight. In this group, the proportion of patients without distant metastasis (M0 stage) was significantly higher compared to those with

distant metastasis (M1 stage): 23 patients (82.1%) *versus* 5 patients (17.9%), respectively.

Discussion

Gastric cancer is a significant global health concern, with one million new cases diagnosed annually. Moreover, it accounts for one in every 13 deaths worldwide (1, 19). In Poland, the standardized mortality rate for gastric cancer in 2019 was 22/100,000 in men and 8/100,000 in women. Annually, nearly 5,000 deaths from gastric cancer are recorder (2, 3).

Overweight and obesity are significant global health issues, contributing to an increased risk of hypertension, type 2 diabetes, heart disease, and poor bone and joint health. They can also negatively affect reproduction and overall quality of life. Additionally, obesity increases the risk of developing certain cancers. Conversely, underweight is also associated with adverse health problems. The evaluation of underweight, overweight or obesity is made by measuring people's weight and height and calculating the BMI using the formula: weight (kg)/height (m^2) (11, 13, 17, 18, 20, 21). A literature review found several articles examining the impact of BMI on outcomes in patients with gastric cancer resection. These findings were comprehensively presented and compared with our conclusions at the end of this section.

Wu *et al.*, in a meta-analysis of 23 studies including 20,678 patients, evaluated the outcomes after gastric cancer resection in 15,781 cases with BMI <25 kg/m^2, and 4,897 cases with BMI ≥25 kg/m^2. Overweight patients had a significantly increased incidence of surgical complications (RR=0.75, 95%CI=0.66-0.85, p<0.00001), including anastomosis leakages (RR=0.59, 95%CI=0.42-0.82, p=0.002), and pancreatic fistulas (RR=0.486, 95%CI=0.34-0.63, p<0.00001). Additionally, overweight patients had poorer long-term survival (RR=1.14, 95%CI=1.07-1.20, p<0.0001) (22). In another meta-analysis, Tsekrekos *et al.* examined the impact of obesity (defined as BMI ≥30 kg/m^2) on outcomes after gastrectomy for gastric cancer. The analysis included 11 studies with a total of 13,538 patients. Obesity was associated with an increased risk of overall complications (RR=1.23, 95%CI=1.06-1.42, p=0.005) and pulmonary complications (RR=3.81, 95%CI=2.24-6.46, p<0.001). Tsekrekos *et al.* did not find statistically significant differences in surgical complications, perioperative mortality, and 5-year survival (23). In a separate study, Muduly *et al.* investigated the influence of preoperative BMI on short-term, and long-term survival outcomes in patients who underwent curative resection for gastric cancer in India. They found that postoperative complications and perioperative mortality were similar. Overweight/obese patients showed significantly better 4-year overall survival compared to underweight patients (47.8% *vs.* 20.4%, p=0.03), whereas was no statistically significant differences in overall survival were observed between normal-weight patients and overweight/obese patients (24).

In the United States, obesity (BMI>30 kg/m^2) is a major health problem, affecting approximately 40% of adults. A report by Bickenbach *et al.* analyzed treatment outcomes of gastric cancer patients who underwent curative resection over a twenty-year period, separating the patients into overweight and non-overweight groups. An overweight status (BMI ≥25 kg/m^2) was associated with a higher rate of postoperative complications (47.9 *vs.* 35.8%, p<0.001), primarily due to an increased incidence of wound infections (8.9 *vs.* 4.7%, p=0.02) and anastomotic leaks (11.8 *vs.* 5.4%, p=0.002). However, no difference in overall survival was observed between the two groups (25). In a separate study from the United States, involving a similar group of patients who underwent curative gastrectomy for gastric cancer between 2000 and 2018, the impact of obesity on response to neoadjuvant chemotherapy was also analyzed. Overall complications were more frequent among obese patients (44.3% for obese *vs.* 24.9% for normal BMI, p<0.001), with intraabdominal infections also being more common in obese patients (13.9% for obese *vs.* 4.7% for normal BMI, p=0.001). In the primary gastric cancer resection cohort without neoadjuvant chemotherapy, overall survival did not differ between patients with normal BMI, and those classified as obese. However,

among obese patients in the cohort receiving neoadjuvant chemotherapy, severe obesity was independently associated with poorer overall survival (HR=1.87, 95%CI=1.01-3.48, p=0.047) (26). In another study from the United States, Ejaz *et al.* analyzed patients undergoing gastric cancer resection and found no statistically significant impact of BMI on postoperative complications, perioperative hospital death, and overall survival (all p>0.05). However, underweight patients (BMI <18.5 kg/m^2) with low preoperative albumin levels had significantly poorer overall survival compared to patients with normal BMI. The study concluded that for patients undergoing gastric cancer resection, those with BMI <18.5 kg/m^2 and low albumin levels should have their nutritional status optimized both before and after gastrectomy (27).

Next, we analyzed reports from East Asia, where morbidity from gastric cancer is the most common. In a report from Wada *et al.*, the impact of BMI on outcomes was evaluated in Japanese patients who underwent gastric cancer resection. Underweight patients (BMI <18.5 kg/m^2) had more advanced disease than the other patients, and the overall survival was worse. While the survival rate of overweight patients (BMI ≥25 kg/m^2) was better than that of normal-weight patients, the difference was not statistically significant. A multivariate analysis of survival rates showed that being underweight was a significant risk factor for a poor prognosis (28). Moreover, in a study by Feng *et al.* from China, the influence of BMI on postoperative complications and prognosis of gastric cancer resectable patients was also examined, and the results were similar to those reported by Wada *et al.* The study included 107 underweight patients (8.9%), 862 patients with normal weight (71.2%), and 241 patients who were overweight (19.95%). Multivariate analysis revealed that BMI was an independent prognostic factor. The overall survival of underweight patients (BMI <18.5 kg/m^2) was significantly poorer than patients with normal weight (p<0.05) or overweight (p<0.05); however, overall survival was comparable between patients who had a normal weight and those who were overweight (p>0.05) (29). Another report from Asia, specifically Korea, showed the lowest all-cause mortality risk at a BMI of 26.67 kg/m^2 in patients with curative gastric cancer resection. The study concluded that compared to normal-weight patients, underweight patients had poorer overall survival (HR=1.42, 95%CI=1.15-1.77), while overweight patients (BMI 25-29.9 kg/m^2) had better overall survival (HR=0.77, 95%CI=0.59-1.01). Obesity, in the study by Lee *et al.* was not a statistically significant risk factor for overall survival in patients with curative gastric cancer resection (30).

Struecker *et al.* presented a study from Western Europe with an analysis of the impact of obesity on outcomes after resection for gastric cancer. Postoperative outcomes and long-term survival were compared between patients with a BMI <30 kg/m^2 and those with a BMI ≥30 kg/m^2. Resection for gastric cancer in obese patients was significantly associated with increased postoperative complications (49 *vs.* 33%, p=0.037), and increased postoperative mortality (10 *vs.* 3%, p=0.028). However, there was no significant difference in overall survival between patients with BMI <30 kg/m^2 and patients with BMI ≥30 kg/m^2 (the 5-year survival rate: 62 *vs.* 59%, p=0.587) (31).

In our study, we analyzed the impact of BMI on outcomes in gastric cancer patients, presenting the findings separately for all cases of gastric cancer resection and for cases of curative gastrectomy. This approach offers a novel perspective, allowing for a more detailed and nuanced analysis.

Firstly, in the study we analyzed the impact of BMI on postoperative complications in patients with gastric cancer resection, including those who underwent curative gastrectomy. In the studies by Muduly *et al.* (24) and Ejaz *et al.* (27), BMI was not found to have a statistically significant influence on postoperative complications in patients undergoing gastric cancer resection. In the meta-analysis Tsekrekos *et al.*, obesity was associated with an increased risk of overall complications (OR=1.23, 95%CI=1.06-1.42, p=0.005) and pulmonary complications (OR=3.81, 95%CI=2.24-6.46, p<0.001), but no statistical difference in surgical complications was observed (23).

However, in our study, both underweight and obese patients were statistically significantly associated with increased rates of overall complications, systemic complications and surgical complications compared to patients with normal-weight and overweight patients in all gastric cancer resections (n=765) and curative gastrectomy cases (n=372). Our conclusions about the impact of BMI on postoperative complications in patients undergoing gastric cancer resection align with most of the analyzed reports from the global literature. In the majority of discussed articles, obesity was identified as a statistically relevant prognostic factor for postoperative complications (23-26, 31). Therefore, maintaining a constant body weight within the normal range (BMI 18.5-24.9 kg/m^2) should be a basic recommendation to patients undergoing gastric cancer resection.

Next, in our study we analyzed the impact of BMI on the 5-year survival in patients with gastric cancer resection including those who underwent curative gastrectomy. In cases with gastric cancer resection (n=765), patients who were underweight had a lower chance of 5-year survival (p=0.0016). However, the 5-year survival rates for patients with normal weight, overweight, and obesity did not differ statistically. These conclusions are similar to those from the studies by Tsekrekos *et al.* (23), Ejaz *et al.* (27), Wada *et al.* (28), and Struecker *et al.* (31) regarding the influence of BMI on overall survival in gastric cancer resection patients. In the meta-analysis by Wu *et al.*, BMI ≥25 kg/m^{2}was identified as a prognostic factor of poorer long-term survival (OR=1.14, 95%CI=1.07-1.20, p<0.0001) (22).

Consistent with other reports, our analysis on curative gastric cancer resection did not reveal statistically significant differences in 5-year survival rates in patients with normal weight, overweight, and obesity (24-26, 29, 30). In the study by Nakauchi *et al.*, severe obesity in patients who underwent curative gastrectomy and received neoadjuvant chemotherapy was independently associated with poorer overall survival (p=0.047) (26).

However, in contrast to most reports, in our study, the group of underweight patients did not present with statistically poorer 5-year survival compared to patients with other BMI categories in curative gastric cancer resection; the BMI index was not an independent risk factor of 5-year survival for these patients (24, 29, 30).

Moreover, we analyzed why underweight patients had a statistically significantly poorer 5-year survival compared to other BMI categories in all gastric cancer resections, but not a statistically significant difference in 5-year survival in curative gastrectomy cases. To investigate further, we examined the proportion of underweight patients with distant metastasis in both surgical procedures. Among underweight patients, there were significantly more cases with distant metastasis in all gastric cancer resections (53.3%) compared to curative gastrectomy (17.9%). Ejaz *et al.* recommended optimizing the nutritional status of underweight patients both before and after gastric cancer resection to improve outcomes (27). We strongly agree with this recommendation. However, in our study, patients undergoing gastric cancer resection often presented with advanced stages of the disease, including distant metastasis (M1 stage, according to the TNM classification). Therefore, the most critical factor for improving their prognosis was achieving the earliest possible diagnosis and performing curative gastrectomy whenever feasible.

Study limitations. First, the study was a retrospective single-center project. Second, we examined the influence of a single prognostic factor on the outcomes of patients with gastric cancer resection. Third, in the logistic regression model, we assessed the impact of BMI on the total number of systemic and surgical complications; however, we did not analyze the influence of BMI on individual complications, such as pneumonia, respiratory failure, wound infection, or anastomotic leak. This limitation was due to an insufficient number of specific systemic and surgical complications to conduct a statistically valuable analysis. Fourth, the patient database spans the years 2007-2017, so the data could be more up-to-date. Fifth, all patients in the study

underwent conventional laparotomy, meaning newer surgical methods, such as laparoscopy or robotic surgery, were not utilized. However, in this case, this is not a disadvantage, as it allowed for a more homogeneous group of patients for analysis.

Conclusion

To assess BMI as a potential prognostic factor of gastric cancer resection, we examined its influence on outcomes of treatment for all patients undergoing gastric cancer resection (n=765), and separately for those who underwent curative gastrectomy (n=372).

For patients with underweight, and obesity compared to those with normal weight and overweight there were significantly higher rates of overall complications, systemic complications, and surgical complications in gastric cancer resections including cases of curative gastrectomy. Underweight patients had a significantly lower chance of 5-year survival after gastric cancer resection compared to patients with normal weight, overweight, and obesity. However, BMI was not a prognostic factor for 5-year survival in curative gastric cancer resection.

Conflicts of Interest

The Authors declare that they have no conflicts of interest in relation to this study.

Authors' Contributions

Oliwia Majewska – concept of the study, statistical analysis, database results analysis, reviewed articles for the discussion, writing the manuscript. Radosław Pach – database results analysis, critical review. Paweł Brzewski – statistical analysis, database results analysis. Jan Kulig – concept of the study, critical review. Piotr Kulig – concept of the study, collection and analysis of patients database, statistical analysis, database results analysis, reviewed articles for the discussion.

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