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Reverse total shoulder arthroplasty in patients of varying body mass index

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Background: Body mass index (BMI) is an independent predictor of complications after hip and knee arthroplasty. Whether similar trends apply to patients undergoing reverse total shoulder arthroplasty (RTSA) is unknown.

Methods: A retrospective review of primary RTSAs with a minimum 90-day follow-up were included. Complications were classified as major or minor and medical or surgical. Patients were classified into 3 groups: normal BMI (BMI <25 kg/m^2), overweight or mildly obese (BMI 25-35 kg/m^2), and moderately or severely obese (BMI >35 kg/m^2).

Results: Of the 119 patients met our inclusion criteria, 30 (25%) had a BMI of less than 25 kg/m^2; 65 (55%) had a BMI of 25 to 35 kg/m^2, and 24 (20%) had BMI exceeding 35 kg/m^2. Complications occurred in 30 patients (25%), comprising major in 11 (9%), minor in 19 (16%), surgical in 21 (18%), and medical in 14 (12%). The most common surgical complications were acute blood loss anemia requiring transfusion (8.4%) and dislocation (4.2%). The most common medical complications were atelectasis (2.5%) and acute renal insufficiency (2.5%). Patients with a BMI exceeding 35 kg/m^2 had a significantly higher overall complication rate ($P < .05$) and intraoperative blood loss ($P = .05$) than the other groups. Patients with BMI of less than 25 kg/m^2 had a greater overall complication rate than those with a BMI of 25 to 35 kg/m^2 ($P < .05$). Multivariate regression analysis demonstrated BMI was the only significant determinant of overall complication rates and medical complication rates ($P < .05$).

Conclusion: Patients with a BMI exceeding 35 kg/m^2 (severely obese) or a BMI of less than 25 kg/m^2 have higher rates of complication after RTSA.

Level of evidence: Level III, Retrospective Cohort Study, Treatment Study.

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Keywords: Complications; reverse total shoulder arthroplasty; medical; surgical; obesity

The reverse total shoulder arthroplasty (RTSA) was first introduced in the 1980s by Grammont to treat rotator cuff tear arthropathy. Multiple series have shown significant improvement in pain and function after RTSA[4,7,13,22-24,28] Despite its success, complication rates ranging from 25%

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to 50% have been reported. Intraoperative, perioperative, postoperative, surgical, and medical complications have all been reported. These include, but are not limited to, hematoma formation, instability, superficial and deep infection, periprosthetic fracture, acromial fracture, neurologic compromise, implant loosening, and medical complications.[2,6,8,11,22,26,27,30] Recent improvements in surgical techniques and implant design, however, have demonstrated lower overall complication and failure rates.[7]

Body mass index (BMI) has been shown to be an independent predictor of postoperative complications in patients undergoing joint replacement.[13,14] Obesity predisposes patients to medical comorbidities such as cardiovascular disease, stroke, pulmonary embolism, and diabetes. These conditions may also serve as independent predictors of perioperative and postoperative medical and surgical complications. Preoperative medical comorbidity rates have also been shown to predict postoperative complication rates in patients undergoing orthopedic procedures.[14,17,20,25]

Currently, there is a paucity of data describing the complications associated with RTSA in patients of varying BMIs. The purpose of the study was to analyze complication rates in the operative, perioperative, and early postoperative period in patients of varying BMIs undergoing RTSA. We hypothesized that BMI would serve as an independent risk factor for the development of early medical and surgical complications after RTSA.

Materials and methods

Patients who had undergone primary RTSA with a minimum 90-day postoperative follow-up were included. Indications for RTSA included rotator cuff tear arthropathy, massive irreparable rotator cuff tear with pseudoparalysis, end-stage glenohumeral arthritis with an irreparable rotator cuff tear, inflammatory cuff tear arthropathy, and proximal humeral malunion/nonunion with associated irreparable rotator cuff tear. Excluded were patients with previous shoulder arthroplasty, if RTSA was performed as a revision procedure for a failed prior arthroplasty (hemiarthroplasty or total shoulder arthroplasty), prior deep space infection requiring explantation, or if perioperative or operative records were incomplete.

The following data were recorded in Excel X (Microsoft Corp, Redmond, WA, USA): age, sex, BMI, laterality of the dominant extremity, laterality of the RTSA, indication for operative intervention, medical comorbidities, length of procedure in minutes, estimated intraoperative blood loss in milliliters measured by anesthesia and nursing, specific implants, concomitant procedures, and the need for intraoperative or postoperative transfusion. The operative reports and the intraoperative, perioperative inpatient, and postoperative outpatient records for each patient were reviewed in detail, and all noted complications were recorded. Our institution does not have a specific transfusion threshold, and the decision to transfuse was made case-by-case according to the clinical judgement and mutual agreement of the orthopedic and internal medicine teams.

The Charlson Comorbidity Index (CCI) is a validated predictive tool for complications in patients undergoing surgical procedures.[5] Specifically, it predicts the 10-year mortality of an individual based on his or her comorbid conditions, including heart disease, diabetes mellitus, and cancer. Each condition is assigned a point value of 1, 2, 3, or 6 according to the risk of death associated with the comorbidity. The higher this value, the higher the risk of death. Each patient's preoperative medical comorbidities were determined and used to calculate the CCI for planned multivariate regression analysis to determine the correlation between comorbidities and complications.

Complication classification

Complications were defined as any event that deviated from a normal postoperative course and were further classified as "major" or "minor" and "medical" or "surgical." Complications were categorized according a validated classification scheme described by Dindo et al[9]:

- Minor complication: any deviation from the normal postoperative course requiring pharmacologic treatment.
- Major complication: any deviation from the normal postoperative course requiring prolonged pharmacologic treatment or surgical intervention.
- Medical complications: systemic events such as pulmonary emboli, cardiac events, renal failure, and atelectasis, which was a combined clinical and radiographic diagnosis.
- Surgical complications: local events that stemmed from the surgical site such as need for transfusion, wound complications, periprosthetic fractures, and dislocations.

Statistical analysis

Analyses were performed in SPSS 18 software (IBM Inc, Armonk, NY, USA), and descriptive statistics were calculated. An a priori decision was made to divide patients into 3 groups by BMI (kg/m^2): group 1, normal BMI (BMI <25); group 2, BMI classified as overweight or "mildly obese" or class I (World Health Organization Classification) obesity (BMI 25-35), and group 3, BMI classified as moderately or severely obese or class II or greater obesity (BMI >35).[29] This decision was based on our anecdotal clinical experience, the mean and standard deviation BMI of the average patient undergoing TSA and RTSA in the senior authors' practice ($\sim$30.5), as well as evidence from the hip and knee arthroplasty literature suggesting complication rates may not be increased until severe obesity is reached.[17]

Kolmogorov-Smirnov analysis was performed on continuous variables and all variables that significantly differed from the normal distribution ($P < .05$). Thus Kruskal-Wallis tests were performed to compare continuous variables among the BMI groups. Statistical comparison of categoric variables was done using χ^2 tests.

Given concern that multiple variables may predict complication rates, multivariable logistic regression was planned for those variables that differed between our a priori defined BMI groups to determine whether these covariates or BMI served as the primary determinant of complication rates.

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Results

Demographics and intraoperative variables

Of 150 possible patients assessed, 31 were revisions from a prior failed arthroplasty, leaving 119 who met the inclusion criteria. Of the total cohort, 30 patients (25%) had a normal body mass (BMI <25 kg/m^2; Fig 1), 24 (20%) were moderately or severely obese (BMI >35 kg/m^2), and 65 (55%) were overweight or mildly obese (BMI 25-35 kg/m^2). The mean BMI was 29.6 ± 5.8 kg/m^2. Men and women were evenly distributed among BMI groups (P = .148). Rates of prior surgery were not significantly different among BMI groups (P = .789). Patients in group 3 (BMI >35 kg/m^2) tended to be significantly younger (P = .025), with a higher comorbidity burden (P = .009) than in groups 1 and 2.

Indications for RTSA were similar among BMI groups (P = .837). Patients in group 3 had longer operative times than groups 1 and 2, but this difference did not reach statistical significance (P = .104; Table I). Estimated blood loss significantly differed among BMI groups, with group 3 demonstrating the greatest mean intraoperative blood loss (P = .050). The transfusion rate was higher in group 3 than in groups 1 and 2, but this difference did not reach statistical significance. (P = .174).

Complication rates

Among the overall patient cohort, 30 (25%) sustained 1 or more complications (Table II), including 11 (9%) with a major complication and 19 (16%) with 1 or more minor complications, mostly in the perioperative (inpatient) and postoperative period. Twenty-one patients (18%) sustained a surgical complication, 14 (12%) experienced 1 or more medical complications, and 6 (5%) sustained a medical and surgical complication. The most common surgical complications were acute blood loss anemia requiring transfusion (8.4%) and dislocation (4.2%). Infections occurred in 0.8%. The most common medical complications were atelectasis (2.5%) and acute renal insufficiency (2.5%). No deaths occurred during the study period.

Complication rates differed significantly among BMI groups, with patients in groups 1 (BMI <25 kg/m^2) and 3 (BMI >35 kg/m^2) experiencing greater complication rates (P = .020). This significant difference held true when the group 1 and 2 cohorts were directly compared (P = .046). No significant difference was seen between groups 1 and 3 in complication rates (P = .529). No significant differences were seen between rates of major complications (P = .775), infection (P = .395), dislocation (P = .664), or death (>.99). Significantly more medical complications occurred in group 3 (P = .006). A trend toward increased rates of surgical complications was seen in patients in groups 1 and 3 compared with group 2 (P = .083). The mean CCI was significantly greater for group 3 (P = .009). Although medical complication rates significantly correlated with CCI (P = .011), rates for overall complications (P = .115), major complications (P = .695), and surgical complications (P = .983) did not.

A subgroup analysis for the patients with a BMI of less than 25 kg/m^2 showed among the patients with medical or surgical complications, or both, 6 had isolated hypertension (controlled on medication), 1 had diabetes mellitus and coronary artery disease (CAD), and 2 had isolated CAD. The remaining patients had no comorbidities (Table III).

No significant difference was found in hospital length of stay among BMI subgroups groups 1 (mean 2.4 ± 1.1, 2.3 ± 0.8, and 2.3 ± 0.9 days, respectively, for groups 1, 2, and 3; P = .15). No group 1 patients required admission to the intensive care unit (ICU). ICU admission was required immediately after surgery for 3 patients in group 2 and 2 patients in group 3. All ICU stays were for 1 night only except for 1 patient (BMI 39.6 kg/m^2) who required a 2-day stay in the ICU for postoperative cardiac monitoring owing to a history of paroxysmal ventricular tachycardia. Among the 5 patients admitted to the ICU, the total hospital length of stay ranged from 2 to 4 days (Table IV).

Multivariate regression analysis

Because age and the CCI differed significantly among the BMI groups (P = .009), multivariate logistic regression was performed to determine whether BMI, age, or CCI served as the primary determinant of the presence or absence of all complications, major complications, medical complications, and surgical complications. These analyses confirmed BMI was the only significant covariate with overall complication rates and medical complication rates, whereas no covariate reached significance for major complications or surgical complications (Table V).

Discussion

Surgical intervention on the obese population can be technically demanding. Obesity has been correlated with an increased complication rate in reports on hip and knee arthroplasty.[6,14,17,20,25] The purpose of this study was to determine if BMI correlates with complications after primary RTSA. Patients in our cohort with a BMI of less than 25 kg/m^2 or greater than 35 kg/m^2 had higher overall complication rates than those with a BMI of 25 to 35 kg/m^2. In addition, patients with a BMI greater than 35 kg/m^2 had significantly more blood loss intraoperatively and trended toward longer operations and more postoperative

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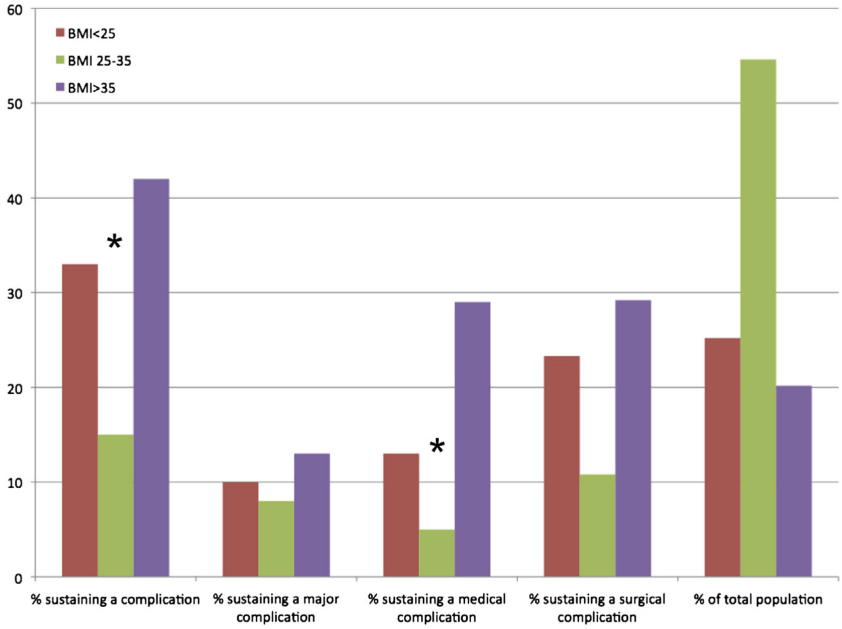

Figure 1 Patients were grouped according to body mass index (*BMI*) <25 kg/m^2 (*red bars*), BMI 25 to 35 kg/m^2 (*green bars*), and BMI >35 kg/m^2 (*purple bars*), with the graph showing the percentage of patients sustaining a complication, sustaining a major complication, sustaining a medical complication, sustaining a surgical complication, and the total population in that subgroup. *Indicates statistically significant differences.

Table I Demographic and intraoperative characteristics segregated by body mass index (*BMI*)

Variable	BMI <25 kg/m^2 (n = 30)	BMI 25-35 kg/m^2 (n = 65)	BMI >35 kg/m^2 (n = 24)	Total patients (n = 119)	*P* value
Age, mean ± SD y	75.7 ± 8.2	74.1 ± 9.8	68.4 ± 10.5	73.3 ± 9.8	.025
Female, %	73	57	75	64	.148
CCI, mean ± SD score	0.10 ± 0.31	0.28 ± 0.55	0.54 ± 0.66	0.29 ± 0.54	.009
Patients with prior shoulder surgery, %	23	23	16	22	.789
Indications, No.					.837
Cuff tear arthropathy	13	23	9	45	
Glenohumeral osteoarthritis with irreparable cuff tear	10	17	8	35	
Massive/irreparable cuff tear	3	12	4	19	
Sequelae of a proximal humeral fracture	3	6	3	12	
Inflammatory arthropathy, etc.	1	5	0	6	
Operative time, mean ± SD min	98 ± 41	96 ± 43	120 ± 29	101 ± 41	.104
Estimated blood loss, mean ± SD mL	261 ± 138	321 ± 161	386 ± 185	324 ± 166	.050
Patients requiring transfusion, % (No.)	3.3 (1)	3.1 (2)	12.5 (3)	5.0 (6)	.174

CCI, Charlson Comorbidity Index; *SD,* standard deviation.

transfusions. Multivariate regression revealed BMI was the sole determinant of complications, without contributions from age or CCI. Our hypothesis that BMI would serve as an independent risk factor for the development of early medical and surgical complications after RTSA was supported.

To our knowledge, this is the first series specifically evaluating varied BMI and the associated medical and surgical complications in patients undergoing RTSA. In a previous series examining outcomes of TSA in obese patients, Linberg et al[21] demonstrated improved pain and function in the morbidly obese population, although with increased intraoperative surgical time, hospital length of stay, and ICU use.

Similar findings have been demonstrated in nonshoulder arthroplasty studies. Silber et al[25] demonstrated that obesity increases the intraoperative and postoperative risk and financial burden in patients undergoing

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Table II Complications segregated by body mass index (*BMI*) groups

Complication	BMI <25 kg/m^2	BMI 25-35 kg/m^2	BMI >35 kg/m^2	Total patients	*P* value
Patients sustaining					
A complication, % (No.)	33 (10)	15 (10)	42 (10)	25 (30)	.020
A major complication, % (No.)	10 (3)	8 (5)	13 (3)	9 (11)	.775
A medical complication, % (No.)	13 (4)	5 (3)	29 (7)	12 (14)	.006
A surgical complication, % (No.)	23 (7)	11 (7)	29 (7)	18 (21)	.083
An infection, % (No.)	0 (0)	1.5 (1)	0 (0)	0.8 (1)	.664
A dislocation, % (No.)	3.3 (1)	3.1 (2)	8.3 (2)	4.2 (5)	.528
Mortality before final follow-up, % (No.)	0 (0)	0 (0)	0 (0)	0 (0)	>.99

a variety of major operations, including hip and knee surgery, colectomy, and thoracotomy. Studies specific to hip and knee arthroplasty have shown obesity is associated with longer operative time, perioperative infection, ICU admission, and slower postoperative recovery.[1,17,18] In a level 2 prognostic study, Jain et al[16] found obesity was an independent predictor of increased postoperative complications and nonhome-bound discharge in patients undergoing shoulder, hip, or knee arthroplasty. Interestingly, we did not see a significant association between hospital length of stay and BMI in this study. The mean hospital length of stay was close to 2 days for all subgroups. This difference between our findings and those in the hip and knee arthroplasty literature may be explained by the ease of mobility associated with upper extremity vs lower extremity surgery. In addition, each patient who underwent shoulder arthroplasty had a multidisciplinary approach to their care (ie, internal medicine and physical and occupational therapy consultation) to allow for expeditious management of postoperative medical or mobility issues, or both. In countries where this is not available, hospital stays for such subgroups may be prolonged, with greater expense to stakeholders.

The cause for the association between an increased complication rate and a BMI of less than 25 kg/m^2 is unclear. Included among a variety of possible explanations are unmeasured or unaccounted covariates, such as malnutrition, and type I error. Our subgroup analysis did not demonstrate any patterns to suggest a correlation between a BMI of less than 25 kg/m^2 and a specific comorbidity that could have accounted for the associated complication. Only one patient had a BMI of less than 18.5 kg/m^2 (classified as ‘‘underweight’’ by the World Health Organization classification).

The hip arthroplasty literature has established that malnutrition can account for failed debridement in the setting of postoperative drainage after total hip arthroplasty.[15] This subgroup did have 2 patients with deep space infection and 1 with wound dehiscence. Therefore, there is a possibility that those specific patients suffered from malnutrition. However, to accurately assess a patient for malnutrition requires a preoperative laboratory workup (ie, serum total protein, albumin, prealbumin, and transferrin level) and caloric intake counts. These data were not available for the patients in our subgroup, and therefore, a malnutrition assessment could not be performed. However, given the clinical relevance of this finding in our study, evaluation of the preoperative nutritional status of patients undergoing RSA and its association with postoperative complications including, but not limited to, infection and wound problems may be warranted in future studies.

A variety of plausible causes exist to explain the complication rate in the group with a BMI exceeding 35 kg/m^2. In addition to the added technical complexity, including difficulty in gaining adequate exposure and increased intraoperative blood loss leading to increased rates of acute blood loss anemia and other surgical complications, obese patients may be less able to physiologically cope with the cardiovascular physiologic stress of surgery, leading to higher rates of postoperative medical complications such as acute renal failure. Obese patients also mobilize less readily, leading to increased rates of atelectasis.[3,12]

As the United States population ages and becomes increasingly obese, the number of RTSAs performed in obese individuals will increase.[19,26] This is also true in other nations, such as Australia.[10] Surgeons need to be aware of the risks associated with RTSA in such patients in order to provide accurate, evidence-based informed consent. Individuals determining health care policy need to be aware of the increased complication rates because they may affect overall health care expenditures. In addition, because complications are costly and time-consuming, individuals determining future public policy may want to consider altered premiums for the morbidly obese population and adjustments in surgeon compensation.

Limitations of this study include short-term follow-up, varied indications for RTSA, and the possibility of missed complications due to the retrospective nature of

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Table III All complications, classifications, and associated comorbidities

BMI (kg/m^2)	Complication	Classification	Comorbidities
18.6	Intraoperative humeral shaft fracture—cable	Major surgical	HTN
19.8	Blood loss anemia—transfusion	Minor surgical	HTN
20.0	Blood loss anemia requiring erythropoietin, no transfusion required	Minor surgical	CAD, DM
22.2	Altered mental status requiring restraints	Minor medical	HTN
22.7	PE—anticoagulation	Major medical	HTN
23.6	Wound dehiscence—local wound care	Minor surgical	HTN
23.8	Hypotension, recurrent dislocation—conversion to hemiarthroplasty	Minor medical, major surgical	CAD
24.0	Drill bit broken in the scapula	Minor Surgical	None
24.9	Respiratory failure requiring supplemental oxygen	Minor medical	HTN
24.9	Intraoperative glenoid fracture	Minor surgical	HTN
25.8	Acromial stress fracture	Minor surgical	HTN
27.1	Acromial stress fracture	Minor surgical	HTN
27.9	Superficial wound infection	Minor surgical	HTN
28.2	Respiratory failure requiring a 2-day ICU stay	Major medical	HTN
28.3	PE, blood loss anemia—transfusion	Major medical, minor surgical	HTN
29.7	Blood loss anemia–transfusion	Minor surgical	HTN, CAD
30.0	Acromial stress fracture, dislocation—closed reduction	Minor surgical, major surgical	Kidney cancer
31.6	CRPS in the ulnar nerve distribution	Minor surgical	HTN, DM
32.3	Asystole requiring pacemaker placement	Major medical	HTN, DM
32.4	Dislocation–closed reduction	Major surgical	HTN
35.0	Dislocation–required revision to a hemiarthroplasty	Major surgical	HTN
35.3	Persistent tachycardia	Minor medical	HTN, DM
36.0	Respiratory failure requiring supplementary oxygen	Minor medical	HTN, CKD
36.9	Respiratory failure, renal failure, transfusion	Minor medical and surgical	HTN
37.3	Renal failure–resolved with medical management	Minor medical	HTN
37.8	Hemorrhagic traumatic hematoma	Major surgical	HTN
37.9	Acromial stress fracture	Minor surgical	HTN
40.7	Hypotension, brachial plexus palsy, dislocation	Major/minor, medical/surgical	HTN, PE, DM
42.4	Blood loss anemia–transfusion, atelectasis	Minor surgical and medical	HTN, PE
43.0	Blood loss anemia–transfusion, atelectasis	Minor surgical and medical	CAD, HTN

CAD, coronary artery disease; *CKD*, chronic kidney disease; *CRPS*, complex regional pain syndrome; *DM*, diabetes mellitus; *HTN*, hypertension; *I+D*, irrigation and debridement; *ICU*, intensive care unit; *PE*, pulmonary embolism.

Table IV Hospital length of stay (*LOS*) and number of intensive care unit (*ICU*) admissions for each body mass index (*BMI*) subcategory

BMI, kg/m^2	LOS, d (Mean ± SD)	ICU admission (No.)
Group 1 (BMI <25)	2.4 ± 1.1	0
Group 2 (BMI 25-35)	2.3 ± 0.8	3
Group 3 (BMI >35)	2.3 ± 0.9	2

SD, standard deviation.

Table V Significance (*P* values) of multivariate logistic regression analyses performed to determine whether age, body mass index (*BMI*) subgroup (<25, 25-35, and 35 kg/m^2), or Charlson Comorbidity Index (*CCI*) served as significant covariates with all complications, major complications, medical complications, and surgical complications after reverse total shoulder arthroplasty

Variable	*P* value		
	Age	BMI subgroup	CCI
All complications	.476	.025	.230
Major complications	.996	.775	.613
Medical complications	.561	.015	.269
Surgical complications	.535	.083	.370

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the study. Lastly, a cost-analysis comparing RTSA in the nonobese obese populations would have strengthened the study.

Conclusion

Patients with a BMI exceeding 35 kg/m^2 (severe obesity) or a BMI of less than 25 kg/m^2 have higher rates of complication after RTSA. Future studies evaluating the association between causative factors, such as malnutrition in patients with a BMI of less than 25 kg/m^2, are needed.

Disclaimer

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