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Original article

Weight loss and BMI criteria in GLIM's definition of malnutrition is associated with postoperative complications following abdominal resections — Results from a National Quality Registry

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SUMMARY

Background & aims: Although malnutrition is thought to be common among patients with intra-abdominal diseases and is recognized as a risk factor for postoperative complications, diagnostic criteria for malnutrition have not been consistent. Thus, the Global Leadership Initiative in Malnutrition (GLIM) has recently published new criteria for malnutrition. The aims of this study were to investigate the prevalence of malnutrition according to weight loss and BMI criteria in GLIM's second step for the diagnosis and their association with severe postoperative complications in patients undergoing gastro-intestinal resections.

Method: The current study includes adult patients who were prospectively included in the Norwegian Registry for Gastrointestinal Surgery in the period between 2015 and 2018. Exclusion criteria were acute surgery and lack of information regarding preoperative weight and/or postoperative complications. Severe surgical complications were classified according to the Revised Accordion Classification system and malnutrition with the GLIM criteria. Associations were assessed by logistic regression analyses, and the adjusted odds ratio included age (continuous), gender (male/female) and scores from the American Society of Anesthesiologists Physical Status Classification System and the Eastern Cooperative Oncology Group.

Results: Out of 6110 patients, 2161 (35.4%) were classified as with malnutrition, 1206 (19.7%) with moderate and 955 (15.6%) with severe malnutrition. Malnourished patients were 1.29 (95% CI: 1.13–1.47) times more likely to develop severe surgical complications, and 2.15 (95% CI: 1.27–3.65) times more likely to die within 30 days, as compared to those who were not.

Conclusion: Preoperative malnutrition is common among patients having gastrointestinal resections and is associated with an increased risk of severe surgical complications.

1. Introduction

Surgery is the only curative treatment option for a broad spectrum of intraabdominal diseases. Even in the era of modern surgery and perioperative care, a significant proportion of patients experience severe postoperative complications, even mortality. The incidence of severe complications following intraabdominal resection surgery is related to the specific organ operated on and type of procedure performed. However, comparison of the severity

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification System; BMI, Body Mass Index; ECOG, Eastern Cooperative Oncology Group; GLIM, Global Leadership Initiative in Malnutrition; NCPS, Nordic Medico-Statistical Committee Classification of Surgical Procedures (NCPS); NOMESCO, Nordic Medico-Statistical Committee; NoRGast, Norwegian Registry for Gastrointestinal Surgery; NPR, National Patient Registry; mE-PASS, modified Estimation of Physiologic Ability and Surgical Stress; WHO, World Health Organization.

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of complications is often difficult since methods for reporting such outcomes are not always uniform [1].

Risk factors for postoperative complications include preoperative weight loss and malnutrition [2–7]. Despite most definitions of malnutrition include the same risk factors [8], there has been a lack of consensus on diagnostic criteria for application in clinical settings. Therefore, the Global Leadership Initiative in Malnutrition (GLIM) recently published new definitions of malnutrition for adults, based on a two-step model for risk screening and diagnosis assessment [9]. The definitions are based on both phenotypic criteria (weight loss, low body mass index (BMI) and reduced muscle mass), and etiologic criteria (reduced food intake or assimilation and inflammation). Although such conditions are thought to be prevalent among patients with gastrointestinal diseases, the frequency and severity of malnutrition among gastrointestinal patients are not well described. Moreover, the GLIM encourages the nutrition community to use the criteria both in prospective and retrospective cohort studies as well as clinical trials in order to validate its relevance for clinical practice [9].

The main purpose of this study was to describe the prevalence of preoperative malnutrition among patients undergoing gastrointestinal resections, and secondly to explore the association between nutrition status and severe postoperative complications and death.

2. Material and methods

2.1. Study sample

The present retrospective study includes 6110 patients from the Norwegian Registry for Gastrointestinal Surgery (NoRGast). NoRGast has collected data prospectively for colorectal, upper gastrointestinal and hepato-pancreato-biliary restrictions in Norway since 2014, and was acknowledged with the status of a National Quality Registry in May 2015 [10]. It is mandatory to enter data in the NoRGast register for resections in the following organs (procedure code according to the classification of the Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCPS) [11]): colon (JFB 20–64 and JFH), rectum (JGB), esophagus (JCC), gastric (JCD and JDD), liver (JJB), pancreas (JLC) and bile duct (JHC 10–99). Small bowel resections, appendectomies, cholecystectomies, stoma surgery without colorectal resection, and hernia repairs are entered in the register on a voluntary basis. By the end of 2015, nine hospitals entered data into the registry, whereas 29 out of the 32 hospitals performing more than 20 gastrointestinal resections per year participated by the end of May 2018. Since 2014, more than 13500 operations have been entered into the database. Among the formal resections are some 3900 colonic, 1500 rectal, 850 liver, 300 gastric, 200 esophageal and 390 pancreatoduodenectomies [10]. The current study includes data for adult patients ($\geq$18 years) with a major intraabdominal operation, here defined as a surgery that included total or partly resection of the colon, rectum, esophagus, gastric, liver, pancreas or bile duct, registered in NoRGast in the period from May 2015 to May 2018 [12]. Patients were excluded if information regarding weight at admission and/or 6 months prior to surgery were not available.

Coverage (completeness) of the Registry was compared to administrative data collected by the National Patient Registry (NPR), which is a compulsory registration for all hospitals in order to be reimbursed for in-hospital patient stays and therapy [10]. Compared to NPR, completeness of the NoRGast varied from 30% to 93% for participating hospitals, mainly due to time-lag in the implementation phase. There was a variation in completeness between hospitals in the implementation phase versus hospitals with a 3-year run-time, but also a variation somewhat within participating centers year by year. Missing values ranged from zero for several variables and up to 52% for preoperative weight changes in colonic resections [10].

2.2. Ethics

All patients included in NoRGast signed a written consent and data were stored in a non-identifiable way in the NoRGast database. The current study was approved by the Regional Committee for Medical and Health Research Ethics (2018/1549) and is in accordance with the Declaration of Helsinki.

2.3. Clinical data

The patient's weight six months prior to surgery was self-reported or retrieved from patient files when available, whereas current weight at admission was scaled by health professionals. Weight changes are reported as percentages. The GLIM criteria for the diagnosis of malnutrition uses a two-step-model for risk screening and diagnosis assessment, where the first step is to identify patients who are at nutritional risk with a validated screening tool [9]. Secondly, patients who meet at least one of the phenotypic and one of the etiologic criteria of malnutrition are identified. Since NoRGast does not include all the information needed in the first step of the GLIM's model to identify malnutrition, the current study only uses the second step. Based on their need for a formal, major resection, all NoRGast-patients were a priori defined as having a chronic gastrointestinal condition that adversely impacts food assimilation or absorption, which is one of the etiologic criteria in the second step of the model. The GLIM's phenotypic criteria for weight loss or BMI were used to diagnose patients with malnutrition and further classify the condition as moderate or severe (Table 1). Underweight was defined according to World Health Organization (WHO)'s cut offs criteria (BMI < 18.5 kg/m^2) [13] and is thus also included in the GLIM criteria of severe malnutrition.

Postoperative complications within 30 days following surgery were scored using the Revised Accordion Classification system [1]. Complications are grouped in four levels: mild (grade 1), moderate (grade 2), severe (grade 3–5) and death (grade 6). Severe complications (grade 3–5) are divided into the following groups: severe complication requiring a procedure without general anesthesia (grade 3), severe complications requiring a procedure with general anesthesia or resulting in single-system organ failure (grade 4), and severe complication requiring a procedure with general anesthesia and resulting in a single-system organ failure or resulting in multisystem organ dysfunction (grade 5) [1]. Accordion grade 6 denotes death.

The American Society of Anesthesiologists Physical Status Classification System (ASA-score) [14], the Eastern Cooperative Oncology Group (ECOG)-score [15] and the modified Estimation of Physiologic Ability and Surgical Stress (mE-PASS) [16] were used to evaluate the patients' physical status prior to surgery. In order to obtain an exact and standardized definition in all operating departments and avoid any personal opinion of this matter, elective surgery was defined as start of anesthesia between 8 am and 4 pm. All relevant data were extracted directly from the NoRGast database.

2.4. Statistical analysis

Analyses were conducted for the total study sample as a whole, with separate analysis for the different nutritional characteristics and specific organ operated upon. Summary measures for continuous variables are reported as medians and range (25th to 75th

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Table 1
Weight loss and BMI criteria in GLIM's second step for the diagnosis of malnutrition.

Malnutrition diagnosis	Criteria *(at least one of the following)*		
	Weight loss during the past 6 months	BMI among those younger than 70 years	BMI among those older than 70 years
Malnutrition	>5%	<20 kg/m^2	<22 kg/m^2
Moderate malnutrition	5–10%	18.5–20 kg/m^2	20–22 kg/m^2
Severe malnutrition	>10%	<18.5 kg/m^2	<20 kg/m^2

BMI: Body Mass Index; **GLIM**: Global Leadership in Malnutrition.

percentile), and categorical variables are reported as counts (percentages).

Multivariate logistic regressions for severe complications and death were constructed to investigate the association between nutritional characteristics (underweight, malnutrition and weight changes) and these outcomes, with adjustment for age (continuous), gender (male/female), ASA-score (score 1–5) and ECOG (score 0–4). The statistical package IBM SPSS Statistics was applied. All p-values were two-tailed and values less than 0.05 were considered statistically significant.

3. Results

3.1. Patients' characteristics

In total, 6110 patients were included in the present study (Fig. 1), and their general and nutritional characteristics are described in Tables 2 and 3, respectively. Overall, 3291 (53.9%) were men and the median (25th, 75th percentile) age and BMI were 68 (58, 75) years and 25.2 (22.5, 28.3) kg/m^2. The majority of the study sample, 4494 (73.6%) patients, had a malignant tumor. Severe complications, excluding death, occurred in 1188 (19.4%) patients, and 61 (1.0%) died within 30 days following surgery.

As compared to the total group of patients registered in NoRGast (n = 11746), patients included in the present study tended to have a higher frequency of surgery due to tumor and neoadjuvant treatment with chemotherapy (Table 2). The prevalence and distribution of severe postoperative complications tended to be similar in both groups, except for a higher mortality-rate among the total NoRGast group.

3.2. The prevalence of malnutrition and underweight

At the time of surgery, 2161 patients (35.4%) suffered from malnutrition, of whom 1206 (19.7%) were moderately malnourished and 955 (15.6%) were severely malnourished. Underweight was observed in 216 (3.5%) patients (Table 3).

The distribution of resected organ in the study sample and their nutritional characteristics are described in Table 4. In general, patients who had pancreatic, esophageal or gastric surgery tended to be more often malnourished (356 (52.9%), 87 (44.6%) and 100 (37.3%) patients, respectively), as compared to those having surgery in other gastrointestinal organs.

3.3. Nutritional status and severe surgical complications/mortality

3.3.1. Malnutrition and underweight

Patients with malnutrition at time of surgery were more likely to develop severe surgical complications and to die within 30 days, as compared to those who were not (OR (95% CI): 1.29 (1.13, 1.47) and 2.15 (1.27, 3.65), respectively) (Table 5). These results were not noteworthy altered when adjusting for specific organs operated on or when grade 3 were excluded from the definition of severe surgical complications (data not shown).

When investigating the different nutritional categories separately, the multivariate analysis demonstrated that both patients

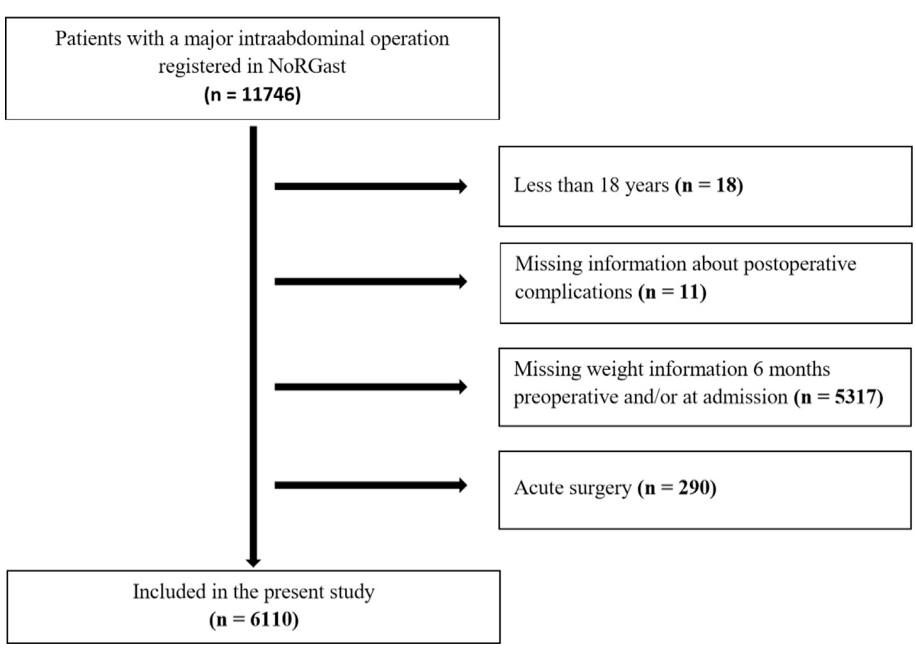

Fig. 1. Flow chart of the study sample.

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Table 2
General characteristics and postoperative complications among patients included in the study sample and in NoRGast.

	Study sample	NoRGast
	n = 6110	n = 11746
General characteristics		
Male[a]	3291 (53.9)	6156 (52.4)
Age[b]	68.0 (58.0, 75.0)	68.0 (58.0, 76.0)
Age ≥ 70 years	2626 (43.3)	5321 (45.3)
BMI[b]	25.2 (22.5, 28.3)	25.2 (22.6, 28.4)
Surgery due to tumor[a]	4494 (73.6)	7932 (67.5)
Chemotherapy[a]	572 (9.4)	811 (6.9)
Radiotherapy[a]	98 (1.6)	175 (1.5)
Chemo- and radiotherapy[a]	418 (6.8)	610 (5.2)
mE-PASS[b]	0.35 (0.28, 0.50)	0.36 (0.29, 0.53)
ASA-score[a]		
1	311 (5.1)	693 (5.9)
2	3516 (57.5)	6531 (55.6)
3	2162 (35.4)	4115 (35.0)
4	118 (1.9)	377 (3.2)
5	3 (0.0)	20 (0.2)
ECOG-score[a]		
0	4306 (70.5)	7858 (66.9)
1	1298 (21.2)	2524 (21.5)
2	381 (6.2)	843 (7.2)
3	92 (1.5)	252 (2.1)
4	15 (0.2)	87 (0.7)
Classification of postoperative complications[a, c]		
None, mild or moderate (grade < 3)	4861 (79.6)	9228 (78.6)
Severe, excluding death (grade 3–5)	1188 (19.4)	2298 (19.6)
Death (grade 6)	61 (1.0)	198 (1.7)

ASA-score, American Society of Anesthesiologists Physical Status Classification System**; BMI**, Body Mass Index; **CRP**, C-reactive protein; **ECOG**, Eastern Cooperative Oncology Group score; **mE-PASS,** modified Estimation of Physiologic Ability and Surgical Stress; **NoRGast**: Norwegian Registry for Gastrointestinal Surgery. Missing information for BMI (n = 34), ECOG-score (n = 19) and ASA-score (n = 1) in the study sample.
[a] n (percent).
[b] Median (25, 75 percentile).
[c] Postoperative complications according to the Accordion classification scale [1].

with moderate and severe malnutrition had an increased risk for severe surgical complications (OR (95% CI): 1.17 (1.00–1.37) and 1.27 (1.07–1.50), respectively), whereas the association with death alone was significant for patients with severe malnutrition (OR (95% CI): 2.16 (1.25–3.73)) only. Patients with underweight had a 2.68 (95% CI: 1.11–6.46) higher risk dying, as compared to those who were not underweight. There were no statistically significant differences in the incidence of severe surgical complications between these two groups.

Table 3
Nutritional characteristics in the study sample (n = 6110).

Nutritional characteristics	n (%)
Categories of preoperative weight loss (%)	
≤0	3320 (54.3)
0.1–4.9	1116 (18.3)
5–9.9	949 (15.5)
10–14.9	467 (7.6)
≥15	258 (4.2)
Categories of BMI (kg/m^2)	
<18.5 (underweight)	216 (3.5)
18.5–24.9 (normal weight)	2709 (44.3)
25–29.9 (pre-obesity)	2176 (35.6)
≥30 (obesity)	974 (15.9)
Diagnosis of malnutrition	
Malnutrition[a]	2161 (35.4)
Moderate malnutrition[b]	1206 (19.7)
Severe malnutrition[c]	955 (15.6)

BMI, Body Mass Index. Missing information for BMI (n = 35).
[a] Malnutrition: weight loss ≥5% within the past 6 months, BMI <20 kg/m^2 (<70 years) and/or BMI < 22 kg/m^2 (≥70 years).
[b] Moderate malnutrition: weight loss 5–10% within the past 6 months, BMI 18.5–20 m/kg^2 (age < 70 years) and/or BMI < 22 m/kg^2 (≥70 years).
[c] Severe malnutrition: weight loss >10% within the past 6 months, BMI <18.5 m/kg^2 (<70 years) and/or BMI < 20 m/kg^2 (≥70 years).

3.3.2. *Categories for age and BMI*

Stratifying for age, we found no significant relationship between BMI <18.5 kg/m^2 and <20 kg/m^2 (cut offs used in the criteria of the diagnosis of moderate and severe malnutrition, respectively), and the incidence of severe surgical complications and death for patients younger than 70 years. However, for those aged 70 years or more, the BMI categories used in the criteria of moderate and severe malnutrition (<20 kg/m^2 and <22 kg/m^2, respectively) demonstrated increased risks for severe surgical complications (OR (95% CI): 1.47 (1.07, 2.03) and 1.25 (1.00, 1.57), respectively). Moreover, the older patients with BMI <20 kg/m^2 had a nearly 2.5-fold increased risk for death (OR (95% CI): 2.46 (1.09, 5.55)), as compared to those with a higher BMI. There was no significant relationship between BMI <22 kg/m^2 and death for older patients with (data not shown).

3.3.3. *Weight change*

Two thousand, seven hundred and ninety patients (45.7%) experienced weight loss during the 6 months prior to surgery. This was significantly associated with both severe complications and death (OR (95% CI): 1.28 (1.13–1.46) and 1.70 (1.00–2.90), respectively). Patients with a weight loss ≥5% demonstrated a higher risk for both severe complications and death (OR (95% CI): 1.27 (1.10–1.46) and 2.35 (1.40–3.94), respectively), whereas those with weight loss > 10% only demonstrated a significant increased risk for death (OR (95% CI): 2.23 (1.30–4.18)) (Table 5), as compared to those with a lower weight loss.

Stratified analysis for obese patients (BMI ≥ 30 kg/m^2) revealed that those with preoperatively weight loss had an increased risk for severe surgical complications, as compared to those who did not lose weight (OR (95% CI): 1.42 (1.04–1.94)). Preoperative weight loss did not increase the risk of death for this patient group as it did for the total population.

As compared to patients having weight loss or weight gain, patients who had a stable weight prior to surgery demonstrated a decreased risk for severe surgical complications and death in the crude analysis (OR (95% CI): 0.68 (0.60–0.78) and 0.46 (0.25–0.84), respectively), but only statistically significant in the adjusted analysis for severe surgical complications (OR (95% CI): 0.75 (0.65–0.85)). There was no significant association between gaining weight and severe surgical complications or death (Table 5).

4. Discussion

The present study demonstrates that even if only 3.5% of the patients undergoing gastrointestinal resections met the WHO's criteria for underweight, over a third (35.4%) of the patients met the weight loss and BMI criteria in GLIM's second step for the diagnosis of malnutrition at time of surgery. In total, patients with malnutrition were near thirty percent more likely to develop severe surgical complications and over two times more likely to die within 30 days postoperatively, as compared to those who did not have malnutrition according to the selected GLIM-criteria. Moreover, almost half of the patients had lost weight prior to surgery, which by itself was significantly associated with increased risk for both severe complications and death.

The prevalence of underweight among patients having gastrointestinal surgery is reported to be higher in Eastern than in Western countries [6,17], probably due to a generally lower BMI in Asian populations. Even though, studies from both Japan [5] and

Table 4
Distribution of organ system operated on and prevalence of malnutrition and/or underweight.

Organ system operated	Study sample[a]	Malnutrition[a,b]	Moderate malnutrition[a,c]	Severe malnutrition[a,d]	Underweight[a,e]
Total	6110 (100)	2161 (35.4)	1206 (19.7)	955 (15.6)	216 (3.5)
Esophagus	195 (3.2)	87 (44.6)	49 (25.1)	38 (19.5)	10 (5.1)
Stomach	267 (4.4)	100 (37.3)	62 (23.2)	38 (14.2)	5 (1.9)
Small bowel	254 (4.2)	79 (31.1)	44 (17.3)	35 (13.8)	12 (4.7)
Colon	2360 (38.6)	789 (33.4)	458 (19.4)	331 (14.0)	93 (3.9)
Rectum	1371 (22.4)	411 (30.0)	237 (17.3)	174 (12.7)	41 (3.0)
Liver	953 (15.6)	329 (34.5)	182 (19.1)	147 (15.4)	27 (2.8)
Pancreas	673 (11.0)	356 (52.9)	169 (25.1)	187 (27.8)	25 (3.7)
Spleen	37 (0.6)	10 (27.0)	5 (13.5)	5 (13.5)	3 (8.1)

[a] n (%).
[b] Malnutrition: weight loss ≥5% within the past 6 months, BMI <20 kg/m^2 (<70 years) and/or BMI < 22 kg/m^2 (≥70 years).
[c] Moderate malnutrition: weight loss 5–10% within the past 6 months, BMI 18.5–20 m/kg^2 (age < 70 years) and/or BMI < 22 m/kg^2 (≥70 years).
[d] Severe malnutrition: weight loss >10% within the past 6 months, BMI <18.5 m/kg^2 (<70 years) and/or BMI < 20 m/kg^2 (≥70 years).
[e] Underweight: Body Mass Index <18.5 kg/m^2.

Table 5
The association between nutritional characteristics and the incidence of severe surgical complications[a] and death within 30 days after surgery.

Nutritional characteristics	Study sample (n = 6110)	Severe surgical complications, including death[a] (n = 1249)		Death (n = 61)	
	n (%)	Crude OR (95% CI)[f]	Adjusted OR (95% CI)[f,g]	Crude OR (95% CI)[f]	Adjusted OR (95% CI)[f,g]
Malnutrition[b]	2161 (35.3)	1.33 (1.17, 1.52)	1.29 (1.13, 1.47)	2.84 (1.69, 4.76)	2.15 (1.27, 3.65)
Moderate malnutrition[c]	1206 (19.7)	1.17 (1.00, 1.36)	1.17 (1.00, 1.37)	1.45 (0.82, 2.57)	1.23 (0.69, 2.21)
Severe malnutrition[d]	955 (15.6)	1.35 (1.15, 1,59)	1.27 (1.07, 1.50)	2.86 (1.68, 4.88)	2.16 (1.25, 3.73)
Underweight[e]	216 (3.5)	1.31 (0.96, 1.80)	1.34 (0.97, 1.85)	3.02 (1.29, 7.09)	2.68 (1.11, 6.46)
Weight loss > 0%	2790 (45.7)	1.36 (1.20, 1.54)	1.28 (1.13, 1.46)	2.13 (1.26, 3.59)	1.70 (1.00, 2.90)
Weight loss ≥ 5%	1674 (27.4)	1.37 (1.19, 1.56)	1.27 (1.10, 1.46)	2.96 (1.79, 4.91)	2.35 (1.40, 3.94)
Weight loss > 10%	701 (11.5)	1.33 (1.11, 1.60)	1.19 (0.98, 1.43)	3.03 (1.72, 5.33)	2.33 (1.30, 4.18)
Stable weight	2388 (39.1)	0.68 (0.60, 0.78)	0.75 (0.65, 0,85)	0.46 (0.25, 0.84)	0.57 (0.31, 1.04)
Increased weight	932 (15.3)	1.09 (0.92, 1.29)	1.04 (0.88, 1.24)	0.84 (0.40, 1.77)	0.90 (0.42, 1.92)

[a] Severe surgical complications are defined as grade 3–6 in the Revised Accordion Scale.
[b] Malnutrition: weight loss ≥5% within the past 6 months, *or* a BMI <20 kg/m^2 if age <70 years *or* BMI <22 kg/m^2 if age ≥70 years).
[c] Moderate malnutrition: weight loss 5–10%, *or* BMI <20 m/kg^2 if younger than 70 years *or* BMI <22 m/kg^2 if age ≥70 years.
[d] Severe malnutrition: weight loss >10%, *or* BMI <18.5 m/kg^2 if younger than 70 years *or* BMI <20 m/kg^2 if age ≥70 years.
[e] Body mass index <18.5 kg/m^2.
[f] Estimate of odds ratio by logistics regression models. Patients who met the criteria for the different nutritional characteristics were compared with those who were not.
[g] Adjusted for age, gender, American Society of Anesthesiologists Physical Status Classification System score (ASA-score) and Eastern Cooperative Oncology Group score (ECOG-score).

USA [6] demonstrates that patients with underweight are more likely to have postoperative complications, which is in accordance with our findings. However, the strength in this relationship tends to be stronger in the American population [6], as compared to both the Japanese [5] and the Norwegian population (the current study), possible due to a shift towards a higher BMI in the general population.

In the current study, half of the patients were overweight or obese. The experience from the North-American population, where overweight or obesity is prevalent, is that patients need to lose substantial weight before the definition of underweight occurs [9]. Thus, it is important to emphasize that BMI by itself is not adequate to identify all those who have nutritional challenges, and especially not in populations where BMI tends to increase. For example, BMI may remain relatively unchanged despite the patient's muscle mass decreases and visceral fat increases, leading to sarcopenic obesity [18]. Sarcopenia is recognized to have high personal, social and economic burdens when untreated [19]. Thus, the European Working Group on Sarcopenia in Older People 2 recently published new recommendations with the aim to increase the awareness of sarcopenia and its risk [20]. Despite sarcopenia can occur earlier in life, it is most common among older people. Moreover, also older people may be a vulnerable group for the BMI definitions of underweight since their current height may have decreased due to fractures and thus camouflages a low BMI [21]. The current study observed that among patients 70 years or more, a BMI <22 kg/m^2 was associated with an increased risk of severe surgical complications, and that a BMI <20 kg/m^2 was associated with both an increased risk for severe surgical complications and death alone, as compared to those with a higher BMI. Therefore, we find it appropriate that the new malnutrition criteria use an age-adjusted BMI cut off for those 70 years or more when the patients' current height is used [9].

Hospitalized patients with weight loss have previously been demonstrated to have an increased risk for both morbidity and mortality the following year [1,3,4,7,22], as compared to patients not having weight loss. In the present study, any preoperative weight loss had a statistically significant association with severe surgical complications, whereas the WHO's definition of underweight did not. Reporting weight loss as a stronger predictor of complications than underweight has been shown in some published studies [23], whereas others do not confirm this [17,24]. Interestingly, stratified analysis among patients with obesity (BMI ≥ 30 kg/m^2) in the current study population demonstrated that weight loss increased the risk of severe surgical complications also in this group. Thus, weight loss as a risk factor is not restricted to patients with a lower BMI. This is supported in results from previous studies [25,26], and underlines the importance of also evaluating sarcopenia, weight loss and malnutrition among patients with a normal or high BMI.

Weight loss leads to a reduction in both fat-free mass and fat mass, which further results in decreased muscle strength [27].

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Reduction of fat-free mass and muscle strength are associated with an increased mortality rate [28]. Reduction of fat mass, which is not only a lipid storage depot, but also a nutritional reserve that influence the inflammatory and immune response, may decrease the patients ability to handle the stress of surgery [29]. Additionally, a low dietary intake or depleted nutrient storage may lead to a delayed wound healing since several nutrients are needed for the healing process [30]. In summary, a low BMI and/or weight loss may lead to ill-prepared patients regarding the stress of surgery through a complexity of pathways, and thus increase the risk for adverse outcomes. Unfortunately, information regarding preoperative weight loss often tends to be missing in the clinic, as demonstrated in NoRGast where only 48% of the patients undergoing resections of the large bowel had this information. This indicates that information about weight loss is still not recognized as relevant in all surgical environments.

4.1. Clinical relevance

Preventing severe surgical complications are of major interest for patients, health professionals and hospital administration, due to the impact on the patients' health and the health care system's costs. Guidelines recommend focusing on nutritional counseling if indicated by the preoperative testing [31,32]. Our study points towards WHO's definition of underweight and GLIM criteria for weight loss and low BMI being such indicators. Thus, patients with these conditions should receive nutritional counseling in order to stop the development of malnutrition. Moreover, the current study indicates that the severity grading in the GLIM criteria (moderate and severe malnutrition) is appropriate in the clinical setting since the criteria for severe malnutrition tends to be more strongly associated with severe postoperative complications, as compared to the criteria for moderate malnutrition. Of note, since gaining weight prior to surgery have demonstrated limited results on the outcome, it may be more important to prevent weight loss and malnutrition. This may be especially challenging in the current patient group due to underlying gastrointestinal diseases in a major part of the study population, but possibly all the more important. These topics should further be evaluated in prospective studies.

4.2. Strengths and limitations

The current study analyses a large, nationwide study sample and the use of standardized definitions of postoperative complications. Moreover, the diagnostic criteria for underweight and malnutrition are well-defined and are collected prior to surgery.

Analyses based on registry data might always inherit some biases. Many people are involved in the registration, and since the completeness of the registry is limited, selection biases might be introduced. However, the limited completeness is mainly due to lack of personnel and logistics at the hospitals, and not due to lack of consent from the patients. Although we did not observe any striking differences in morbidity and mortality between the total NoRGast population and the patients included in the current study, some biases might occur. Potentially, this could be related to weight information since nearly fifty percent of the NoRGast population was excluded due to missing weight information 6 months prior to surgery and/or at admission. Moreover, the current study were not able to exclude those who were not at nutritional risk according to first step of the GLIM criteria. Thus, the observed associations between weight loss and BMI criteria in GLIM's second step for the diagnosis of malnutrition may even be stronger than reported here. It should also be mentioned that we only disclosed associations and no causalities.

5. Conclusions

Our study demonstrates that preoperative weight loss and malnutrition are common among patients having colorectal, upper gastrointestinal or hepato-pancreato-biliary restrictions, and that these conditions are associated with an increased risk of severe surgical complications.

Statement of authorship

Eli Skeie: methodology, formal analysis, writing – original draft, review & editing, visualization. **Randi Julie Tangvik**: writing – review & editing, supervision. **Linn Såve Nymo**: investigation, writing – review & editing, project administration. **Kristoffer Lassen**: investigation, writing – review & editing, project administration. **Stig Harthug**: writing – review & editing, supervision. **Asgaut Viste**: conceptualization, investigation, supervision, writing – review & editing. All authors gave final approval of the version to be submitted.

Conflict of interest

The authors declare that they do not have any conflict of interest.

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