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Original article

The new body mass index formula; not validated as a predictor of outcome in a large cohort study of patients undergoing general surgery

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SUMMARY

Background and aims: A new and interesting body mass index (BMI) formula has been proposed. This formula was designed to provide a more accurate estimation of weight categories, not limited in a two-dimensional manner. The objective of this study was to evaluate the predictive value of the new BMI formula on postoperative complications and long-term survival in a large cohort of patients undergoing general surgery.

Methods: 4293 consecutive patients undergoing general surgery in a general teaching hospital were included. Data on comorbidity and demographics were gathered prior to surgery. We also collected data on surgery related characteristics. BMI was calculated using the conventional as well as the new BMI formula. Patients were then divided into four weight categories (BMI < 18.5, 18.5–25, 25–30 and >30 kg/m^2) as recommended by the World Health Organization.

Results: The study population consisted of 4293 patients. Multivariate regression analyses and the area under the ROC-curve (0.531 ± 0.011 and 0.539 ± 0.011) showed comparable results in predicting outcome between the two formulas. A demographic shift was noticed after complementing the new BMI formula. Male patients were the subjects of this shift, usually towards a lower BMI. According to the conventional BMI formula, 58% of men were overweight BMI > 25 kg/m^2, compared to 51.4% according to the new formula.

Conclusions: This study showed no difference in prediction of outcome after general surgery when comparing the current BMI formula to the new BMI formula. Thus, despite the fact that the new mathematical proposition seemed more logical and interesting, both calculations can be used in clinical practice. Moreover, our results do not support a change from the conventional BMI formula, currently used and accepted worldwide.

Introduction

Most often the body mass index (BMI) is the preferred formula to assess different weight categories. The body mass index was developed in the 1840's and is defined as weight divided by height squared. It was known for years as the Quetelet Index, until it was renamed and popularized by an American scientist as the body mass index [1]. The easy, safe and inexpensive acquirement of weight and stature might explain its popularity. Ever since, many studies have validated the BMI formula as a reasonable marker of adiposity in children and adults [2–4]. Recently, professor Trefethen from the Department of Numerical Analysis at the University of Oxford proposed a new and interesting BMI formula [5]. The reason for this new formula, he claims, is that weight categories should not be limited in a two-dimensional manner. According to Trefethen, the current BMI formula seems to underestimate obesity in shorter people and overestimate obesity in taller people. His suggested new formula is $BMI = 1.3 \times weight(kg)/height(m)^{2.5}$.

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It is well known that body weight is associated with outcome after surgery. Obesity increases the risk of wound infection, results in a longer operation time and more intraoperative blood loss [6–10]. As for long-term outcome, a non-expected inverse and thereby paradoxical relationship between body mass index and survival is described in both cardiac and non-cardiac surgical populations [11–13]. This paradox shows an inverse relationship between body mass index and mortality, with a lower mortality rate in the overweight and mild obese population and an increased mortality rate in the underweight population. Since professor Trefethen emphasizes he is an applied mathematician, it seems interesting to subject his formula to a clinical study population. According to our knowledge, there are two studies describing this new formula in clinical practice, both limited by small groups of patients [14,15]. Therefore, the objective of this study was to evaluate the predictive value of the new BMI formula, compared to the current BMI-formula, on postoperative complications and long-term survival in a large cohort of patients undergoing general surgery.

Materials and methods

We included consecutive patients undergoing general surgery in the Orbis Medical Center (now part of the Zuyderland Medical Center) from March 2005 to December 2006. The study complies with the Helsinki statement on research ethics and the local medical ethical committee gave formal review and approval. Patients younger than 14 years old were excluded. Other exclusion criteria were procedures performed under local anesthesia and assisting procedures for a specialism other than the general surgery department. When a patient underwent more than one procedure during the study period, only the first operation was included. A surgeon or a surgical resident in the outpatient clinic gathered information on comorbidity and demographics prior to surgery. We also collected data on surgery related characteristics. Validation of the database using a random sampling audit procedure confirmed a high level of accuracy and completeness of data.

The original Body Mass Index formula (BMI = weight (kg)/height $(m)^2$) was used to calculate BMI. Subsequently, as recommended by the World Health Organization (WHO), patients with a BMI < 18.5 kg/m^2 were defined as underweight, BMI 18.5–25 kg/m^2 as normal weight, BMI 25–30 kg/m^2 as overweight and patients with a BMI > 30 kg/m^2 were defined as obese [16]. We then calculated patients' BMI with the new formula, after which they were divided into the same WHO recommended weight-categories.

Patients were followed during hospital stay and visits to the outpatient clinic up to one year after surgery. Any event within 30 days after surgery deviating from a normal postoperative course was defined as a complication. The following complications were separately documented: wound infections, pneumonia, cardiovascular and cerebrovascular events, deep vein thrombosis and or pulmonary embolisms, ICU-admission, readmission and need for complication surgery. Information on long-term survival was gathered from the national public register, available in 98.3% of patients, with a median follow-up time of 6.3 (interquartile range 5.8–6.8) years.

We used a chi-square test for comparison of categorical variables and analysis of variance for continuous variables. Univariable and multivariable regression models were used to evaluate which of the two BMI formulas was better in predicting outcome. We entered all potential confounders, such as age, gender, surgical risk, type of anesthesia, ASA classification (Table 1), diabetes, hypertension, pulmonary –, cardiac – or cerebrovascular disease, and the presence of a malignancy in the multivariable regression model. Finally, we used the receiver operating characteristic (ROC) curves to determine which of the two formulas was a better predictor of outcome. Results were reported as odds ratios (OR) or hazard ratios (HR) with a 95% confidence interval. Significance was defined as a two-sided P-value < 0.05. Primary endpoints of this study were 30-day complications and long-term mortality. Statistical analyses were performed with SPSS, version 22.0.0 statistical software (SPSS Inc., Chicago, Illinois).

Table 1
The American Society of Anesthesiologists (ASA) Classification [21].

ASA I	A normal healthy patient
ASA II	A patient with mild systemic disease
ASA III	A patient with severe systemic disease
ASA IV	A patient with severe systemic disease that is a constant threat to life
ASA V	A moribund patient who is not expected to survive without the operation

Results

A total of 4479 patients underwent surgery during the study period and were found suitable for analyses. Information on height or weight was not available in 186 patients (4,2%), whom were subsequently excluded. Therefore, our study population consisted of 4293 patients. There was an equal percentage of men and women in the cohort and the mean height was 1.77 ± 0.79 m and 1.65 ± 0.69 m respectively. For each patient we calculated BMI and the new BMI, after which they were categorized into the four different weight groups. Table 2a shows the baseline characteristics for both BMI formulas. The mean BMI for male patients was 26.1 ± 4.0 kg/m^2 when using the current BMI formula and 25.5 ± 4.0 kg/m^2 when calculated with the new formula. For female patients these numbers were 26.2 ± 5.1 kg/m^2 and 26.5 ± 5.3 kg/m^2 respectively. Table 2b shows demographic shifts after complementing the new formula. Especially male patients seemed the subject of this shift, usually towards the better end. 58% of all men

Table 2a
BMI values calculated according to current and new BMI-formula for different baseline characteristics.

	Current BMI (mean)	New BMI (mean)
Demographics		
Age		
Age >60 years	26.2 ± 4.3	26.2 ± 4.4
Age <60 years	26.1 ± 4.7	25.8 ± 4.8[a]
Sex		
Male sex	26.1 ± 4.0	25.5 ± 4.0
Female sex	26.2 ± 5.1	26.5 ± 5.3[b]
ASA classification[d]		
I	25.1 ± 3.8	24.8 ± 3.9
II	27.0 ± 4.7	27.0 ± 4.8
III	26.2 ± 4.9	26.2 ± 5.0
IV	25.3 ± 4.7	25.3 ± 4.8
V	24.8 ± 8.0	24.7 ± 7.9
Medical history		
Diabetes mellitus	28.6 ± 5.4	28.6 ± 5.6
Hypertension	27.5 ± 4.9	27.6 ± 5.0
Cerebrovascular disease	26.1 ± 4.5	26.1 ± 4.6
Malignant disease	26.0 ± 4.5	26.1 ± 4.7
Pathological cardiac history	26.5 ± 4.6	26.5 ± 4.7
Pathological pulmonary history	26.5 ± 5.1	26.5 ± 5.3
Current smoking[c]	25.6 ± 4.7	25.4 ± 4.7

[a] Significantly different (p < .05) when compared to age >60 years, within the new BMI-group.
[b] Significantly different (p < .05) when compared to male sex, within the new BMI-group.
[c] Data available in 75.7% of patients.
[d] American Society of Anesthesiologists.

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