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ORIGINAL CONTRIBUTIONS

ABSI (A Body Shape Index) and ARI (Anthropometric Risk Indicator) in Bariatric Surgery. First Application on a Bariatric Cohort and Possible Clinical Use

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Abstract

Background BMI (body mass index) is used to identify candidates for bariatric surgery, with a criterion of BMI ≥ 40. For lesser degrees of obesity, BMI 35–39.9, comorbidities are also considered. A Body Shape Index (ABSI) was derived to correct WC (waist circumference) for BMI and height. ABSI has been shown to be a linear predictor of long-term mortality across the range of BMI. Anthropometric risk indicator (ARI) combines the complementary contributions of BMI and ABSI and further improves mortality hazard prediction. We report for the first time ABSI and ARI for a bariatric surgical cohort at baseline and with 3-year follow-up.

Methods ABSI and BMI were calculated for 101 subjects from our bariatric surgery center database at baseline and after 3 years of follow-up. Raw values for BMI and ABSI were converted to *Z* scores and ARI values based on sex- and age-specific normals and risk associations from the National Health and Nutrition Examination Survey (NHANES) III sample of the US general population.

Results Baseline scores for the anthropometric variables BMI and ABSI and the corresponding ARI were all higher than for the NHANES population sample. At 3-year post surgery, all three measures decreased significantly. While baseline BMI did not predict the change in mortality risk by ARI, baseline ABSI did ($r = -0.73$), as did baseline ARI ($r = -0.94$).

Conclusion Sleeve gastrectomy lowers ABSI and the associated mortality risk estimated from population studies after 3 years of follow-up. Considering our results, bariatric surgical candidates with BMI in the range of 35 to 39.9 with an increased ABSI-related mortality risk may have considerable survival benefit from bariatric surgery, even in the absence of qualifying comorbidities.

Trial Registration Number 2814

Keywords ABSI (A Body Shape Index) · ARI (anthropometric risk indicator) · Bariatric surgery · Indications for bariatric surgery

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Introduction

Obesity is the non-infective pandemic illness of the twenty-first century and represents a dramatic public health problem in many Western countries, worldwide, affecting 11–15% of population [1]. The global prevalence of obesity doubled between 1975 and 2014 [1] and spread to the pediatric population [2]. The cardiovascular and metabolic diseases associated with obesity have been analyzed and reported in numerous epidemiological articles [3]. To guide medical interventions, it is essential to have precise criteria to diagnose obesity-associated health risks.

The current definition of obesity is based on BMI (body mass index) > 30 kg/m^2 [4]. The use of BMI and waist circumference (WC) in the diagnosis of obesity and their association with cardiometabolic disease and all-cause mortality has been supported by a large number of studies [5, 6].

Nevertheless, some important limitations were reported from the Global BMI Mortality Collaboration work [5]. In fact, as Berrigan et al. [7] underline, there is considerable heterogeneity in the association between BMI and mortality across different continents, and in older populations, especially in those aged 70 years and older, the associations are weaker.

Uniform BMI-based standards may not be suitable for the evaluation of body fat with respect to ethnicity [8], and according to other authors, BMI underestimates diagnosis of body fatness [9]. Moreover, BMI does not provide any indication of fat distribution, where a central or abdominal deposition thought to be related to metabolic disturbances and health risks [10]. WC itself or divided by hip circumference are widely used as indicators of abdominal obesity. However, the correlation of BMI and waist circumference is high at nearly 0.9 [11] and for BMI and WC/HC about 0.4 [12], making it difficult to untangle the measures.

A newly constructed index, A Body Shape Index (ABSI), see yellow that normalizes WC for BMI and height, has been recently proposed [13] as a complement to BMI. ABSI was derived from height, weight, and WC and has been demonstrated to be a substantial risk factor for premature mortality in general populations.

ABSI predicted mortality across sex, age, and to some extent ethnicity in a linear fashion, as compared to U-shaped distributions for BMI and WC [11, 12, 14]. Anthropometric risk indicator (ARI) is an approach to combine the risk profiles estimated separately from BMI and ABSI (and also height and when available hip circumference) in population studies to produce an improved risk measure, exploiting the statistical independence of ABSI from BMI [12]. To date, however, there has not been official recognition of a role for ABSI or ARI for obesity risk assessment among bariatric or other medical societies, pending confirmatory research.

Here, we investigate patterns of ABSI and ARI in a bariatric surgery population of 101 patients and suggest a possible role for it in daily practice.

Methods

Objectives

The objective is to calculate ABSI and ARI in our obese population and to compare to normal values in the wider population, before surgery and after a 3-year period of follow-up.

Ethics and Administrative Information

The study has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and approved by a local committee. The trial was registered in the public registry on http://www.researchregistry.com/ with the following number research registry 2814.

This article was reported according to STROBE (Strengthening The Reporting of Observational Studies in Epidemiology) guidelines [13]. All patients accepted anonymous publication for scientific purpose and the storage of data in a database. Authors declare that there will not be any communication of personal data to third parties in order to respect patients' privacy.

Setting, Participants, Recruitment Period, Inclusion and Exclusion Criteria, and Follow-up Methods

A retrospective analysis was carried out from our general database. All patients who underwent sleeve gastrectomy performed in our institutes from 1 January to 31 December 2013 were considered eligible for inclusion in this study. Indication for bariatric surgery was given following the recommended indications of International Federation for the Surgery of Obesity (IFSO).

During the recruitment period, informed consent was obtained for scientific analysis of clinical data before and after the sleeve gastrectomy.

Surgical technique used was described in our previously published article [15].

Exclusion criteria included contraindications to bariatric surgery defined by IFSO.

Follow-up was carried out with routine visits at 1, 3, 6, 12, 24, and 36 months.

During each visit, anthropometrics parameters, blood analysis, and comorbidities (diabetes, hypertension, etc.) were assessed. The calculation of % excess weight loss (EWL) was based on kilogram above BMI 25 as excess weight. Loss to follow-up was defined as the missing of one of the routine visits. Patients missing follow-up were excluded from the study.

Comorbidities improvement was defined as follow:

Hypertension

Improvement	Defined as a decrease in dosage or number of antihypertensive medication or decrease in systolic or diastolic blood pressure (BP) on the same medication (better control)
Partial remission	Defined as prehypertension values (120–140/80–89) when off medication
Complete remission	Defined as being normotensive (BP < 120/80) off antihypertensive medication

Diabetes

Remission (complete)	Normal measures of glucose metabolism (HbA1c < 6%, FBG < 100 mg/dL) in the absence of antidiabetic medications
Remission (partial)	Prediabetic hyperglycemia (HbA1c 6–6.4%, FBG 100–125 mg/dL) in the absence of antidiabetic medications
Improvement	Statistically significant reduction in HbA1c and FBG not meeting criteria for remission or decrease in antidiabetic medication requirement (by discontinuing insulin or one oral agent, or one half reduction in dose)

Hypercholesterolemia

Improvement	Decrease in number or dose of lipid-lowering agents with equivalent control of dyslipidemia *or* improved control of lipids on equivalent medication
Remission	Normal lipid panel (or specific component being studied) off medication

OSAS

Complete remission	In those patients with preoperative polysomnography (PSG) with diagnosis of OSA, complete remission would be defined as AHI/RDI of < 5 off CPAP/BIPAP on repeat objective testing with PSG.
Improvement Objective	Requires some form of measurable improvement:

Reduced pressure settings on CPAP/BI-PAP as recommended by a sleep medicine provider

Decreased severity of disease on repeat objective testing with PSG (e.g., going from severe to mild). Improved repeat score on screening tool compared with preoperative

Subjective: Patients with preoperative documentation of OSA who have not or will not undergo repeat objective testing with PSG. Document personal or witnessed improvement in sleep hygiene and symptoms of sleep apnea. Have self-discontinued the use of sleep apnea treatment CPAP/BiPAP based on improved symptoms

Table 1 Demographics and comorbidities before surgery

	Overall (101)	Male (45)	Female (56)
Age ± SD	33.4 ± 8.6	33.4 ± 7.6	33.4 ± 9.3
Height (cm) ± SD	170.2 ± 8.4	176.6 ± 6.7	165.16 ± 5.7
Weight (kg) ± SD	117.7 ± 21.8	128.98 ± 22.7	108.66 ± 16.4
Waist (cm) ± SD	127.9 ± 11.3	135.9 ± 8.4	121.5 ± 9.0
BMI ± SD	40.3 ± 4.7	41.1 ± 5.4	39.7 ± 4.0
ABSI ± SD	0.08364 ± 0.005495	0.08634 ± 0.00541	0.08148 ± 0.00456
z_BMI ± SD	2.53 ± 0.9	2.9 ± 1.1	2.1 ± 0.7
z_ABSI ± SD	1.35 ± 1.2	1.8 ± 1.3	0.9 ± 1.0
Comorbidities			
Hypertension (HTA)	27 (26.7%)	10 (22.2%)	17 (30.3%)
Diabetes	15 (14.8%)	6 (13.3%)	9 (16%)
OSAS (with CPAP)	33 (32.6%)	20 (44.4%)	13 (23.2%)
Hypercholesterolemia	10 (9.9%)	3 (6.6%)	7 (12.5%)
Others (arthritis, vascular disease, etc.)	39 (38.6%)	21 (46.6%)	18 (32.14%)

SD standard deviation

Table 2 Demographics and comorbidities at 3-year follow-up. *Z* scores, comparison of bariatric population to NHANES population

	Overall (101)	Male (45)	Female (56)
Weight (kg) ± SD	75.3 ± 11.5	80.4 ± 10.8	71.2 ± 10.4
Waist (cm) ± SD	85.7 ± 9.7	92.6 ± 8.4	80.2 ± 6.7
BMI ± SD	25.9 ± 3.0	25.6 ± 2.3	26.0 ± 3.4
ABSI ± SD	0.07516 ± 0.00573	0.08009 ± 0.003785	0.07119 ± 0.003502
z_BMI ± SD	0.009 ± 0.5489	− 0.03408 ± 0.5330	0.044 ± 0.5637
z_ABSI ± SD	− 0.5498 ± 1098	0.1977 ± 0.9917	− 1150 ± 0.7620
Comorbidities			
Hypertension (HTA)	5 (4.9%)	2 (4.4%)	3 (5.3%)
Diabetes	2 (1.9%)	1 (2.2%)	1 (1.8%)
OSAS (with CPAP)	5 (4.9%)	3 (6.6%)	1 (1.8%)
Hypercholesterolemia	2 (1.9%)	1 (2.2%)	1 (1.8%)
Others (arthritis, vascular disease, etc.)	20 (19%)	12 (26.6%)	8 (14.3%)

SD standard deviation

ABSI and Other Outcomes Definition

We defined ABSI as derived from the NHANES reference population [11]: ABSI ≡ WC/(BMI$^{(2/3)}$height$^{(1/2)}$). In that population, mean ± SD of ABSI was 0.0808 ± 0.0053.

Correlation coefficients of ABSI with height, weight, BMI, and WC in the bariatric population were analyzed and reported in the result section.

Based on NHANES reference data (11), *Z* scores were calculated for the anthropometric variables ABSI and BMI using their population mean and standard deviation stratified by gender and age, for example:

$$\text{ABSI } z \text{ score} = (\text{ABSI}{-}\text{ABSImean})/\text{ABSISD}$$

We computed mortality risk estimates for ABSI and BMI as well as combined ABSI- and BMI-associated risk by ARI as previously defined [12]. ARI expresses the risk of a particular combination of anthropometric measurements (here, ABSI and BMI) relative to average age- and sex-matched general population risk. ARI was estimated here based on approximately 20-year mortality follow-up for the NHANES III US national population sample [12]. Other normalized body measures, such as hip circumference transformed to hip index (HI), may also be included in computing ARI, but here, we only include the effects of ABSI and BMI because hip circumference was not measured in the current cohort. In addition, ABSI and BMI have been found to be the best mortality predictors of those considered so far [12].

Statistical Analysis

The software InStat by GraphPad® Vers. 3.10, 32 bit for Windows (2009) was used to carry out statistical analysis. The Pearson correlations were calculated after normalization of anthropometric values to *z* scores. A two-tailed *t* test was used to match means of paired data, comparing values for the same patients at time 0 and at 3-year distance from surgery. A two-tailed *t* test (Welch corrected) was used to match unpaired

a

Months of follow-up	BMI±SD	%EWL±SD
1	39.8 ± 4.52	8.3 ± 1.02
3	35.4 ± 3.83	27.2 ± 2.06
6	30.2 ± 3.59	56 ± 3.2
12	28.7 ± 4.2	86 ± 15.2
24	26.2 ± 3.9	90.1 ± 6.33
36	25.9 ± 3.0	84 ± 5.8

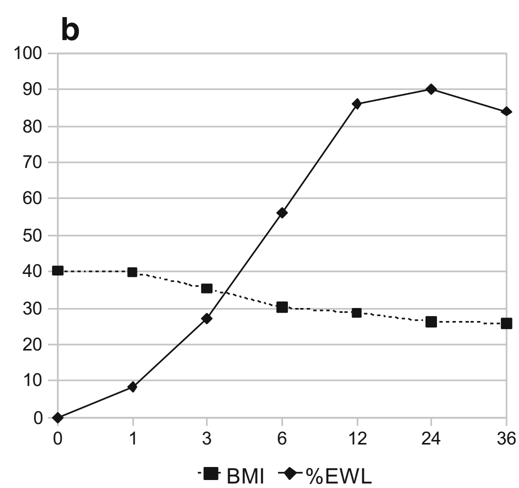

Fig. 1 **a**, **b** Data of follow-up BMI and %EWL. In Fig. 1b, on X axis = months of follow up, on Y axis for BMI = value of BMI as kg/m^2, and Y axis for EWL = % of excess weight loss

Table 3 Correlation coefficients between height, weight, BMI, WC, and ABSI among bariatric population ($n = 101$). Right side (above diagonal) shows correlations of the raw values; left side (below diagonal) shows correlations of the z scores relative to age- and sex-specific means

Baseline					
Overall	Height	Weight	BMI	WC	ABSI
Height	1	0.7762	0.3543	0.699	0.1761
Weight	0.536	1	0.861	0.7876	−0.216
BMI	0.301	0.91	1	0.6169	−0.4570
WC	0.2437	0.881	0.7059	1	0.3855
ABSI	−0.2388	−0.259	−0.2402	0.0566	1
Male	Height	Weight	BMI	WC	ABSI
Height	1	0.693	0.3748	0.4683	−0.3153
Weight	0.6703	1	0.9158	0.7612	−0.7066
BMI	0.3277	0.9311	1	0.7256	−0.7529
WC	0.4422	0.7923	0.7041	1	−0.1385
ABSI	−0.2988	−0.7066	−0.6940	−0.0788	1
Female	Height	Weight	BMI	WC	ABSI
Height	1	0.7377	0.3495	0.4807	−0.052
Weight	0.7356	1	0.8863	0.7084	−0.3
BMI	0.3482	0.8794	1	0.6628	−0.3847
WC	0.459	0.1222	0.6078	1	0.4091
ABSI	−0.0775	−0.035	−0.0590	0.1145	1
3 years					
Overall	Height	Weight	BMI	WC	ABSI
Height	1	0.6729	0.0128	0.5259	0.4179
Weight	0.4705	1	0.7451	0.7851	0.2325
BMI	0.0845	0.7803	1	0.5785	−0.0726
WC	0.009	0.7866	0.5293	1	0.7401
ABSI	−0.2834	0.2684	0.0869	0.7082	1
Male	Height	Weight	BMI	WC	ABSI
Height	1	0.7499	0.2761	0.3159	−0.1591
Weight	0.7355	1	0.841	0.7734	0.0842
BMI	0.2629	0.8755	1	0.8675	0.2513
WC	0.2792	0.7741	0.7658	1	0.6588
ABSI	−0.2086	0.1233	0.3644	0.6707	1
Female	Height	Weight	BMI	WC	ABSI
Height	1	0.452	−0.042	−0.019	−0.3242
Weight	0.4549	1	0.8705	0.7353	−0.3283
BMI	−0.0367	0.8891	1	0.8271	−0.2030
WC	−0.0062	0.7923	0.7455	1	0.3405
ABSI	−0.3078	−0.3354	−0.0258	0.3270	1

data, comparing our sample at time 0 or 3 years with standard population (NHANES III) values.

The Mann-Whitney test was used in order to match quantitative variables of unpaired data. Since the variables studied do not necessarily assume a Gaussian distribution, Wilcoxon matched paired test was used for comparison between 0 and 3-year values. $p < 0.05$ was considered as significant.

Results

A pool of 121 eligible patients was extracted from our database, but 20 were lost to follow-up and excluded. A total of 56 female patients and 45 male were included in the statistical analysis. Demographic variables, including ABSI and ABSI z scores, and comorbidities are reported in Table 1 (time 0 or baseline) and Table 2 (at 3-year follow-up). Furthermore, data concerning BMI variation and % EWL are illustrated in Fig. 1a, b.

The differences between baseline and 3-year ABSI, as well as BMI and WC, were statistically significant ($p < 0.0001$).

At baseline (before surgery), we find also a statistically significant difference ($p < 0.0001$) between our sample and the population mean ABSI from NHANES, with a mean difference of 0.002840 (95% confidence interval (IC) 0.001752 to 0.003928) suggesting an increased ABSI in the bariatric sample population compared to NHANES (normal) population. At 3 years, we also found a statistically significant difference ($p < 0.0001$) in ABSI between our sample and the NHANES population, but this time, the difference was negative, − 0.005640 (IC = − 0.006775 to − 0.004505) suggesting that at 3 years of follow-up, these patients have a lower ABSI-related mortality risk compared to normal population. At 3 years, all patients with higher value of ABSI (excluding one who experienced surgical failure of the procedure) returned in the normal range of ABSI.

We provide the Pearson correlations between anthropometric variables before surgery and at 3-year follow-up (Table 3).

Table 3 shows that at baseline, there is a small but significant correlation between BMI and ABSI ($r = -0.24$, $p = 0.02$). The 3-year correlation is not significant, as expected for independent variables ($r = -0.09$, NS). Table 4 shows significant improvements in all the anthropometric variables and in mortality risk by ARI. Table 5 gives correlations for the difference between year 3 and baseline for ARI, which indicates the

Table 4 Improvement of overall anthropometric risk indexes at 3-year follow-up

	Before surgery	3-year follow-up	p value	Difference significant (S)/non-significant (NS)
BMI risk ± SD	1404 ± 0.2153	0.9272 ± 0.0899	< 0.0001	S
ABSI risk ± SD	1278 ± 0.2789	0.9396 ± 0.1389	< 0.0001	S
ARI risk ± SD	1789 ± 0.5338	0.8650 ± 0.1757	< 0.0001	S

Table 5 Correlation of baseline anthropometrics with observed change in 20-year mortality risk estimate by ARI

Baseline anthropometrics	ARI 3 years—ARI baseline	Correlation S/NS
BMI	0.185	NS
ABSI	− 0.733	S
ARI	− 0.944	S

change in mortality risk for this surgical cohort. Whereas the correlation of change in estimated mortality risk with baseline BMI and with weight loss (change in BMI) is not significant (which may reflect the fact that almost all patients lost large amounts of weight and reached near-normal BMI), ABSI is negatively correlated ($r = -0.73$) and baseline ARI is nearly completely predictive ($r = -0.94$), meaning that patients with initially high ABSI and especially ARI tended to see greater absolute reductions in mortality risk estimated by ARI.

Discussion

ABSI addresses the WHO recommendation for inclusion of waist circumference into health risk evaluation [16]. At present, it is generally accepted that WC is a better indicator of abdominal obesity than BMI [17, 18] with the caveat that visceral fat contributes to metabolic and cardiovascular complication much more than subcutaneous fat [19]. In our sample, WC was found to be drastically reduced by sleeve gastrectomy at 3 years of follow-up ($p < 0.0001$) with a mean reduction of 42 ± 19 (− 45.114 to − 39.262 CI) cm. A key limitation mentioned in the WHO report is that WC is sensitive to body size (BMI) as well as body fat distribution. In general, the use of WC in an obese population is not well established, as its correlation with BMI is high, and almost all patients who are classified as obese by BMI also have above WHO threshold WC [20]. On the other hand, ABSI normalizes WC so that the correlation with BMI is small or negligible.

Since 2012, when Krakauer and Krakauer [11] described ABSI to render WC statistically independent from BMI and height, at least 70 studies have researched ABSI, but to our knowledge, there are no studies applying ABSI in the bariatric surgery context. As a simple and very inexpensive anthropometric tool, ABSI may predict diabetes and hypercholesterolemia risk and remission [21] and is associated with the components of the metabolic syndrome [22]. One would expect that when combined with BMI as a complementary measure through the ARI methodology, ABSI should be especially useful.

ABSI is a risk factor for premature mortality in general populations, with higher values associated with higher mortality hazard. Furthermore, it has little correlation with height, weight, and BMI in normal populations and a moderate correlation with WC [11]. In our bariatric sample, we found moderate to weak correlation of ABSI with WC, height, and weight at baseline. ABSI had a moderate negative correlation with BMI at baseline (particularly in men), which is unexpected considering its near-independence from BMI in the general population. However, the low correlation of BMI and ABSI at 3 years fits with expectation.

The most important finding of our study is the effect of bariatric surgery on ABSI and especially the decrease in the mortality risk by ARI at 3-year follow-up. On average, after sleeve gastrectomy, the elevated pre-op ABSI and ARI returned to normal or lower than population mean values at 18 months from surgery (range 17–19 months) (see Fig. 2a, b).

Moreover, our results imply that there are likely a large number of individuals whose BMI is in the range of 35 to 39.9 with increased ABSI, in which case they might benefit from bariatric surgery even without established comorbidities such as diabetes or hypertension. This implies that if a goal of bariatric surgery is to decrease obesity-related mortality risk

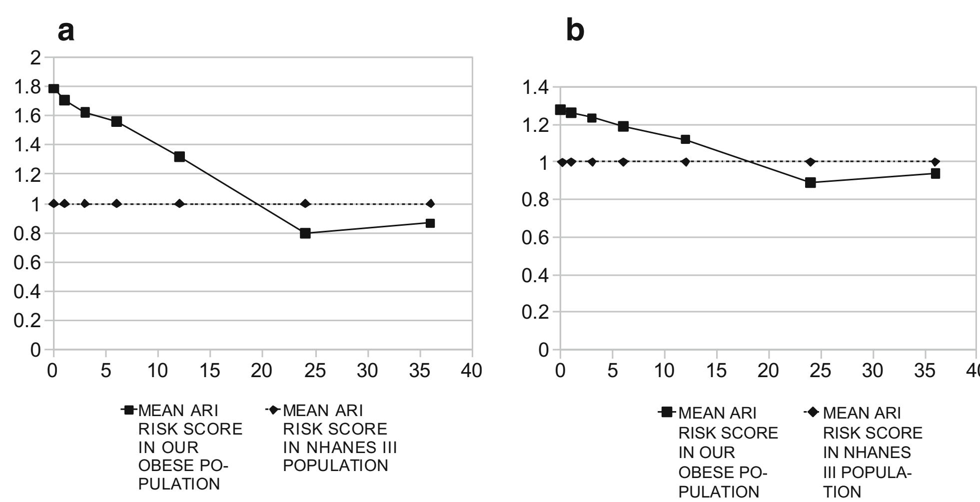

Fig. 2 **a**, **b** The variation of mean ARI and ABSI attributable mortality hazard during our follow-up compared to mean values of NHANES III cohort. These scores are normalized so that their mean in the US general population sample (NHANES III) is 1. Note that from about 18 months (range 17–19 months) after surgery, mean estimated mortality hazards in the operated bariatric population are lower than the general population mean

(ARI), the calculation of baseline ARI can help identify the patients who are likely to benefit most. Our findings support that pending further research that ABSI and ARI might be of value in assessing indications for bariatric surgery.

An observational result is that if we consider an upper value for the normal ABSI range as $0.0808 + 0.0053 = 0.0861$ (1 standard deviation above the general population average), out of 101 patients in which bariatric surgery was formally indicated by actual guidelines, 35 had ABSI above the cutoff value. Of these, only seven had a BMI > 40, suggesting that there is a large part of population of candidates to bariatric surgery whose BMI is in the range of 35 to 39.9 but which has an increased ABSI-related mortality risk. However, a study of a larger cohort of patients with BMI 35–40 without comorbidities and undergoing bariatric surgery is necessary to draw a confident conclusion.

Limitations

The main limitations of this study are the sample size and 3-year follow-up period, such that actual long-term survival could not be ascertained. A larger population and longer follow-up period are necessary in order to have more definitive results.

Conclusion

ABSI is an index based on simple anthropometrics that predicts mortality risk independently from BMI in general and obese populations. After 3 years, we found that sleeve gastrectomy improves ABSI scores. Mortality risk estimated from ARI, which combines risk associated with both BMI and ABSI, also decreases. Obese patients at baseline in our study averaged higher ABSI score and ARI mortality risk than the NHANES US population sample, while at 3 years after surgery, their average scores were actually lower than the NHANES reference. In addition, we find that baseline ARI 20-year mortality risk appears to be an excellent predictor of risk reduction at 3 years post sleeve gastrectomy.

Our results suggest there may potentially be a large population with BMI in the range of 35 to 39.9 and elevated ABSI who may derive long-term benefit from bariatric surgery. However, any change to current indications for bariatric surgery must await confirmatory studies across surgical centers and large numbers of patients.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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