Original Article

Effect of COVID-19 pandemic on hospital admission rates of patients with malnutrition and/or neuromuscular complications after bariatric surgery

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ABSTRACT

الأهداف: تقييم ومقارنة معدلات الدخول للمستشفى بسبب المضاعفات الطبية (MC) بعد جراحة السمنة والأيض (BMS) على مدى 6 سنوات قبل وأثناء الجائحة. يمكن أن يرتبط BMS بـ MC، وتشمل على سوء التغذية والمضاعفات العصبية العضلية (NC).

المنهجية: أجريت دراسة بأثر رجعي لجميع المرضى الذين تم إدخالهم إلى مستشفى حمد العام ، قطر، مع مضاعفات الطبية بعد إجراء BMS قبل فترة الوباء وأثناء فترة الوباء (العدد = 12، يناير 2014م– ديسمبر 2019م) وأثناء الوباء (العدد=36، يناير 2020م– 31 مايو 2021م). قمنا بتقييم 17 عنصرًا غذائيًا، والتوصيل العصبي/التخطيط الكهربائي للعضل الذي تم تشخيصه في NC، واستكشفنا ما إذا كان المرضى لديهم مجموعة من الأعراض المعدية المعوية، أو نتائج وجبة الباريوم، أو نسبة فقدان الوزن الزائد (EWL%)، أو عدم الامتثال لزيارات العيادة بعد BMS ومكملات الفيتامينات المتعددة.

النتائج: اشتملت العينة على 95.8% من عمليات تكميم المعدة، وكان متوسط العمر 26.62 سنة، و 54.2% من النساء. زاد القبول من 0.29 لكل 100 BMS قبل الجائحة إلى 11.04 أثناء الجائحة (p<0.0001)، على الرغم من عدم وجود فروق ذات دلالة إحصائية في الخصائص الديموغرافية/الجراحية للمرضى، ونقص المغذيات، أو خصائص MC. عبر العينة، كانت الاعتلالات العصبية الأكثر شيوعًا مختلطة الحسية/الحركية/المحور العصبي؛ لوحظ نقص الألبومين والبروتين الكلي في 54.2% و 29.2% من المرضى على التوالي (لا توجد فروق قبل الجائحة/الجائحة). وكان النقص الأكثر شيوعًا في المغذيات الدقيقة والعناصر النزرة هو البوتاسيوم وفيتامين د والزنك (لا توجد فروق في فترة ما قبل الجائحة / الجائحة). كان لدى المرضى الذين تم قبولهم نسبة عالية من عدم الامتثال لمكملات الفيتامينات المتعددة (87.5%)، ارتفاع الغثيان 66.7%/القيء بعد BMS 62.6%، نسبة EWL عالية (mean=74.19±27.84%)، لايوجد متابعة للمرضى الخارجيين بعد BMS أعلى (75% أثناء فترة ما قبل الجائحة، و 88.9% أثناء الجائحة) (لا توجد فروق في فترة ما قبل الجائحة/الجائحة للجميع)، والارتجاع المعدي المريئي (أعلى أثناء الجائحة، p=0.016).

الخلاصة: على الرغم من انخفاض عدد BMS أثناء الجائحة، فقد زاد دخول المستشفى بشكل ملحوظ.

Objectives: To assess and compare the admission rates of medical complications (MC) after Bariatric and metabolic surgery (BMS) over a period of 6 years prior to and during the pandemic. Bariatric and metabolic surgery could be associated with MC, including malnutrition and neuromuscular complications (NC).

Methods: Retrospective study of all patients admitted to Hamad General Hospital, Qatar, with post-BMS MC before (n=12, January 2014-December 2019) and during the pandemic (n=36, January 2020-31 May 2021). We assessed 17 nutrients, nerve conduction/electromyography diagnosed NC, and we explored whether patients had clustering of gastrointestinal symptoms, barium meal findings, excess weight loss percentage (EWL%), or non-compliance with post-BMS clinic visits and multivitamin supplements.

Results: The sample comprised 95.8% sleeve gastrectomies, mean age was 26.62 years, and 54.2% were women. Admissions increased from pre-pandemic 0.29 per 100 BMS to 11.04 during the pandemic (p<0.0001), despite no significant differences in patients' demographic/surgical profiles, nutrient deficiencies, or MC characteristics. Across the sample, the most frequent neuropathies were mixed sensory/motor/axonal; albumin and total protein deficiencies were observed in 54.2% and 29.2% of patients, respectively (no pre-pandemic/pandemic differences). Most frequent micronutrient and trace element deficiencies were potassium, vitamin D, and zinc (no pre-pandemic/pandemic differences). Admitted patients had high non-compliance with multivitamins supplementation (87.5%), high post-BMS nausea/vomiting (66.7%, 62.6%, respectively), high EWL% (mean=74.19±27.84%), no post-BMS outpatient follow up (75% during pre-pandemic, 88.9% during pandemic) (no pre-pandemic/pandemic differences for all), and gastroesophageal reflux (higher during the pandemic, p=0.016).

Conclusion: Despite the reduced number of BMS during the pandemic, hospital admissions of MC significantly increased.

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Obesity is a chronic condition that can lead to serious metabolic and cardiovascular diseases.[1] Bariatric and metabolic surgery (BMS) is an effective long-term management strategy for obesity and its related comorbidities, with low morbidity and mortality.[2-6] Therefore, the numbers of BMS has steadily increased over the years.[7-9] However, BMS can be associated with medical complications (MC), such as macro/micronutrient deficiencies and neurologic complications.[10,11] Bariatric and metabolic surgery modifies the anatomy and physiology of the gastrointestinal tract to different extents.The resultant malabsorption and gastric upset lead to inadequate food intake and reduced compliance to macro/micronutrient supplementation, resulting in neuromuscular complications of various severities in 2%-16% of patients.[12-24] Protein malnutrition (mainly hypoalbuminaemia) is a major marker of post-BMS complications that may require hospitalisation.[12,13,25]

The global COVID-19 pandemic declared in March 2020 disrupted face-to-face outpatient encounters.[26,27] Measures were applied at our institution to ensure that post-BMS patients received adequate follow-up care. To decrease the risk of viral transmission, elective surgery was limited or postponed, clinic visits were converted to telephone consultations, and postal delivery of multivitamins and other medications was initiated, although hospital blood tests to monitor nutritional deficiencies were allowed.[28-30]

Many health registries across the world documented a decline in the rate of non-COVID-19 hospital admissions during the lockdown compared with the pre-pandemic levels. In Denmark, admissions of all major non-COVID-19 disease groups decreased,[31] and in Qatar, admission rates of stroke were reduced, possibly due to anxiety about hospital settings and fear of viral exposure.[32,33] Conversely, admission rates for alcohol misuse, overdoses, and psychiatric conditions increased during the pandemic.[34]

Sparse BMS research has been conducted with regard to the pandemic. Examples include the pandemic's impact on patients' health, BMI, use of energy-dense food, gastric bypass outcomes, and weight loss 1 year after BMS.[35-39] However, hospital admission rates due to MC after BMS before and during the pandemic have not yet been examined. This is despite the fact that malnutrition and neuromuscular complications are time-sensitive, require urgent attention, might necessitate prolonged hospitalisation, and could lead to disability that requires extended rehabilitation.[40,41] Generally, concerns have been voiced over delays in time-sensitive management during the pandemic.[42]

The literature reveals gaps in knowledge. The MC among post-BMS patients have been previously examined.[43,8] However, these studies suffer several limitations. First, in terms of the type of patients, both studies examined outpatients only and retrieved their cases from the Neurophysiology Unit of a tertiary care hospital in Kuwait and from the Neurology Unit at King Abdulaziz Medical City, Saudi Arabia. Hence, both studies seem not to have accounted for inpatients, and also do not account for any patients with MC post-BMS that might have been treated in the bariatric units. Second, in terms of the breadth of the clinical parameters that were appraised, no study reported on the length of stay or whether rehabilitation services were required.[43,8] Another study[14] examined the neurologic manifestations of vitamin B deficiency after BMS and reported that out of a total of 47 patients, only 7 needed admissions; however, the study did not report on the length of stay or whether rehabilitation services were required, given that prolonged hospitalisation is usually necessary for such patients. Third, in terms of biochemical examination pertaining to the breadth of the investigation, published studies seem to have had a narrow focus instead of the holistic and broad biochemical examination required in such studies of deficiencies, e.g., protein-related, micronutrient, vitamin, and trace element deficiencies. For instance, one study reviewed only the available nutritional laboratory results (B1, B12, B9, vitamin D, and copper).[8] Another study reported that 'limited blood nutritional assessment was undertaken', where they assessed only 5 micronutrients (B12, folate, vitamin D, copper, B1-erythrocyte transketolase).[43] One study evaluated only vitamin B (B1, B6, B2, B12).[14] Fourth, in terms of time span and duration of investigation, some studies were of a short period of time, for example, patients referred between May 2014-April 2015.[8] Fifth, none of the studies[43,8,14] undertook comparisons of COVID-19 and pre-COVID-19 periods, as well as comparisons of admission rates during these periods.

Therefore, the current study bridges these knowledge gaps. We assessed and compared the admission rates of MC after BMS over a period of 6 years prior to and during the pandemic. The study included all patients hospitalised for the conditions under examination.

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Biochemically, we performed comprehensive blood nutritional assessments of a very broad spectrum of macro/micronutrients, including macronutrients (albumin, total protein), micronutrients (7 vitamins, B1, B6, B12, D, A, K, folate), 5 minerals (iron, potassium, calcium, phosphorus, magnesium) and 3 trace elements (copper, zinc, selenium). We categorised MC by type of macro/micronutrient deficiency and neuropathy, and appraised whether certain characteristics clustered in such patients. Clinically, we reported on the length of hospital stay or whether rehabilitation services were required. The appraisal of the effects of pandemics on admission rates of potentially disabling MC provides important knowledge pertaining to time-sensitive healthcare delivery.

Methods.

Ethics, study design, setting, and participants. We retrospectively reviewed the charts of patients available in the Bariatric Surgery/ Medicine database at Hamad General Hospital in Qatar which was started in 2014. Patients of any age admitted to our institution because of BMS-related MC (that is, malnutrition and/or neuromuscular) within the duration of the database (≤7 years after surgery) were included. The exclusion criteria were: 1) non-BMS-related malnutrition (inflammatory bowel disease, celiac disease, protein-losing enteropathy); and 2) non-BMS-related neuromuscular conditions (Guillain Barre syndrome, myasthenia graves, chronic inflammatory demyelinating polyneuropathy, disc prolapse and related myelopathy, alcoholism), endocrinological (hypothyroidism, Cushing disease), rheumatological (rheumatoid arthritis, systemic lupus erythematosus), or medication-related conditions (steroids, statins).

We assessed the levels of 17 nutrients (7 macro/micronutrients, 7 vitamins, and 3 trace elements). **Table 1** depicts the definitions used for malnutrition and neuromuscular complications.[44,45] We examined data for the period of January 2014-31 May 2021, categorised into 2 intervals: pre-COVID-19 (January 2014-December 2019, n=12 patients) and COVID-19 (January 2020-31 May 2021, n=36 patients). Hence, 48 patients were eligible for inclusion in this analysis.

Admission rates and variables under examination. To calculate admission rates, we retrieved data on the total number of BMS undertaken (denominator) and the number of admissions due to BMS-related MC (numerator) in the pre-pandemic and pandemic periods. We also collected data on demographics, type and date of procedure, pre-BMS (baseline) weight and BMI, weight loss, interval between surgery and admission, length of stay during admission (LOS), and whether patients were subsequently referred to in-hospital physiotherapy and/or occupational therapy. To explore the characteristics of patients with MC, we retrieved barium meal data and information on post-surgery gastroesophageal reflux disease (GERD), nausea/vomiting, excess weight loss percentage (EWL%), and number of visits to the bariatric clinic during the first year after surgery. Compliance with multivitamin supplements was assessed by retrieving data about whether patients took their supplements at least 5 times per week in the last 2 months prior to admission.

Ethical considerations. This study was approved by the ethics committee of the Medical Research Centre (IRB) at our institution (MRC-01-20-1007).

Statistical analysis. Descriptive statistics are reported as mean and standard deviation for normal interval variables, and frequency with percentage for categorical variables. Comparisons were undertaken between the pre-COVID-19 (January 2014-December 2019) and COVID-19 (January 2020-31 May 2021) periods. Chi-square tests were used to assess the associations between categorical variables, and the t-test or Mann-Whitney test was used to compare continuous variables. Two continuous variables [length of stay (LOS) and duration from surgery] displayed few outliers; hence, the results were presented as medians and ranges.

Table 1 - Diagnosis of malnutrition and neuromuscular complications after BMS.

Medical complications	Descriptions
Malnutrition[44]	Albumin < 35 gm/L and/or total protein < 66 gm/L ± one or more of: magnesium < 0.7 mmol/L, calcium < 2.1 mmol/L, phosphorus < 0.74 mmol/L, potassium < 3.5 mmol/L, iron < 9 umol/L, vitamin B1 < 66.08 nmol/L, vitamin B6 < 20 nmol/L, folate (B9) < 10 nmol/L, vitamin B12 < 145 pmol/L, vitamin D < 30 umol/L, vitamin A < 1 umol/L, vitamin K < 0.2 ng/mL, copper < 12.6 umol/L, zinc < 10 umol/L, selenium < 70 ng/mL
Neuromuscular*[45]	Abnormal findings of either: MRI (for central lesions) or nerve conduction study (NCS) and/or electro myelography (EMG) (for peripheral lesions) undertaken as in/outpatient

*Diagnosed by neurologists and clinical neurophysiologists based on clinical, laboratory, and electrodiagnostic findings

Table 2 - Characteristics of bariatric patients admitted with medical complications after surgery before and during the pandemic (n=48)

Parameters	Total	COVID-19		*P*-value
		Before	During	
	N=48	n=12	n=36	
Demographic				
Age, years (M±SD)	26.62±10.76	28.50±11.28	26±10.67	0.492
Range	16-62	18-51	16-62	
Gender, female, n (%)	26 (54.2)	4 (33.3)	22 (61.1)	0.94
Anthropometric (M±SD)				
Weight before BMS (kg)	123.04±21.37	128.09±24.67	121.50±20.40	0.377
BMI before BMS (kg/m^2)	44.41±5.37	45.88±5.54	43.96±5.31	0.305
Weight at admission with MC (kg)	85.02±19.37	87±26.34	84.41±17.12	0.900
BMI at admission with MC (kg/m^2)	30.70±5.61	30.95±7.34	30.63±5.64	0.880
Weight loss (kg)	38.02±14.40	41.09±13.87	37.08±14.62	0.426
Surgery				
Type, n (%)				
Sleeve gastrectomy	46 (95.8)	11 (91.7)	35 (97.2)	0.404
Gastric bypass	2 (4.2)	1 (8.3)	1 (2.8)	
Duration from surgery [a], m				0.738
Median	3	3	4	
Range	1-12	1-12	1-12	
Outcomes, n (%)				
Rehabilitation [b]	27 (56.3)	9 (33.3)	18 (66.7)	0.131
LOS during admission with MC, days				0.277
Median	14	15	8	
Range	3-79	3-78	3-79	
Admission rate				
Total number of BMS	4534	4208	326	
Total number of admissions due to MC	48	12	36	*<0.0001*
Admission rate per 100 BMS [c]	1.06	0.29	11.04	*<0.0001*

BMS - bariatric and metabolic surgery, LOS - length of hospital stay, m - months, MC - medical complications. [a] Duration from date of surgery to admission with MC, [b] In-hospital physiotherapy and/or occupational therapy rehabilitation after medical treatment, if required, [c] Admission rate = (number of admissions with MC/total number BMS) × 100, Italicised cells indicate statistical significance.

Admission rates were calculated as [(number of admissions with MC/total number of BMS)×100] for each of the pre-pandemic and pandemic periods. The SPSS 26.0 statistical package was used for the analysis, with p-value<0.05 considered statistically significant.

Literature search. An extensive literature search using appropriate search terms was performed using the PubMed, Scopus, Web of Science, and Science Direct databases to identify relevant publications up to August 2021 pertaining to the subject area under examination. The results suggested few articles published on the topic area, with a noticeable gap in research specifically in hospital admission rates, characteristics, and outcomes of patients admitted with malnutrition and/or neuromuscular complications post-BMS before and during the COVID-19 pandemic.

Results. Characteristics of admitted patients. The 48 patients comprised pre-COVID-19 (n=12, 25%) and during COVID-19 (n=36, 75%) cases (**Table 2**). The sample's mean age was 26.62 years, with women comprising 54.2%; at admission, mean weight loss achieved after surgery was 38.02 kg. Most patients underwent laparoscopic sleeve gastrectomy, with a few gastric bypasses (4.2%). The median interval between surgery and admission was 3 (pre-COVID-19) and 4 months (COVID-19), and the median length of stay (LOS) was 15 (pre-COVID-19) and 8 days (COVID-19). After therapy at the medical floor, 56.3% of patients were referred to a rehabilitation hospital.

Comparisons between the pre-pandemic and pandemic periods showed no differences for any of the variables under examination. The only exception was the admission rate. During the pre-pandemic period,

Table 3 - Neuromuscular and malnutrition characteristics of medical complications of admitted patients

Medical Complications	Total	COVID-19		P-value
		Before n=12	During n=36	
Neuromuscular				
Investigation*				
Not Done	20 (41.7)	6 (50)	14 (38.9)	0.499
Normal	4 (8.3)	1 (8.3)	3 (8.3)	1.0
Abnormal				
Peripheral				
Motor Axonal	2 (4.2)	0 (0)	2 (5.6)	0.404
Sensory Axonal	6 (12.5)	2 (16.7)	4 (11.1)	0.614
Sensory Motor Axonal	13 (27.1)	3 (25)	10 (27.8)	0.851
Sensory Peripheral Neuropathy	2 (4.2)	0 (0)	2 (5.6)	0.404
Central				
Werneck Encephalopathy	1 (2.1)	0 (0)	1 (2.8)	0.560
Malnutrition				
Protein-related				
Albumin	26 (54.2)	8 (30.8)	18 (69.2)	0.316
Protein	14 (29.2)	5 (35.7)	9 (64.3)	0.271
Micronutrient deficiency				
Minerals				
Magnesium	8 (19)	1 (12.5)	7 (87.5)	0.494
Calcium	1 (2.1)	0 (0)	1(100)	0.560
Phosphorus	3 (7.9)	0 (0)	3 (100)	0.315
Potassium	17 (35.4)	4(23.5)	13 (76.5)	0.862
Iron	8 (21.1)	3 (37.5)	5 (62.5)	0.419
Vitamins				
A	16 (66.7)	3 (18.8)	13 (81.3)	0.722
B1	8 (19)	0 (0)	8 (100)	0.127
B6	3 (11.1)	0 (0)	3 (100)	0.719
B9 (Folic acid)	10 (35.7)	6 (60)	4 (40)	*0.046*
B12	1 (2.1)	1 (100)	0 (0)	0.084
D	35 (79.5)	9 (25.7)	26 (74.3)	0.829
K	7 (41.2)	1 (14.3)	6 (85.7)	0.761
Trace elements				
Copper	7 (15.2)	1 (14.3)	6 (85.7)	0.604
Zinc	9 (19.6)	4 (44.4)	5 (55.6)	0.066
Selenium	8 (38.1)	3 (37.5)	5 (62.5)	0.965

Cells represent frequency and percentage n (%) based on the total sample as denominator. *Comprises nerve conduction study, electromyelography or magnetic resonance imaging. Nerve conduction studies/electromyography data was available for 26 of the 48 patients. Italicised cells indicate statistical significance. Reference values for malnutrition or deficiency: albumin 35-50 gm/L, total protein <66 gm/L, vitamin B1<66.08 nmol/L, vitamin B6 <20 nmol/L, vitamin B12 <145 pmol/L, vitamin D <30 umol/L, copper <12.6 umol/L, folate <10 nmol/L, zinc <10 umol/L, iron <9 umol/L, TIBC (total iron binding capacity) <45 umol/L, potassium <3.5 mmol/L, calcium <2.1 mmol/L, phosphorus <0.74 mmol/L, magnesium <0.7 mmol/L.

12 patients were admitted out of 4208 cases of BMS performed during the same period, generating a rate of 0.29 per 100 BMS; during the pandemic, 36 patients were admitted out of 326 cases of BMS, significantly increasing the admission rate to 11.04 per 100 BMS (p-value <0.0001).

Medical complications: types and characteristics. **Table 3** shows that the most frequent types of neuromuscular complications were mixed sensory/motor/axonal (13 patients), followed by sensory/axonal involvement (6 patients); other types were less represented. There was one case of a central neurologic

Table 4 - Characteristics common among bariatric patients admitted with medical complications.

Factors	Total	COVID-19		*P*-value
		Before	During	
	N=48	n=12	n=36	
Clinical				
Post-BMS nausea	32 (66.7)	8 (66.7)	24 (66.7)	1
Post-BMS vomiting	30 (62.6)	7 (58.3)	23 (63.9)	0.731
Multivitamin non-compliant	42 (87.5)	12 (100)	30 (83.3)	0.131
EWL% (M±SD)	74.19±27.84	75.12±26.81	73.91±28.52	0.901
Barium Meal				
Not Done	8 (16.7)	1 (8.3)	7 (19.4)	0.371
Normal	19 (39.6)	10 (83.3)	9 (25)	*<0.0001*
Anastomotic ulcer	1 (2.1)	0 (0)	1(2.8)	0.560
Gastritis	2 (4.2)	0 (0)	2 (5.6)	0.404
GERD	18 (37.5)	1 (8.3)	17 (47.2)	*0.016*
Number of clinic visits after surgery				0.247
0	41 (85.4)	9 (75)	32 (88.9)	
1	5 (10.4)	2 (16.7)	3 (8.3)	
2	1 (2.1)	0 (0)	1 (2.8)	
3	1 (2.1)	1 (8.3)	0 (0)	

All cells represent frequency and percentage n (%) based on the column header as denominator, except where indicated. BMS - bariatric and metabolic surgery, GERD - gastroesophageal reflux disease, EWL% - excess weight loss percentage. Italicised cells indicate statistical significance

complication (Wernicke encephalopathy). Protein malnutrition in terms of albumin and total protein deficiencies was observed in 54.2% and 29.2% of the patients, respectively. The highest percentage of micronutrient deficiencies was for potassium (35.4%), iron (21%), and magnesium (19%). Vitamin deficiency was highest for vitamin D (79.5%), vitamin A (66.7%), and B9 (folic acid, 35.7%). Trace element deficiencies were highest for zinc (9%), selenium (8%), and copper (7%). Comparisons between the pre-COVID-19 and COVID-19 periods showed no differences in any of the variables under examination, with the exception of folic acid deficiency, which was significantly higher during the pandemic (*p*-value=0.046).

Across the sample, the characteristic most prevalent with MC was non-compliance with prescribed multivitamin supplementation (87.5%), followed by post-BMS nausea and vomiting (66.7% and 62.6%, respectively) (**Table 4**). Barium meal showed other potential characteristics, including gastroesophageal reflux disease (GERD) (37.5%), while a few patients had gastritis or anastomotic ulcer (4.2% and 2.1%, respectively). For other potential risk factors, the mean EWL% of the sample was 74.19±27.84%, and most patients (85.4%) reported no clinic visits/telephone conultations after surgery. There were no differences between the pre-pandemic and pandemic periods across most characteristics examined. An exception was that GERD was significantly higher during the pandemic (*p*=0.016). Conversely, normal barium meal findings were significantly higher in the pre-pandemic period (83.3% vs. 25%, *p*-value <0.0001).

Discussion. This study, to our knowledge, is the earliest to compare the admission rates of post-BMS patients with MC before and during the COVID-19 pandemic. We observed a significant many-fold increase in hospital admissions during the pandemic (rate of 11.04 per 100 BMS during COVID-19 vs 0.29 in the pre-pandemic period, *p*<0.0001). Such findings concur with the increased admissions during the pandemic for drug misuse, psychiatric conditions, and alcohol-related mental/behavioural disorders elsewhere,[34] conditions that require behavioural modification therapy as a cornerstone in their prevention and management.

Admission rates were computed using a numerator and dominator; hence decreases in the denominator and/or increases in the numerator lead to increased rates. Accordingly, 3 main features might have contributed to the observed increase in admissions during the pandemic. These include an element that decreases the denominator, the sudden stoppage of BMS; and two

elements that increase the numerator, the sudden halt of face-to-face consultations and changes in patients' health behaviour/health care utilisation behaviour during the lockdown.

In terms of the first element, in line with global measures, BMS (elective surgery) was suddenly stopped at our institution, leading to a steep reduction from 4208 surgeries during the pre-pandemic period to 326 surgeries during the pandemic. This sharp decrease in the denominator contributed to an increase in the computed admission rate.

Regarding the second feature, non-essential appointments were postponed to reduce viral transmission, and face-to-face hospital encounters were substituted by telemedicine.[46,47,48] Despite its benefits, telemedicine has limitations.[49,50] Not all patients are familiar with telemedicine; they might not explain all their complaints or might feel distanced, thus delaying their health consultation, and physicians are unable to examine the patient or deliver motivational interviews and mindfulness.[51-56] Telemedicine can impede the relationship between health professionals,[52] making it less suitable for cases that require multidisciplinary care.[57] Collectively, such limitations could result in patients' low awareness of the services available during the lockdown (for example, postal delivery of medications or supplements), delayed presentations/discovery of important signs, and low delivery of behavioural/educational interventions to motivate patients to adhere to interventions and supplemental instructions. These aspects could result in more patients with MC, thereby increasing the numerator and admission rates. Such findings concur with the fact that the increased admissions witnessed globally during the pandemic seem to be primarily for conditions that require behavioural modifications in their prevention and management (drug misuse, psychiatric, alcohol-related mental/behavioural disorders).[34,46]

In terms of the third reason, during the lockdown, patients' health behaviour might have been negatively influenced, leading to worsened dietary quality compromising the nutrients and vitamins needed for nerves and muscles.[35,47,58-60] Likewise, patients' healthcare utilisation behaviour changed, as many elected not to turn up for clinic appointments due to fear of infection, missing their scheduled nutritional workups and blood tests, and not seeking medical advice until symptoms turned severe.[32,47,61] Negative changes in patient health behaviour could lead to a decrease in the factors that contribute to the prevention of MC, while negative changes in patients' health care utilisation behaviour could lead to delayed investigations and diagnosis and possibly delayed initiation of urgently needed treatment. These features increase the numerator and admission rates.

In terms of the demographics, most of our admitted patients were young (mean age 26.62±10.76 years), consistent with pre-pandemic research of post-BMS patients with neuropathic complications elsewhere (mean age 32.8-37.1 years).[8,43] Younger patients might be less compliant with vitamin supplements[62] and thus prone to post-BMS potentially disabling neurological complications. We found no sex differences before and during the pandemic, consistent with a pre-pandemic study of post-BMS outpatients with peripheral neuropathies.[43]

As for anthropometry, we observed no difference in the weight loss (WL) of admitted patients before and during the pandemic, supporting prior research.[39] A point to note is that our patients had both rapid (≈38.02±14.40 kg within 1 year after BMS) and significant WL (admission weight was significantly less than pre-BMS weight, p-value<0.0001). These findings are consistent with those of other pre-pandemic studies. Rapid WL was a risk factor for post-BMS neuropathy; and post-BMS patients with neuromuscular complications/neuropathy had either rapid or rapid and significant WL (mean WL 35.8±11.1 kg).[43,40,63] The links between significant rapid WL and neuromuscular complications are probably due to gastrointestinal upset, poor oral intake, and non-compliance with multivitamins.[19,43]

In connection with the bariatric procedure, we observed no difference among patients admitted before and during the pandemic by type of BMS. Most of our sample (95.8%) had sleeve gastrectomies (SG), consistent with others, in which 88% of patients with post-BMS neuromuscular complications had SG.[8] Evidence suggests a malabsorptive component in SG, as its benefits exceed those of only a smaller stomach, with improvement in obesity-related comorbidities that are superior or comparable to those of other restrictive procedures.[64] After SG, there is a risk of multivitamin/mineral deficiencies due to poor food choices, food intolerance, microbiota changes, decreased hydrochloric acid, and intrinsic factors leading to B12 malabsorption.[11,65-69]

Regarding length of hospital stay, we found no differences before and during the pandemic. Patients with MC usually require prolonged hospitalisation for acute treatment, frequently followed by rehabilitation (56.3% of our sample underwent hospital

rehabilitation). The median LOS was longer in the pre-pandemic group, but the difference was not statistically significant (15 vs. 8 days, *p*-value=0.277). Shorter stays during the pandemic might be due to our protocols, which included early parenteral multi-nutrients, early referral to hospital rehabilitation, and early discharge to minimise viral transmission. No comparable data exist; others reported only outpatients with neuropathies or did not report LOS. However, a case report included prolonged hospitalisation due to post-BMS foot drop.[8,43,63,68]

Peripheral neuropathy is a common neuromuscular complication of BMS.[41] Among the current sample, mixed sensory/motor/axonal peripheral neuropathies were the most common, consistent with other reports where all or most post-BMS patients with peripheral neuropathy were axonal or axonal sensory/predominant-sensory.[23,43,69] Multiple micronutrient deficiencies frequently coexist, causing neurological complications after BMS.[5,15,20] Malnutrition and neuromuscular complications are not unrelated.[43] Post-BMS patients can develop protein malnutrition/low serum albumin as well as deficiencies in vitamins B1, B6, B9, and B12, which are vital for peripheral nerves, due to decreased oral intake, protein intolerance, prolonged vomiting, and fear of weight regain.[13,70,71] Hence, multidisciplinary intensive nutritional management and follow-up may decrease the development of peripheral neuropathy.[70]

In terms of the characteristics of patients with MC, we found no difference between patients admitted before and during the pandemic. Our observations agree with others; with regard to imaging findings, we found no stenosis, supporting other research among post-SG patients with neurological complications.[63] Likewise, in our sample, barium meal diagnosed GERD most frequently (37.5%), concurring with the fact that GERD was common before neuromuscular complications.[62] With regard to the clustering of nausea and vomiting, we observed gastric upset, for example, nausea (66.7%) and vomiting (62.6%), consistent with the high percentage of nausea and vomiting among post-BMS patients with neuromuscular complications.[43] Recurrent vomiting episodes and excessive WL are the most likely reasons for the depletion of vitamin stores.[12] In addition, most of our patients were noncompliant with multivitamins (no significant difference before and during the pandemic), which is in agreement with other studies.[43,70] We concur that low compliance could be patient-related (age) and BMS-related (postoperative complications and gastrointestinal complaints).[19,62] Hence, appropriate education of patients on post-BMS eating habits (for example, liquid, soft then solid tender food, small bites, chewed well, eaten slowly) could improve their intake and contribute to less gastric upset, reducing the risk of neuromuscular disorders.[70]

In the pre-pandemic period, a large proportion of our sample had no clinic visits to our institution during the first year after BMS, which was higher than the numbers reported by others (27.7%) during the first year after BMS in the pre-pandemic period.[8] For the pre-pandemic period, the explanation could be that many patients (particularly nationals) might have sought follow-up at private clinics instead of at our institution (a public facility); in addition, most of our patients were young and less adherent to clinic visits, as non-adherence is greater among younger patients.[72] During lockdown, fewer clinic visits may be expected as most of these were substituted by telephone consultations. Our patients were inpatients admitted with MC, suggesting that their symptoms were severe (possibly due to their low adherence to clinic visits/telephone consultations). Other studies examined outpatient samples,[8] which could be of less severity. This generally highlights the value of post-BMS outpatient follow up where multidisciplinary comprehensive evaluations, laboratory nutritional workups, and compliance with multivitamins and dietary instructions are conducted to prevent nutritional complications.[12]

Study limitations. This study has some limitations. Retrospective studies suffer from the quality of the available data. Our sample size was modest, comprising 12 patients before vs. 36 patients during COVID-19. These were all the patients we encountered during the two time periods that satisfied the inclusion criteria, that is, patients admitted to our institution due to BMS-related MC (malnutrition and/or neuromuscular). However, our modest number of patients is not entirely surprising, given that globally, such post-BMS patients with neuropathy and/ or malnutrition (whether as in- or outpatients) are scarce, ranging between only 2-16% of patients across 13 studies.[12-24] In addition, very few publications explicitly state whether they assessed hospitalised patients; for example, out of these 13 studies, 12 did not report whether their findings were related to inpatients or outpatients[12,13,15-24] An exception was a study that examined the neurologic manifestations of vitamin B deficiency after BMS and reported that out of a total of 47 patients, only seven needed admissions.[14] Likewise, protein malnutrition associated with BMS has a very low annual hospitalisation rate of 1%.[12] These examples demonstrate the relative scarcity of such admitted patients. Collectively, the

small fraction of patients that were admitted might explain the small sample sizes. Future research would benefit from addressing these limitations. Nevertheless, the differences in admission rates before and during the pandemic were large and significant. Information about the patients' dietary habits after BMS would have been useful,[73] as food tolerance, portion size, and micronutrient-poor diet could affect nutrient levels[35,70] and neuromuscular integrity.[8,43] Our computed admission rates for the periods under examination could be overestimated, as BMS is frequently undertaken in private clinics and medical tourism overseas, and such numbers are difficult to estimate; hence, they might not be captured in the denominators used to compute our admission rates before and during the pandemic. If added to the denominators, these additional BMS numbers would slightly reduce the admission rates.

This study had several strengths. Others did not compare the changes in the admission rates of post-BMS patients with MC before and during the pandemic.[8,43] Patient data were obtained from our updated inpatient database, and our institution is the largest tertiary care facility equipped to manage post-BMS neurological and nutritional insults. Other studies on post-BMS neuropathy were among outpatients who could represent less severe cases,[8,43] assessed patients with neurological complications regardless of whether the aetiology was BS-related or otherwise,[43] appraised few vitamin/trace elements as causes of MC,[8,16,69] and seem not to have undertaken upper gastrointestinal tract imaging (barium meal) or reviewed such findings in detail.[8,43] We examined 7 macro/micronutrients, 7 vitamins, and 3 trace elements, categorised by the type of micronutrient deficiency and neuropathy, and assessed barium meal findings as risk factors to shed light on the potential causes of MC. These findings provide new insights into a thin evidence base.

In conclusion, during the pandemic, admissions for post-BMS malnutrition and/or neuromuscular complications significantly increased despite no significant differences in patients' demographic and surgical profiles, their identified nutrient deficiencies, or the characteristics of their MC. Most admitted cases included young patients with significant WL within a relatively short period associated with gastrointestinal symptoms which possibly resulted in severe non-compliance with multivitamin supplementation, leading to nutrient deficiencies and neuromuscular complications. The MC after BMS are preventable; hence, younger patients and their family members might warrant life-long preventive measures, including multidisciplinary team pre/post-BS education about the risks that lead to MC and how to avoid them, as well as nutritional assessment and monitoring.

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