Nutritional Status of Sleeve Patients, Micronutrients and Vitamins: Post-op

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1 Introduction

The preoperative nutritional status of patients undergoing sleeve gastrectomy (SG) has already been discussed in the previous chapter and represents at least one precondition for the postoperative nutritional status.

In addition, postoperative specific changes such as the limited oral intake, emerging food intolerances, and possible malabsorption in the short and long term have further impact on the postoperative nutritional status. Studies have shown that the most affected micronutrients after SG are **iron, thiamine, folate, vitamin B12,** and **vitamin D** [1]. It seems that the nutritional consequences of SG are fundamentally different from that of bypass surgery. Bypass surgery excludes the duodenum from food passage, which is the major absorption site for minerals, with resulting respective resorption limitations.

SG differs fundamentally. This procedure exclusively modifies the anatomy of the stomach by reducing its extensible volume along the "Magenstrasse" by about 90%. Thus, the cause of possible postoperative deficiency symptoms may be explained with anatomical and physiological alterations of the stomach.

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2 Effect on Vitamin B12

SG involves, in particular, the resection of the fundus and the largest part of the corpus, while the volume of the antrum is only marginally diminished [2]. Thus, the parietal cells that produce acid and **intrinsic factor** are drastically reduced in number (Fig. 1), while the number of gastrin-producing antral G cells remains only slightly reduced.

The intrinsic factor forms a complex with **vitamin B12** (cobalamin) ingested from food, thus enabling its absorption. Subsequently this certainly plays an influential part after SG on the absorption of vitamin B12. Vitamin B12 cannot be synthesized by the body itself and must therefore be gained through food. As it is sensitive to acids, it is first attached to haptocorrin secreted by the parotid glands and thus protected from the acidic pH of the stomach. Haptocorrin is then split off from vitamin B12 in the alkaline milieu of the duodenum by pancreatic proteases and further linked to intrinsic factor. This complex formation between vitamin B12 and the intrinsic factor is essential for its absorption which is mediated by the cubam receptor complex in the terminal ileum [3–6].

3 Effect on Iron

Furthermore, volume reduction can interfere with **iron** absorption. The human organism utilizes both bivalent (Fe2+) and trivalent (Fe3+) iron ions, only divalent iron is able to be absorbed directly, whereas trivalent iron needs to be converted into bivalent ions. A distinction is made between heme–iron, which is

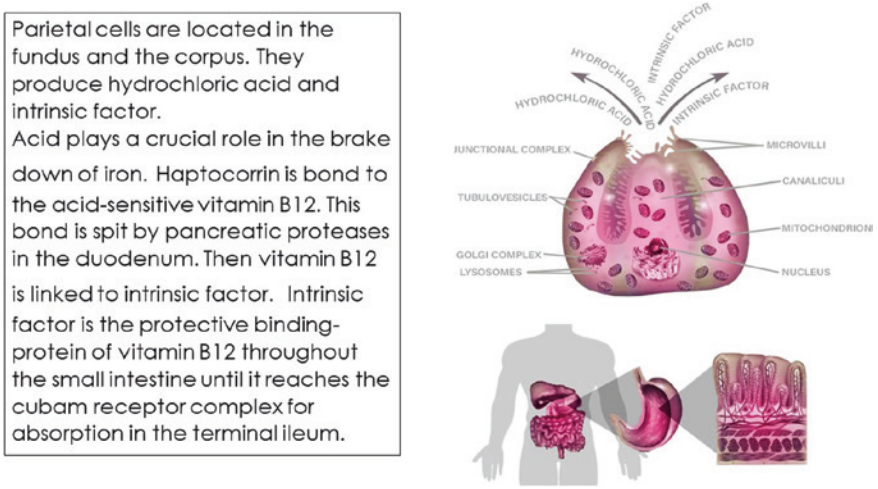


Fig. 1 Parietal cell of the stomach

present as bivalent iron protoporphyrin, and non-heme iron, which is present as free ionized iron bivalent or trivalent iron. Since Fe3+ and Fe2+ are basically firmly bound to food proteins, the breakdown of the proteins by special digestive enzymes such as pepsin is a prerequisite for the absorption of iron. If there is sufficient gastric acid (HCl) production in the stomach, this breakdown is ensured. The amount of gastric acid production is modified after SG, as well. Thus, another influence of the remaining petite gastric volume with thereby reduced acid and pepsin production on the absorption behavior of iron can be supposed. However, usually SG only marginally affected the antrum with its gastrin-producing G-cells. Gastrin is a peptide hormone and is the strongest stimulus for the production of gastric acid, but the interaction between the surgical significantly increased numbers of parietal cells at almost the same number of G-cells in SG still remains unclear [4, 7, 8].

4 Effect of Volume Reduction on Vitamin Status

A further anatomical influence can be derived from the quantity of volume reduction and the resulting shape of SG. In adults the average stomach volume is about 1.5–2 L. SG reduces stomach volume down to 75–150 ml [2]. There is very little literature available that describes objectively the volume determination with SG, and only one paper dealt specifically with the preoperative stomach volume, the achieved SG volume, and the volume of the obtained specimen and its correlation to weight (Fig. 2a, b) [9]. Hence, it does not seem to be clear at what extent the quantity of volume change itself exactly influences weight loss, nor are there many facts available regarding the influence of the extend of gastric volume change on possible postoperative nutritional deficiencies, especially on vitamin B 12 and iron. However, it appears that the rhythm and speed of gastric emptying has a significant influence on many aspects of the effects and side effects of bariatric interventions. In the physiological stomach the exact tuned regulation of gastric emptying speed of the chyme into the duodenum is crucial for further digestion processes and subsequently provides feedback from the intestine via a variety of gastrointestinal hormones [10, 11]. However, it seems to be clear that a too rapid gastric emptying of the physiological stomach alters the secretion of intestinal hormones and thus has complex effects not only on carbohydrate metabolism. A surgical induced accelerated gastric emptying has been reliably proven for SG, even if only few data are available due to rare publications on basic physiology of bariatrical procedures [12]. In addition, it has not yet been demonstrated to what extent and how pronounced the influence of the reduced volume leads to this acceleration of gastric emptying [13–15]. It is conceivable whether this will lead to a shorter enterocyte contact time with subsequently reduced absorption rates of vitamins and minerals, but this has not yet been investigated. In the case of **folic acid**, this could be an aspect for the, albeit low, rates of folic acid deficiencies observed following SG [16]. Folic acid must be broken down enzymatically in the duodenum and proximal jejunum, but is subsequently absorbed in the entire small

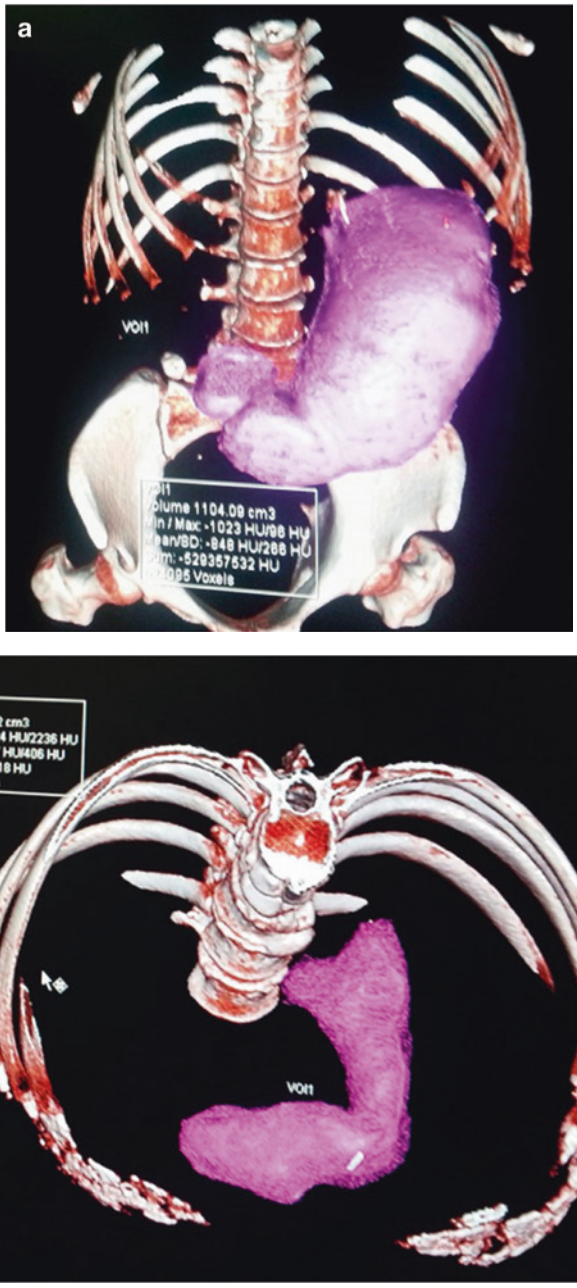


Fig. 2 **a** Volume-rendered 3D image of the distended stomach with multi-detector CT (preoperative) (volume 1108 ml). b Volume-rendered 3D image of the gastric sleeve 3 months postoperatively (volume 158 ml)

intestine. The ubiquitous nutritional undersupply with folic acid can be another aspect of the observed deficiencies [4].

5 Effect on Thiamine

Thiamine (Vitamin B1) is also absorbed throughout the entire small intestine. The enteral uptake of thiamine is subject to a dose-dependent dual mechanism. Physiological amounts of thiamine below a concentration of 2 µmol/l are absorbed by an energy-dependent sodium-mediated carrier mechanism, above a concentration of 2 µmol/l, vitamin B1 is absorbed by passive diffusion. The comparison of biopsies of the intestinal mucosa of patients with and without thiamine deficiency revealed a significantly higher intestinal vitamin B1 intake in subjects with poor thiamine status. The increased absorption of thiamine in the deficient state results from the upregulation of apical thiamine transporters in the intestinal mucosa cells [17–19].The biological **half-life of thiamine is relatively short** and is reported to be 9.5–18.5 days in humans. The maximal limited storage capacity and high conversion rate of thiamine make a daily supply of sufficient quantities necessary to meet demand [19]. These facts may lead to special nutritional problems with thiamine, which must be kept in mind after bariatric surgery, and especially after SG, as postoperative nausea and vomiting (PONV) may be considered the most common adverse effect of LSG. Without prophylaxis the incidence can be as high as 80% [20]. Another and even more important and longer lasting reason for chronic vomiting after SG is due to functional gastric stenosis at the angulus fold [21–24]. The incidence can be as high as 4%, but with that incidence only proven and treated cases are represented [21–24]. In fact, more patients suffer from chronic vomiting after SG. Further reasons for this issue can be the presence of a hiatal hernia or emerging food intolerances. Important in this context is the fact that chronic vomiting easily leads to a **thiamine deficiency** based on its short half-life and its absolute limited storage capacity. Another contributing aspect is the fact that these patients often almost stop eating due persistent nausea.

This can lead to two clinical pictures with a pronounced thiamine deficiency, both of which can take a dramatic course. Acute thiamine deficiency occurs when patients in an already catabolic state (e.g. like after bariatric surgery) additionally fast for some time, (e.g. due to chronic vomiting) and then resume eating.

5.1 Refeeding Syndrome

The initial phase of starvation (e.g. low food intake after bariatric surgery plus nausea) leads to a high consumption of the total concentration of essential electrolytes within the extracellular space. During such a period carbohydrate metabolism is minimized, and thus insulin release is suppressed, whereas gluconeogenesis,

lipolysis and proteolysis are increased, the substrates of which are fatty acids, glycerol, ketones and amino acids. At the same time intracellular electrolyte concentration is still high. Subsequently, along this concentration gradient magnesium, phosphate and potassium shift to the extracellular space. "Starvation seizes the cellular level" is probably the best way to describe convincingly this state. In this phase of starvation, when electrolytes already have been shifted from intra- to extracellular, resumption of food results in a massive insulin release, which immediately leads to increased glycogeno-, proteino- and lipogenesis. Henceforth, massive amounts of thiamine are consumed by acting as cofactor for the glucose transport into the intracellular space. Simultaneously, with indication of this metabolic process, phosphate, potassium and magnesium massively flux back into the cell. This results in an engraving and persisting deficiency of potassium, phosphate, magnesium and thiamine in the extra cellular space followed by all its clinical consequences. This phenomenon is known as **refeeding syndrome** (Fig. 3a–c) that has so far been recognized mainly in the context with anorexia [25–28]. The hallmark biochemical feature of this phenomenon is **hypophosphatemia**. Regardless of the serious symptoms of that malignant electrolyte imbalance, additionally, the acute thiamine deficiency may result in symptoms of an acute dry and/or wet **Beriberi** syndrome with severe cordial and neurological impairments (Table 1). This situation mostly represents a life-threatening condition. Milder forms of electrolyte shifts have been frequently observed as moderate hypophosphatemia in the post-bariatric phase, characterized by the significant reduction of

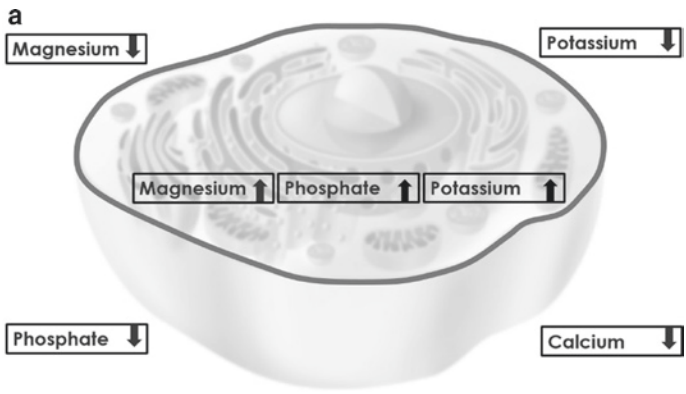
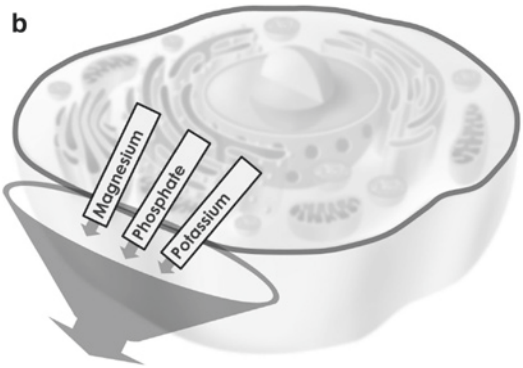


Fig. 3 **a** Starvation leads to a consumption of extracellular electrolytes. Carbohydrate metabolism is minimized, gluconeogenesis, lipolysis, and proteolysis is increased. This results in a concentration gradient of electrolytes from intracellular to extracellular. **b** "Starvation seizes the cellular level". This results in a shift of intracellular phosphate, magnesium and potassium into the extracellular space. **c** Refeeding Syndrome. Resumption of food in the state of starvation results in a massive insulin release, which simultaneously leads to increased glycogeno-, proteino- and lipogenesis. Thiamine is consumed as cofactor for the transport of glucose, phosphate, potassium and magnesium back into the intracellular space. The hallmark biochemical feature of refeeding syndrome is **hpophosphatemia and thus phosphate is the indicator electrolyte**



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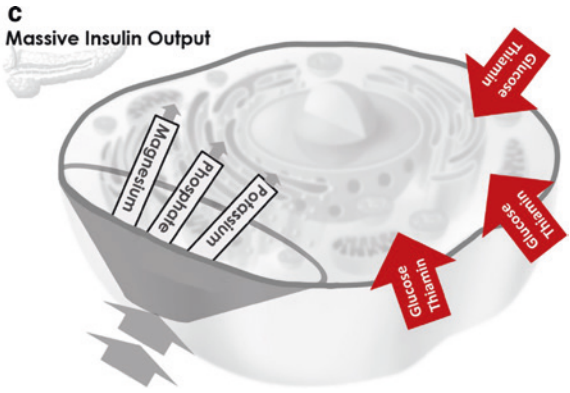

Fig. 3 (continued)

food intake over weeks. Some published cases of patients with "bariatrical refeeding syndrome" demonstrated impressively that this clinical picture can occur independently of body weight, but is solely induced by prolonged starvation with a subsequent electrolyte shift [28].

Emergency intensive care therapy of the refeeding syndrome includes a reduced and controlled protocol of nutrient supply under monitoring and ad hoc substitution of electrolytes and thiamine, potassium and magnesium according to the NICE guidelines [25]. Often the adequate therapy necessitates very high doses especially of phosphate and thiamine for several days,

The Refeeding Syndrome leads to an excessive lack of thiamine by shifting the vitamin between the different spaces of the body. If the deficiency is due to an insufficient extrinsic supply or waste through vomiting, Beriberi syndrome can develop without further phosphate imbalance. The Beriberi syndrome shows

Table 1 Classification and symptoms of beriberi syndrome

Dry Beriberi More frequent than wet Beriberi	Wet Beriberi Cardio-vascular manifestation	Cerebral Beriberi Wernicke-Korsakoff syndrome Complete remission is rare Mortality rate: 10–20%
Neuritis	Cardiac insufficiency	Encephalopathy
Neuropathy, esp. of the lower limbs with loss of tendon reflexes	Tachycardia	Omphtalmoplegia, with nystagmus and impairment of eye movements
Muscle atrophy with muscle pain	Right heart insufficiency	Hemorrhagic lesions of the 3.and 4. Ventricle
General weakness	Edema	Ataxia
	Respiratory symptoms	Korsakoff pychosis
	Hypertension	Coma

three different clinical manifestations, with dry Beriberi being the most common of all. Its symptoms include neuritis and neuropathy that manifests particularly at the lower extremity, but also muscle pain and atrophy with loss of tendon reflexes. The cardio-vascular manifestation with hypertension, formation of edemas and possible respiratory symptoms is called wet beriberi. An acute severe thiamine deficiency may even lead to cerebral Beriberi, which is also known as Wernicke-Korsakoff Syndrome. If the disease occurs in this severe form, complete remission is rare and mortality rate ranges high as between 10–20%. Even early therapy cannot cure the cognitive impairment, which is not reversible in most cases [29].

Therapy of symptomatic Beriberi is the immediate administration of thiamine (up to 400 mg parenteral per day) [29, 30], directly after the blood sample has been taken for current vitamin level determination. In suspected cases, there is no need to wait for the result and an initial dose of 100 mg is administered ex juvantibus. In such situations, however, it is always worth controlling the indicator electrolyte phosphate to differentiate suspected Beriberi from refeeding syndrome.

6 Effect on Vitamin D

Vitamin D deficiency is not specific.

Although only parts of the stomach are removed in SG, the resulting reduction in gastric acid and intrinsic factor and the rapid emptying of the stomach can have effects on the vitamin and mineral balance. Other influencing factors are the drastically reduced postoperative food and vitamin intake or recurrent vomiting after SG. Additionally, proton pump inhibitor (PPI) intake, which is frequently after SG, has a considerable effect on iron, and vitamin B12 levels, as well as it

Table 2 Nutrient supplementation for patients with weight loss surgery according to the guidelines of American Society for Metabolic and Bariatric Surgery integrated health nutritional guidelines for the surgical weight loss patient 2016 update: micronutrients [35]

	Patients after sleeve gastrectomy
Vit B1	At least 12 mg/d At risk patients: at least 50–100 mg/d
Vit B12	350–500 ug/d oral, disintegrating tablet, sublingual or liquid or nasal—as directed or 1000mcg/mo IM
Folate	400–800 mcg oral 800–1000 mcg F childbearing ages
Calcium	1200–1500 mg/d1800
Vit A	5000 IU/d
Vit E	15 mg/d
Vit K	90–120ug/d
Vit D	At least 3000 IU/d to maintain D,25(OH) levels > 30 ng/mL
Iron	At least 18 mg/d from multivitamin At least45–60 mg/d in F with menses and/patients with history of anemia
Zinc	8–11 mg/d
Copper	1 mg/d

interferes with the calcium and bone metabolism [31–34]. Besides that, PPI retard the clinical response to iron supplementation [34].

A **vitamin D** deficiency is not specific after SG, but is generally widespread in obese patients. Indeed, deficiencies of fat-soluble vitamins are more likely after bypass procedures due to the duodenal exclusion.

7 Conclusion

In summary of all these influences on the absorption of vitamins and minerals following SG, the lifelong supplementation is obligatory according to the guidelines (Table 2). Standardized follow up examinations and lab tests are necessary to monitor the vitamin and mineral status in bariatric patients after SG, to conclude, according to the current state of knowledge, postoperative supplementation after SG should be recommended life-long, since anatomical and physiological changes provide at least deficiencies in **iron, thiamine, folate, vitamin B12,** and **vitamin D.**

References

1. Al-Mutawa A, Al-Sabah S, Anderson AK, Al-Mutawa M. Evaluation of nutritional status post laparoscopic sleeve—5 years outcome. Obes Surg. 2018;28:1473–83.

2. Bhandari M, Fobi Mal, Buchwald JN, Bariatric Metabolic Surgery Standardisation (BMSS Working Group). Standardization of bariatric metabolic procedures: world consensus meeting statement. Obes Surg. 2019;29(Suppl 4):309–45.
3. Shane B. Folate and vitmin B12 metabolism: overview and interaction with riboflavin, vitamin B6, and polymorphisms. Food Nutr Bull. 2008;29(2 Suppl):5–16.
4. Gu L, Fu R, Chen P, et al. In terms of nutrition, the most suitable method for bariatric surgery:laparoscopic sleeve gastrectomy or Roux-en-Y gastric bypass? A systematic review and meta-analysis. Obes Surg. 2020. https://doi.org/10.1007/s11695-020-04488-2. [Epub ahead of print].
5. Herrmann W, Obeid R. Cobalamin deficiency. Subcell Biochem. 2012;56(3):01–22.
6. Herrmann W, Obeid R, Schorr H, Geisel J. Functional vitamin B12 deficiency and determination of holotranscobalamin in populations at risk. Clin Chem Lab Med. 2003;41(11):1478–88.
7. German Society for Nutrition, Austrian Society for Nutrition, Swiss Society for Nutrition Research, Swiss Association for Nutrition: reference values for nutrient intake. 5 Edn. In: DGE/ÖGE/SGE/SVE. Umschau- Braus-Verlag, Frankfurt/Main (2013).
8. Camaschella C, Nai A, Silvestri L. Iron metabolism and iron disorders revisited in the hepcidin era. Haematologica. 2020;105(2):260–72.
9. Pawanindra L, Vidal A, Migha M, et al. Early post-operative weight loss after laparoscopic sleeve gastrectomy correlates with the volume of the excised stomach and not with that of the sleeve! Preliminary data from a multi-detector computed tomography-based study. Surg Endosc. 2015;29(10):2921–7.
10. Goyal RK, Guo Y, Mashimo H. Advances in the physiology of gastric emptying. Neurogastroenterol Motil. 2019;31(4):e13546.
11. Khiyani N, Tulchinsky M, Hava S, et al. Gastric emptying results may influence the selection of the type of bariatric surgery. Medicine (Baltimore). 2019;98(41):e17205.
12. Vargas EJ, Bazerbachi F, Calderon G, et al. Changes in time of gastric emptying after surgical and endoscopic bariatrics and weight loss: A systematic review and meta-analysis. Clin Gastroenterol Hepatol. 2020;18:57–68.
13. Coupaye M, Rivière P, Breuil M, et al. Comparison of nutritional status during the first year after sleeve gastrectomy and roux-en-Y gastric bypass. Obes Surg. 2014;24(2):276–83.
14. Ben-Porat T, Elazary R, Yuval J, et al. Nutritional deficiencies after sleeve gastrectomy: can they be predicted preoperatively? Surg Obes Relat Dis. 2015;11(5):1029–36.
15. van Rutte P, Aarts E, Smulders J, et al. Nutrient deficiencies before and after sleeve gastrectomy. Obes Surg. 2014;24(10):1639–46.
16. Campos AJ, Risch L, Nydegger U, et al. Diagnostic accuracy of holotranscobalamin, Vitamin B12, Methylmalonic acid, and Homocysteine in detecting B12 deficiency in a large, mixed patient population. Dis Markers. 2020;2020:7468506.
17. Singleton CK, Martin PR. Molecular effects of thiamine deficiency. Curr Mol Med. 2001;1(2):197–207.
18. Song Q, Singleton CK. Mitochondria from cultured cells derived from normal and thiamine-responsive megaloblastic anemia individuals efficiently import thiamine diphosphate. BMC Biochem. 2002;25(3):8.
19. Pan X, Nan X, Yang L, et al. Thiamine status, metabolism and application in dairy cows: a review. Br J Nutr. 2018;120(5):491–9.
20. Chandrakumar A, Bhardwaj A, Jong GW. Review of thiamine deficiency disorders: Wernicke encephalopathy and Korsakoff psychosis. J Basic Clin Physiol Pharmacol. 2018;30(2):153–62.
21. Fathy M, Abdel-Razik MA, Ayman. Impact of Pyloric Injection of Magnesium Sulfate-Lidocaine Mixture on Postoperative Nausea and Vomiting After Laparoscopic Sleeve Gastrectomy: a Randomized-Controlled Trial Obesity Surgery 2019; 29:1614–1623

22. Parikh A, Alley JB, Peterson RM, et al. Management options for symptomatic stenosis after laparoscopic vertical sleeve gastrectomy in the morbidly obese. Surg Endosc. 2012;26:738–46.
23. Yu JX, Baker JR, Watts et al. Functional lumen imaging probe is useful for the quantification of gastric sleeve stenosis and prediction of response to endoscopic dilation: a pilot study. Obes Surg. 2020;30(2):786–9.
24. Turcu F, Balahura C, Doras I, et al. Symptomatic stenosis after laparoscopic sleeve gastrectomy—incidence and management in a high-volume bariatric surgery. Chirurgia. 2018;113:826–36.
25. National Institute for Health and Clinical Excellence. Nutrition support in adults. Clinical guideline CG32;2006. www.nice.org.uk/page.aspx?o=cg032.
26. Mehanna HM, Moledina J, Travis J. Refeeding syndrome: what it is, and how to prevent and treat it. BMJ. 2008;336:1495–8.
27. Pacei F, Iaccarino L, Bugiardini E, et al. Wernicke's encephalopathy, refeeding syndrome and wet beriberi after laparoscopic sleeve gastrectomy: the importance of thiamine evaluation. Eur J Clin Nutr. 2020. https://doi.org/10.1038/s41430-020-0583-x. [Epub ahead of print].
28. Chiappetta S, Stein J. Refeeding syndrome: an important complication following obesity surgery. Obes Facts. 2016;9(1):12–6.
29. Stroh C, Meyer F, Manger T. Beriberi, a severe complication after metabolic surgery - review of the literature. Obes Facts. 2014;7(4):246–52.
30. Alves LF, Gonçalves RM, Cordeiro GV, et al. Beriberi after bariatric surgery: not an unusual complication. Report of Two Cases and Literature ReviewArq Bras Endocrinol Metabol. 2006;50(3):564–8.
31. Qorraj-Bytyqi H, Hoxha R, Sadiku S, et al. Proton pump inhibitors intake and iron and vitamin B12 status: a prospective comparative study with a follow up of 12 months. Maced J Med Sci. 2018;6(3):442–6.
32. Johnson DA. Nutritional consequences of long-term acid suppression; are they clinically important? Curr Opin Gastroenterol. 2016;32(2):136–40.
33. Schubert ML. Functional anatomy and physiology of gastric secretion. Curr Opin Gastroenterol. 2015;31(6):479–85.
34. McColl KE. Effect of proton pump inhibitors on vitamins and iron. Am J Gastroenterol. 2009;104(Suppl 2):S5–9.
35. Parrott J, Fran L, Rabena R, et al. American society for metabolic and bariatric surgery integrated health nutritional guidelines for the surgical weight loss patient 2016 update: Micronutrients SOARD. 2017.