BMC Surgery

REVIEW

Open Access

Research progress on bariatric surgery for hyperuricemia

Ke Song[1,2], Xiangxin Kong[1,2], Zhenghang Yu[1,2], He Xiao[2] and Yixing Ren[1,2,3*]

Abstract

Hyperuricemia is closely linked to obesity. As lifestyles and dietary patterns evolve, the prevalence of hyperuricemia has been on the rise. Bariatric surgery, an efficacious intervention for morbid obesity and its associated metabolic disorders, not only manages the weight of patients with severe obesity but also exerts beneficial therapeutic effects on hyperuricemia and gout. Moreover, it demonstrates substantial efficacy against other obesity-related metabolic conditions. However, the dramatic fluctuations in serum uric acid levels and acute gouty attacks in the immediate postoperative period are issues that should not be overlooked, and effective preventative strategies for some related adverse complications are still underexplored. This review discusses and reviews the advancements in the treatment of obese patients with hyperuricemia through bariatric surgery. By reviewing pertinent literature, it summarizes the short-term and long-term therapeutic outcomes of bariatric surgery for hyperuricemia, as well as common adverse reactions. Furthermore, by discussing preoperative and postoperative interventional measures and influential factors, this review aims to provide novel perspectives for the clinical management of hyperuricemia and offer insights for the prevention of related complications.

Keywords Bariatric surgery, Hyperuricemia, Obesity, Serum uric acid, Gout

Introduction

Hyperuricemia (HUA), a chronic metabolic disorder stemming from dysregulation of purine metabolism, is typically characterized by serum uric acid (SUA) levels greater than or equal to 6.0 mg/dL in females and greater than or equal to 7.0 mg/dL in males [1, 2]. When SUA concentrations surpass the saturation point, monosodium urate crystals precipitate, potentially leading to gout, a condition that can cause destructive arthropathy and severe renal disease [3]. HUA represents a substantial public health challenge globally. With the economic growth and dietary changes in China, the prevalence of HUA has been increasing annually, emerging as the second most common metabolic disease after diabetes [4]. Over the past four decades, the rates of overweight and obesity among Chinese children and adolescents aged 7–18 have risen from 1% to 0.1% in 1985 to 14.0% and 6.4% in 2014, respectively. Similarly, the prevalence of overweight and obesity among adults has increased from 18.9% to 2.9% in 2002 to 27.1% and 5.2% in 2010 [5]. Obesity is closely associated with a spectrum of diseases, including type 2 diabetes mellitus (T2DM), cardiovascular diseases, hyperlipidemia, and several types of cancer [6], and it is also a major risk factor for HUA and gout. Weight reduction has a positive protective effect against these conditions [3, 7]. Bariatric surgery stands as the sole sustainable treatment option for morbidly obese

*Correspondence:
Yixing Ren
yixingren@nsmc.edu.cn
[1]Department of Gastroenterology, Affiliated Hospital of North Sichuan Medical College, Nanchong 637000, Sichuan Province, China
[2]Institute of Hepatobiliary Pancreatic Intestinal Diseases, North Sichuan Medical College, Nanchong 637000, Sichuan Province, China
[3]General Surgery, Chengdu XinHua Hospital Affiliated to North Sichuan Medical College, Chengdu 610000, Sichuan Province, China

patients, offering benefits that extend beyond weight loss to the improvement of other metabolic parameters [8]. An in-depth investigation into the therapeutic effects of bariatric surgery on obese patients with HUA holds substantial clinical significance.

HUA and obesity

Numerous studies have demonstrated a close association between obesity, insulin resistance, and a variety of metabolic comorbidities such as HUA, hyperglycemia, hyperlipidemia, and hypertension [9–11]. A study focusing on male patients with a history of gout revealed that a decrease in SUA levels is potentially correlated with a reduction in visceral fat, particularly in those with a higher baseline level of visceral fat [12], Obesity is not only positively correlated with the prevalence of obesity-related glomerulopathy, characterized by proteinuria, glomerulomegaly, progressive glomerulosclerosis, and a decline in renal function, potentially leading to chronic kidney disease (CKD) in later stages [13, 14], but also plays a significant role in the etiology of gout, the most prevalent form of inflammatory arthritis. Gout is caused by the persistent elevation of SUA levels, leading to the deposition of monosodium urate crystals in joints, tendons, and other tissues, which triggers recurrent acute inflammatory episodes [1]. Patients with severe obesity are at an increased risk of developing HUA [15–17]. A prospective cohort study conducted by McCormick et al. indicated that the majority of gout cases might be prevented by achieving and maintaining a normal weight [18]. The mainstream urate-lowering medications currently include drugs that inhibit uric acid production (such as allopurinol) and those that increase uric acid excretion (such as benzbromarone). However, traditional pharmacotherapy may have limitations and is accompanied by side effects such as urate nephrolithiasis, hepatorenal stones, and liver function impairment [19]. Patients diagnosed with HUA or gout may require long-term or even lifelong medication use, where medication adherence and ongoing side effects pose the greatest challenges [20].

Bariatric surgery

By the mid-20th century, obesity had emerged as a rapidly increasing global epidemic, with limited strategies to curb this disease [21]. During this period, pharmacological treatments for weight loss in obese patients often resulted in temporary effects. In contrast, bariatric surgery, although only accessible to a select few who met the criteria, was proven to be the most effective intervention for ensuring significant weight loss and improving associated comorbidities [22–25]. In 1954, Kremen et al. [26] from the University of Minnesota performed a procedure known as jejuno-ileal bypass (JIB) (Fig. 1A), which

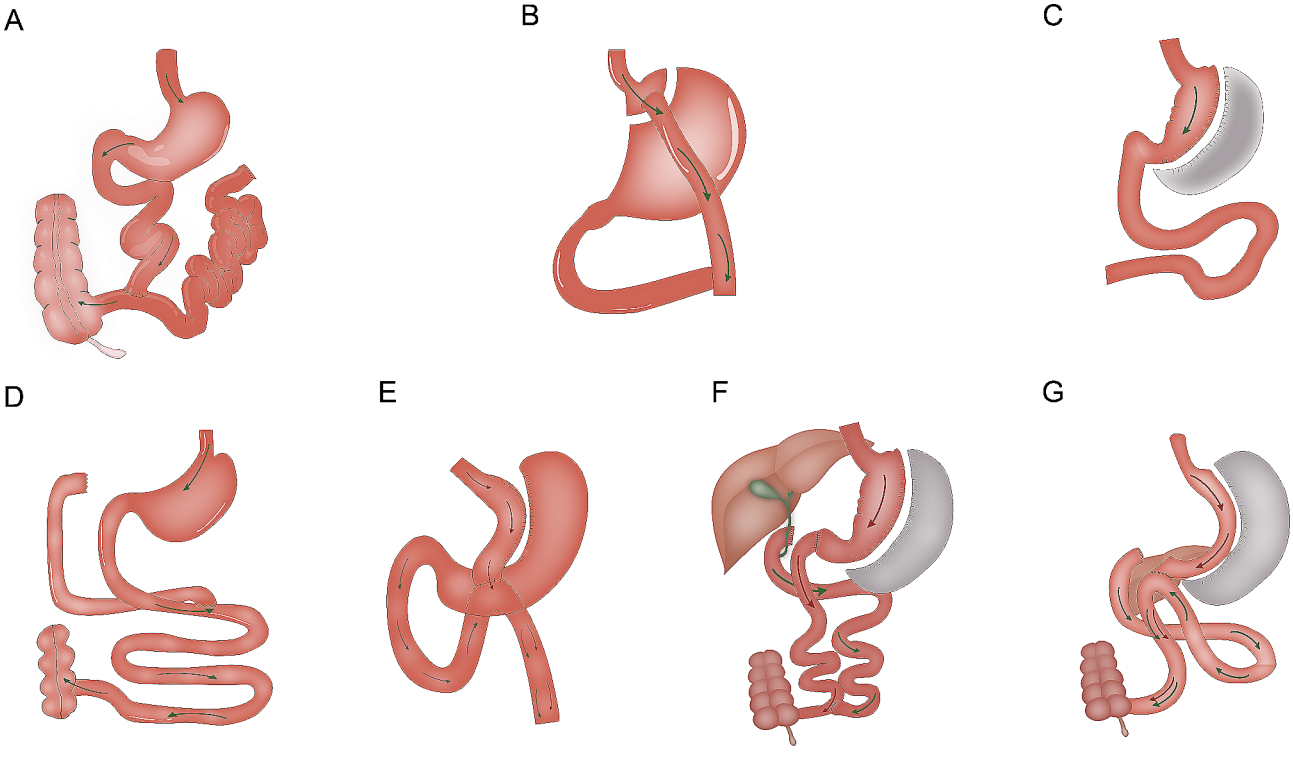

Fig. 1 Diagram of different weight loss surgeries. (**A**) jejuno-ileal bypass, (**B**) Roux-en-Y gastric bypass, (**C**) sleeve gastrectomy, (**D**) duodenal-jejunal bypass, (**E**) one anastomosis gastric bypass, (**F**) biliopancreatic diversion with duodenal switch, (**G**) single anastomosis duodeno-ileal bypass with sleeve gastrectomy

altered the path of food through the intestines, thereby reducing nutrient absorption. JIB resulted in substantial and sustained weight loss, laying the groundwork for subsequent bariatric operations, however, it was associated with many side effects related to bypass of the ileum. In 1967, Mason and Ito [27] carried out the first gastric bypass surgery.

At present, the Roux-en-Y gastric bypass (RYGB) (Fig. 1B) and sleeve gastrectomy (SG) (Fig. 1C) have emerged as the predominant surgical approaches for the treatment of obesity and are widely applied in clinical practice [28]. Other surgical modalities, such as the duodenal-jejunal bypass (DJB) (Fig. 1D), one anastomosis gastric bypass (OAGB) (Fig. 1E), biliopancreatic diversion with duodenal switch (BPD-DS) (Fig. 1F) and single anastomosis duodeno-ileal bypass with sleeve gastrectomy (SADI-S) (Fig. 1G), are supported by evidence-based medical research and have been recommended; however, their implementation is relatively limited due to a paucity of systematic efficacy and safety clinical evidence [29]. Beyond the treatment of obesity, bariatric surgery also offers unique advantages in ameliorating obesity-related metabolic diseases. The mechanisms at play extend beyond a mere reduction in body mass index (BMI) to encompass a decrease in urinary microalbumin levels and improvements in incretin levels, insulin secretion, and insulin sensitivity [30–32]. The manner in which bariatric surgery modulates metabolism and ameliorates metabolic diseases constitutes a focal point of current foundational research in bariatric surgery.

Efficacy of bariatric surgery in the treatment of HUA and gout

A prospective study from Sweden serves as a cornerstone in exploring the therapeutic potential of bariatric surgery for HUA [33]. This study conducted a 10-year follow-up of 1,982 subjects who underwent bariatric surgery and compared them with 1,999 Swedish obese subjects. The findings revealed that, in contrast to conventional treatment, bariatric surgery reduced the long-term incidence of gout and HUA. Additionally, several retrospective studies have corroborated this perspective [34–36]. Oberbach et al. [37] conducted a study focusing on obese adolescents and discovered that after bariatric surgery, the levels of SUA and obesity-related metabolic diseases were ameliorated, with the extent of improvement being related to the choice of surgical procedure. However, Antozzi et al. [38] proposed that patients with recurrent gout might not respond positively to weight loss induced by bariatric surgery, particularly for those with higher uric acid levels. In the retrospective study conducted by Antozzi et al., the patients who underwent bariatric surgery did not achieve substantial improvement in gout, contradicting the findings of Oberbach and colleagues. Yet, considering the metabolic improvements post-bariatric surgery are a process that requires long-term monitoring, this viewpoint necessitates further validation. Apart from the beneficial effects on HUA and gout, bariatric surgery also exerts positive effects on kidney function. Through a retrospective study, Hung et al. [35] suggested that patients with a history of renal dysfunction, after undergoing bariatric surgery, showed a negative correlation between postoperative SUA levels and kidney function. Although patients with high preoperative SUA levels do not necessarily have renal dysfunction, for those with pre-existing renal impairment, the viewpoint of Huang et al. can provide a certain reference value for the selection of their treatment plan.

Common postoperative adverse reactions and management strategies

As previously discussed, bariatric surgery has been shown to ameliorate the SUA levels and the frequency of gout attacks in patients with obesity and HUA. However, the reports of dramatic fluctuations in SUA levels and frequent acute gout attacks in the immediate postoperative period should not be overlooked [36, 39]. Katsogridaki et al. [40] reported the incidence of HUA and gout one month after SG, noting that patients with a preoperative diagnosis of HUA exhibited a substantially higher incidence of postoperative HUA and gout compared to those without HUA preoperatively (18.8% vs. 6.8%; 7.1% vs. 5.1%). Kang et al. [41] observed that postoperative gout typically manifests within eight days, predominantly affecting the first metatarsophalangeal joint. There is controversy regarding the direct diagnosis of gout, which is traditionally established through the aspiration of synovial fluid and the identification of typical negatively birefringent monosodium urate crystals under polarized light microscopy [42]. However, in clinical practice, the diagnosis of gout is often based on characteristic symptoms and relevant medical history, with synovial fluid aspiration not being routinely performed. Consequently, there may be a tendency to overlook or misdiagnose gout attacks, particularly in patients following bariatric surgery. Obese patients frequently experience acute exacerbations of chronic joint disease, which may be clinically misdiagnosed as acute gouty arthritis attacks. Furthermore, without obtaining a synovial fluid sample, it may be challenging to identify gout attacks, especially when atypical joints are involved (such as joints other than the first metatarsophalangeal joint) [43–45]. Therefore, when the diagnosis is ambiguous, it is advisable to perform synovial fluid aspiration to facilitate a direct diagnosis of gout.

During the acute flare-up of gout, the administration of oral colchicine, nonsteroidal anti-inflammatory drugs (NSAIDs), and corticosteroid hormones is recognized as

the primary treatment for acute inflammation [46]. However, it is essential to be vigilant for potential contraindications to NSAID therapy [47]. Colchicine, a naturally occurring alkaloid with anti-inflammatory properties, is commonly used to treat acute gout attacks, but monitoring should be conducted during treatment for signs of bone marrow suppression and substantial gastrointestinal symptoms [48]. Corticosteroid hormones are also effective in the management of acute gout flares, but caution is advised for patients with diabetes and hyperglycemia. Given the additive risk of peptic ulcers and upper gastrointestinal bleeding, the clinical co-administration of corticosteroid hormones and NSAIDs should be avoided whenever possible to mitigate these risks. This approach ensures patient safety while effectively managing the acute inflammatory response associated with gout.

Regarding postoperative asymptomatic hyperuricemia (i.e., elevated serum uric acid levels without gout attacks), current management strategies are still a subject of debate [49, 50]. Joosten et al. [51] argue that soluble and crystalline uric acid are bioactive molecules that can lead to adverse vascular, metabolic, and inflammatory events, and the association between HUA and kidney, cardiovascular, and diabetes diseases is well-established. Therefore, given the high prevalence of asymptomatic hyperuricemia and the rising incidence of vascular and metabolic diseases, as well as kidney diseases, Joosten and colleagues adopt a more proactive stance towards the treatment of asymptomatic hyperuricemia. Conversely, Sellmayr and colleagues [52] believe that asymptomatic hyperuricemia does not accelerate the progression of chronic kidney disease unless uric acid crystals form in the kidneys. Hence, Sellmayr and his team maintain a more conservative approach to the treatment of asymptomatic hyperuricemia. This divergence in opinion underscores the complexity of managing asymptomatic hyperuricemia postoperatively and highlights the need for further research to clarify the benefits and risks associated with different treatment strategies.

Some scholars have posited that HUA occurring in the early postoperative period following SG can resolve spontaneously without the need for pharmacological intervention [53]. This perspective suggests that while preoperative SUA levels are correlated with BMI and body weight, the primary factor contributing to postoperative HUA is total body weight. The sustained weight loss resulting from the surgical procedure is believed to lead to long-term control of HUA. This viewpoint underscores the potential for weight loss to mitigate the effects of HUA and highlights the importance of considering the natural course of HUA in the postoperative context. It suggests that, in some cases, a conservative approach to management, with close monitoring and lifestyle modifications, may be sufficient to address HUA following SG. However, it is crucial to balance this perspective with the need for individualized patient care, taking into account the specific circumstances and medical history of each patient.

Influencing factors and perioperative management

Xu et al. [54] have identified preoperative estimated glomerular filtration rate (eGFR), glycated hemoglobin, sex, and serum zinc levels as independent factors that influence the magnitude of postoperative short-term SUA fluctuations. They found that patients with higher preoperative eGFR levels tend to exhibit less pronounced fluctuations in SUA postoperatively. Additionally, there is evidence suggesting that zinc supplementation can have a positive effect on obesity-related kidney diseases [55]. The research by Xu et al. supports this notion, confirming that optimizing postoperative serum zinc levels may be beneficial for SUA changes and could potentially aid in controlling gout attacks. This underscores the importance of a comprehensive preoperative assessment that takes into account renal function, metabolic status, and nutritional factors such as serum zinc levels. By identifying and addressing these factors, clinicians can better tailor perioperative management strategies to mitigate the risk of postoperative SUA fluctuations and associated complications like gout. The findings also highlight the potential therapeutic role of zinc in managing SUA levels and could pave the way for further research into the use of zinc supplementation as an adjunct to standard care for patients undergoing bariatric surgery.

Postoperative diet is an equally important concern that should not be overlooked. According to the "Chinese Expert Consensus on Precision Obesity Metabolic Surgery (2022 Edition)" [56], patients are typically advised to consume a residue-free, easily digestible full liquid diet postoperatively. However, this dietary pattern may enhance purine metabolism, thereby increasing uric acid levels and potentially triggering gout attacks [57]. In response to this, Schiavo and colleagues conducted a study on diet [58], exploring the effects of low-purine and normal-purine diets on SUA levels and the frequency of gout attacks after bariatric surgery. The results indicated that a low-purine diet, which replaces animal protein with soy protein, eggs, and cheese, may play a key role in preventing the recurrence of gout. This provides valuable reference for dietary patterns after bariatric surgery.

Tana et al. [59] mentioned in a review article that discontinuing uric acid-lowering treatment, fasting, and purine release after bariatric surgery are considered the main causes of acute gout attacks. Incorrectly stopping preventive medications (such as allopurinol) after surgery or using of diuretics can increase SUA levels and the risk of acute gout attacks [60]. Additionally, advocating for

early postoperative activity can promote rapid improvement in joint function and prevent further episodes of acute arthritis [61, 62]. In a long-term follow-up, bariatric surgery has been proven to alleviate joint pain caused by obesity and prevent further destruction of articulation cartilage [63]. Over time, regular rehabilitation exercises are expected to improve joint function.

The catabolic state induced by perioperative caloric restriction is also considered a potential cause of gout attacks [64]. The American Society for Metabolic and Bariatric Surgery (ASMBS) and the International Federation for Surgery of Obesity and Metabolic Diseases (IFSO) advocate for a postoperative diet that is high in protein, low in carbohydrates, and low in fat [65, 66]. However, a low-carbohydrate diet induces fatty acid mobilization in the abdomen and liver, along with an increase in protein intake, promoting purine release. The accompanying ketogenic state can impair renal excretion of uric acid, thereby increasing the frequency of acute gout attacks [59]. In contrast to this dietary pattern, traditional Chinese dietary habits place more emphasis on the intake of grains and vegetables with lower protein content. However, postoperative soup consumption may lead to micronutrient deficiencies [67, 68]. Therefore, in addition to standard dietary recommendations, patients should also be advised to control protein intake and receive appropriate fluid therapy. Protein intake should be adjusted according to the individual needs of the patient, and the usual intake is 60–80 g per day.

The impact of relevant genes on the treatment of HUA by bariatric surgery

One area of research that deserves attention is the investigation of genetic factors that may influence the metabolic response to bariatric surgery, particularly in relation to SUA levels and the treatment of HUA. One such study has zeroed in on the estrogen receptor-α (ESR1) gene, examining its potential role in SUA metabolism following bariatric surgery [69]. Intriguingly, this research has identified a specific genetic variant, the rs712221 polymorphism within the ESR1 gene, which appears to be associated with the postoperative decrease in SUA levels. Patients who are carriers of this risk allele have been observed to experience more pronounced reductions in both BMI and SUA after undergoing bariatric procedures. This line of inquiry is particularly compelling given the known role of ESR1 in various physiological processes, including those related to metabolism and inflammation [70, 71], which could indirectly influence uric acid handling by the body. The modulation of SUA levels through genetic factors could have very important implications for the management of HUA and associated conditions such as gout and kidney disease. However, while this study sheds light on a possible genetic influence, it is important to note that the research has been conducted primarily on the Chinese Han population. This limitation underscores the need for further investigation to determine whether these findings are applicable across different ethnic groups. Genetic diversity across populations can lead to variations in gene expression and function, which may in turn affect the response to bariatric surgery. Future studies should aim to broaden the scope by including diverse ethnicities to enhance the generalizability of the findings. Additionally, a more comprehensive genetic analysis could be beneficial, examining not only the ESR1 gene but also other genes that might play a role in SUA metabolism and the body's response to bariatric surgery. Understanding the genetic underpinnings of HUA treatment through bariatric surgery could pave the way for personalized medicine approaches, tailoring treatment strategies based on an individual's genetic profile to optimize outcomes and mitigate risks. In conclusion, the identification of the ESR1 rs712221 polymorphism as a potential predictor of SUA reduction post-bariatric surgery is a promising development in the field of genomic medicine. As research continues to unravel the complex interplay between genetics and bariatric surgery, it is hoped that a more nuanced understanding will emerge, guiding clinical practice towards more effective and personalized treatment of HUA and obesity.

Summary and prospects

Bariatric surgery is a therapeutic intervention that induces weight loss and alters gastrointestinal physiology to impact metabolism. It is the only intervention proven to not only maintain long-term weight reduction but also significantly improve the comorbidities associated with severe obesity [72]. Compared to pharmacological treatments, bariatric surgery offers unique advantages in managing extreme obesity and its related metabolic disorders. Hyperuricemia, a chronic condition with a high prevalence among the obese population, often does not respond well to medication alone. This review evaluates the clinical effects of bariatric surgery on the treatment of HUA, drawing from literature reports that highlight the surgery's impact on improving this condition. Additionally, based on guidelines and evidence from literature, the review provides recommendations for the management of early postoperative adverse events. While the clinical efficacy of bariatric surgery in treating HUA has been well-established, exploration into the specific molecular biological mechanisms underlying this improvement remains sparse. There is a need for more foundational research to uncover the potential mechanisms by which bariatric surgery ameliorates HUA. Looking ahead, the integration of genetic research with clinical outcomes will be crucial. As discussed earlier, the role of genes

such as ESR1 in the context of bariatric surgery and SUA metabolism is a promising area of study. Future research should aim to dissect the genetic factors that contribute to the variability in responses to bariatric surgery, potentially leading to personalized treatment strategies. Finally, long-term follow-up studies are necessary to evaluate the sustainability of the effects of bariatric surgery on HUA. In summary, while bariatric surgery has demonstrated substantial promise in the treatment of HUA, there is a clear path forward for research to enhance our understanding of the mechanisms involved. This knowledge will be instrumental in advancing the field, improving patient care, and potentially leading to the discovery of new therapeutic approaches for HUA and related metabolic disorders.

Acknowledgements
We would like to express our sincere gratitude to Dr. Dingqi Xiao for his invaluable contributions to the figure in this manuscript. His expertise and assistance greatly enhanced the visual representation of the contents of our manuscript.

Author contributions
K.S. and X.X.K. contributed equally to this work and should be considered as co-first authors. Conceptualization, K.S. and Y.X.R.; writing—original draft preparation, K.S.; writing—review and editing, K.S. and X.X.K.; language editing and stylistic refinement: Z.H.Y. and H.X.; funding acquisition, Y.X.R. All authors reviewed the final version and agreed to publish it.

Funding
This work was supported by the National Natural Science Foundation of China (82370601) .

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Patient consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 5 June 2024 / Accepted: 6 August 2024
Published online: 21 August 2024

References

1. Dehlin M, Jacobsson L, Roddy E. Global epidemiology of gout: prevalence, incidence, treatment patterns and risk factors [J]. Nat Rev Rheumatol. 2020;16(7):380–90. https://doi.org/10.1038/s41584-020-0441-1
2. Maiuolo J, Oppedisano F, Gratteri S, et al. Regulation of uric acid metabolism and excretion [J]. Int J Cardiol. 2016;213:8–14. https://doi.org/10.1016/j.ijcard.2015.08.109
3. Dalbeth N, Gosling AL, Gaffo A et al. Gout [J]. Lancet. 2021;397(10287):1843–55. https://doi.org/10.1016/s0140-6736(21)00569-9
4. Ny Fang L, Lv X, Lv et al. Multidisciplinary Expert Consensus on the diagnosis and treatment of Hyperuricemia-related diseases in China (2023 Edition) [J]. ZHONGGUO SHIYONG NEIKE ZAZHI. 2023;43(06):461–80. https://doi.org/10.19538/j.nk2023060106
5. The Lancet Diabetes E. Obesity in China: time to act [J]. Lancet Diabetes Endocrinol. 2021;9(7):407. https://doi.org/10.1016/s2213-8587(21)00150-9
6. Piché ME, Tchernof A, Després JP. Obesity phenotypes, diabetes, and Cardiovascular diseases [J]. Circ Res. 2020;126(11):1477–500. https://doi.org/10.1161/circresaha.120.316101
7. Fritz J, Brozek W, Concin H et al. The Association of Excess Body Weight with risk of ESKD is mediated through insulin resistance, hypertension, and hyperuricemia [J]. J Am Soc Nephrol. 2022;33(7):1377–89. https://doi.org/10.1681/asn.2021091263
8. Sandoval DA, Patti ME. Glucose metabolism after bariatric surgery: implications for T2DM remission and hypoglycaemia [J]. Nat Rev Endocrinol. 2023;19(3):164–76. https://doi.org/10.1038/s41574-022-00757-5
9. Acevedo-Fernández M, Porchia LM, Elguezabal-Rodelo RG et al. Concurrence of hyperinsulinemia and hyperuricemia significantly augmented all-cause mortality [J]. Nutr Metab Cardiovasc Dis. 2023;33(9):1725–32. https://doi.org/10.1016/j.numecd.2023.05.023
10. Li Z, Gao L, Zhong X et al. Association of Visceral Fat Area and Hyperuricemia in Non-Obese US Adults: A Cross-Sectional Study [J]. Nutrients. 2022;14(19). https://doi.org/10.3390/nu14193992
11. McCormick N, Yokose C, Lu N et al. Impact of adiposity on risk of female gout among those genetically predisposed: sex-specific prospective cohort study findings over > 32 years [J]. Ann Rheum Dis. 2022;81(4):556–63. https://doi.org/10.1136/annrheumdis-2021-221635
12. Ran Z, Xue X, Han L et al. Decrease in serum urate level is Associated with loss of visceral Fat in male gout patients [J]. Front Endocrinol (Lausanne). 2021;12:724822. https://doi.org/10.3389/fendo.2021.724822
13. Friedman AN, Kaplan LM, le Roux CW et al. Management of obesity in adults with CKD [J]. J Am Soc Nephrol. 2021;32(4):777–90. https://doi.org/10.1681/asn.2020101472
14. Zhu P, Herrington WG, Haynes R et al. Conventional and genetic evidence on the Association between Adiposity and CKD [J]. J Am Soc Nephrol. 2021;32(1):127–37. https://doi.org/10.1681/asn.2020050679
15. Yang Y, Xian W, Wu D et al. The role of obesity, type 2 diabetes, and metabolic factors in gout: A Mendelian randomization study [J]. Front Endocrinol (Lausanne). 2022;13:917056. https://doi.org/10.3389/fendo.2022.917056
16. Hong C, Zhang Q, Chen Y et al. Elevated uric acid mediates the effect of obesity on Hypertension Development: a Causal Mediation Analysis in a prospective longitudinal study [J]. Clin Epidemiol. 2022;14:463–73. https://doi.org/10.2147/clep.S363429
17. Manca C, Pintus S, Murru E et al. Fatty Acid Metabolism and Derived-Mediators Distinctive of PPAR-α Activation in Obese Subjects Post Bariatric Surgery [J]. Nutrients. 2021;13(12). https://doi.org/10.3390/nu13124340
18. McCormick N, Rai SK, Lu N et al. Estimation of Primary Prevention of Gout in Men through Modification of Obesity and other Key Lifestyle factors [J]. JAMA Netw Open. 2020;3(11):e2027421. https://doi.org/10.1001/jamanetworkopen.2020.27421
19. Chang YH, Chiang YF, Chen HY et al. Anti-inflammatory and anti-hyperuricemic effects of Chrysin on a high fructose corn syrup-Induced Hyperuricemia Rat Model via the amelioration of Urate Transporters and Inhibition of NLRP3 Inflammasome Signaling pathway [J]. Antioxidants (Basel). 2021;10(4). https://doi.org/10.3390/antiox10040564
20. Strilchuk L, Fogacci F, Cicero AF. Safety and tolerability of available urate-lowering drugs: a critical review [J]. Expert Opin Drug Saf. 2019;18(4):261–71. https://doi.org/10.1080/14740338.2019.1594771
21. Zhang H, Fealy CE, Kirwan JP. Exercise training promotes a GDF15-associated reduction in fat mass in older adults with obesity [J]. Am J Physiol Endocrinol Metab. 2019;316(5):E829–36. https://doi.org/10.1152/ajpendo.00439.2018
22. Martin M, Beekley A, Kjorstad R et al. Socioeconomic disparities in eligibility and access to bariatric surgery: a national population-based analysis [J]. Surg Obes Relat Dis. 2010;6(1):8–15. https://doi.org/10.1016/j.soard.2009.07.003
23. Nguyen N, Champion JK, Ponce J et al. A review of unmet needs in obesity management [J]. Obes Surg. 2012;22(6):956–66. https://doi.org/10.1007/s11695-012-0634-z
24. Pories WJ, Swanson MS, MacDonald KG et al. Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus [J]. Ann Surg. 1995;222(3):339–52. https://doi.org/10.1097/00000658-199509000-00011
25. Phillips BT, Shikora SA. The history of metabolic and bariatric surgery: Development of standards for patient safety and efficacy [J]. Metabolism. 2018;79:97–107. https://doi.org/10.1016/j.metabol.2017.12.010

26. Kremen AJ, Linner JH, Nelson CH. An experimental evaluation of the nutritional importance of proximal and distal small intestine [J]. Ann Surg. 1954;140(3):439–48. https://doi.org/10.1097/00000658-195409000-00018
27. Mason EE, Ito C. Gastric bypass [J]. Ann Surg. 1969;170(3):329–39. https://doi.org/10.1097/00000658-196909010-00003
28. Wiggins T, Majid MS, Agrawal S. From the Knife to the Endoscope-a history of bariatric surgery [J]. Curr Obes Rep. 2020;9(3):315–25. https://doi.org/10.1007/s13679-020-00386-x
29. Wei Y, Li P, Zhang S. From surgery to endoscopy: the evolution of the bariatric discipline [J]. Chin Med J (Engl). 2022;135(20):2427–35. https://doi.org/10.1097/cm9.0000000000002409
30. Docherty NG, le Roux CW. Bariatric surgery for the treatment of chronic kidney disease in obesity and type 2 diabetes mellitus [J]. Nat Rev Nephrol. 2020;16(12):709–20. https://doi.org/10.1038/s41581-020-0323-4
31. Pareek M, Schauer PR, Kaplan LM et al. Metabolic surgery: weight loss, diabetes, and beyond [J]. J Am Coll Cardiol. 2018;71(6):670–87. https://doi.org/10.1016/j.jacc.2017.12.014
32. Ferraz-Bannitz R, Kashyap S, Patti ME. Bariatric Surgery: It's Not Just Incretins! [J]. J Clin Endocrinol Metab. 2022;107(2):e883–5. https://doi.org/10.1210/clinem/dgab694
33. Maglio C, Peltonen M, Neovius M et al. Effects of bariatric surgery on gout incidence in the Swedish obese subjects study: a non-randomised, prospective, controlled intervention trial [J]. Ann Rheum Dis. 2017;76(4):688–93. https://doi.org/10.1136/annrheumdis-2016-209958
34. Vafa L, Amini M, Kamran H et al. The impact of obesity surgery on serum uric acid in people with severe obesity: a retrospective study [J]. Clin Nutr Res. 2023;12(1):21–8. https://doi.org/10.7762/cnr.2023.12.1.21
35. Hung KC, Ho CN, Chen IW et al. Impact of serum uric acid on renal function after bariatric surgery: a retrospective study [J]. Surg Obes Relat Dis. 2020;16(2):288–95. https://doi.org/10.1016/j.soard.2019.10.029
36. Lu J, Bai Z, Chen Y et al. Effects of bariatric surgery on serum uric acid in people with obesity with or without hyperuricaemia and gout: a retrospective analysis [J]. Rheumatology (Oxford). 2021;60(8):3628–34. https://doi.org/10.1093/rheumatology/keaa822
37. Oberbach A, Neuhaus J, Inge T et al. Bariatric surgery in severely obese adolescents improves major comorbidities including hyperuricemia [J]. Metabolism. 2014;63(2):242–9. https://doi.org/10.1016/j.metabol.2013.11.012
38. Antozzi P, Soto F, Arias F et al. Development of acute gouty attack in the morbidly obese population after bariatric surgery [J]. Obes Surg. 2005;15(3):405–7. https://doi.org/10.1381/0960892053576802
39. Li M, Liu Y, Zeng N et al. Alterations in the serum urate concentrations after bariatric surgery: a short-term prospective observational study [J]. Obes Surg. 2021;31(4):1688–95. https://doi.org/10.1007/s11695-020-05181-0
40. Katsogridaki G, Tzovaras G, Sioka E et al. Hyperuricemia and acute gout after laparoscopic sleeve gastrectomy [J]. Clin Obes. 2019;9(2):e12296. https://doi.org/10.1111/cob.12296
41. Kang EH, Lee EY, Lee YJ et al. Clinical features and risk factors of postsurgical gout [J]. Ann Rheum Dis. 2008;67(9):1271–5. https://doi.org/10.1136/ard.2007.078683
42. Yip K, Berman J. What is gout? [J]. Jama. 2021;326(24):2541. https://doi.org/10.1001/jama.2021.19770
43. Favero M, El-Hadi H, Belluzzi E et al. Infrapatellar fat pad features in osteoarthritis: a histopathological and molecular study [J]. Rheumatology (Oxford). 2017;56(10):1784–93. https://doi.org/10.1093/rheumatology/kex287
44. Hui W, Litherland GJ, Elias MS et al. Leptin produced by joint white adipose tissue induces cartilage degradation via upregulation and activation of matrix metalloproteinases [J]. Ann Rheum Dis. 2012;71(3):455–62. https://doi.org/10.1136/annrheumdis-2011-200372
45. Berry KM, Neogi T, Baker JF et al. Obesity progression between young adulthood and midlife and incident arthritis: a retrospective cohort study of US adults [J]. Arthritis Care Res (Hoboken). 2021;73(3):318–27. https://doi.org/10.1002/acr.24252
46. Anderson IJ, Davis AM, Jan RH. Management of gout [J]. Jama. 2021;326(24):2519–20. https://doi.org/10.1001/jama.2021.19763
47. Szeto CC, Sugano K, Wang JG, APAGE/APLAR/APSDE et al. /APSH/APSN/PoA recommendations [J] Gut. 2020;69(4):617–29. https://doi.org/10.1136/gutjnl-2019-319300
48. McKenzie BJ, Wechalekar MD, Johnston RV et al. Colchicine for acute gout [J]. Cochrane Database Syst Rev. 2021;8(8):Cd006190. https://doi.org/10.1002/14651858.CD006190.pub3
49. Zhang L, An K, Mou X et al. Effect of Urate-lowering therapy on the progression of kidney function in patients with asymptomatic hyperuricemia: a systematic review and Meta-analysis [J]. Front Pharmacol. 2021;12:795082. https://doi.org/10.3389/fphar.2021.795082
50. Joosten LAB, Crişan TO, Bjornstad P et al. Asymptomatic hyperuricaemia: a silent activator of the innate immune system [J]. Nat Rev Rheumatol. 2020;16(2):75–86. https://doi.org/10.1038/s41584-019-0334-3
51. Yip K, Cohen RE, Pillinger MH. Asymptomatic hyperuricemia: is it really asymptomatic? [J]. Curr Opin Rheumatol. 2020;32(1):71–9. https://doi.org/10.1097/bor.0000000000000679
52. Sellmayr M, Hernandez Petzsche MR, Ma Q et al. Only Hyperuricemia with Crystalluria, but not asymptomatic hyperuricemia, drives progression of chronic kidney disease [J]. J Am Soc Nephrol. 2020;31(12):2773–92. https://doi.org/10.1681/asn.2020040523
53. Birben B, Akkurt G, Tez M et al. Long-term impact of sleeve gastrectomy on serum uric acid levels [J]. Turk J Med Sci. 2023;53(1):206–10. https://doi.org/10.55730/1300-0144.5574
54. Xu C, Wen J, Yang H et al. Factors influencing early serum uric acid fluctuation after bariatric surgery in patients with hyperuricemia [J]. Obes Surg. 2021;31(10):4356–62. https://doi.org/10.1007/s11695-021-05579-4
55. Luo M, Luo P, Zhang Z et al. Zinc delays the progression of obesity-related glomerulopathy in mice via down-regulating P38 MAPK-mediated inflammation [J]. Obesity (Silver Spring). 2016;24(6):1244–56. https://doi.org/10.1002/oby.21463
56. Cc Wang S, Zhu J, Liu, et al. Chinese Expert Consensus on Precision obesity metabolic surgery (2022 Edition) [J]. ZHONGHUAWEICHANG-WAIKEZAZHI. 2022;25(10):841–51. https://doi.org/10.3760/cma.j.cn441530-20220717-00315
57. Marwah RK. Comorbidities in gouty arthritis [J]. J Investig Med. 2011;59(8):1211–20. https://doi.org/10.2130/JIM.0b013e318239f660
58. Schiavo L, Favrè G, Pilone V et al. Low-purine Diet is more effective Than Normal-Purine Diet in reducing the risk of gouty attacks after sleeve gastrectomy in patients suffering of gout before surgery: a retrospective study [J]. Obes Surg. 2018;28(5):1263–70. https://doi.org/10.1007/s11695-017-2984-z
59. Tana C, Busetto L, Di Vincenzo A et al. Management of hyperuricemia and gout in obese patients undergoing bariatric surgery [J]. Postgrad Med. 2018;130(6):523–35. https://doi.org/10.1080/00325481.2018.1485444
60. Song K, He M, Kong X et al. Benefits of uric acid-lowering medication after bariatric surgery in patients with gout [J]. BMC Surg. 2024;24(1):186. https://doi.org/10.1186/s12893-024-02472-6
61. Oldmeadow LB, Edwards ER, Kimmel LA et al. No rest for the wounded: early ambulation after hip surgery accelerates recovery [J]. ANZ J Surg. 2006;76(7):607–11. https://doi.org/10.1111/j.1445-2197.2006.03786.x
62. Siu AL, Penrod JD, Boockvar KS et al. Early ambulation after hip fracture: effects on function and mortality [J]. Arch Intern Med. 2006;166(7):766–71. https://doi.org/10.1001/archinte.166.7.766
63. Richette P, Poitou C, Garnero P et al. Benefits of massive weight loss on symptoms, systemic inflammation and cartilage turnover in obese patients with knee osteoarthritis [J]. Ann Rheum Dis. 2011;70(1):139–44. https://doi.org/10.1136/ard.2010.134015
64. Dessein PH, Shipton EA, Stanwix AE et al. Beneficial effects of weight loss associated with moderate calorie/carbohydrate restriction, and increased proportional intake of protein and unsaturated fat on serum urate and lipoprotein levels in gout: a pilot study [J]. Ann Rheum Dis. 2000;59(7):539–43. https://doi.org/10.1136/ard.59.7.539
65. ZoomForward2022. European Congress on Obesity [J]. Obes Facts. 2022;15 Suppl 1:1-240. https://doi.org/10.1159/000524469
66. Eisenberg D, Shikora SA, Aarts E et al. 2022 American Society for Metabolic and bariatric surgery (ASMBS) and International Federation for the Surgery of Obesity and metabolic disorders (IFSO): indications for metabolic and bariatric surgery [J]. Surg Obes Relat Dis. 2022;18(12):1345–56. https://doi.org/10.1016/j.soard.2022.08.013
67. Bal BS, Finelli FC, Shope TR et al. Nutritional deficiencies after bariatric surgery [J]. Nat Rev Endocrinol. 2012;8(9):544–56. https://doi.org/10.1038/nrendo.2012.48
68. Bettini S, Belligoli A, Fabris R et al. Diet approach before and after bariatric surgery [J]. Rev Endocr Metab Disord. 2020;21(3):297–306. https://doi.org/10.1007/s11154-020-09571-8
69. Wang W, Liou TH, Lee WJ et al. ESR1 gene and insulin resistance remission are associated with serum uric acid decline for severely obese patients undergoing bariatric surgery [J]. Surg Obes Relat Dis. 2014;10(1):14–22. https://doi.org/10.1016/j.soard.2012.10.011

70. Hartmaier RJ, Trabucco SE, Priedigkeit N et al. Recurrent hyperactive ESR1 fusion proteins in endocrine therapy-resistant breast cancer [J]. Ann Oncol. 2018;29(4):872–80. https://doi.org/10.1093/annonc/mdy025
71. Yang W, Jiang W, Liao W et al. An estrogen receptor α-derived peptide improves glucose homeostasis during obesity [J]. Nat Commun. 2024;15(1):3410. https://doi.org/10.1038/s41467-024-47687-6
72. Arterburn DE, Telem DA, Kushner RF et al. Benefits and risks of bariatric surgery in adults: a review [J]. Jama. 2020;324(9):879–87. https://doi.org/10.1001/jama.2020.12567

Publisher's Note