Review Article

Metabolic–Bariatric Surgery in Patients with Insulin Resistance and Uncontrolled Arterial Hypertension: Current Selection Criteria and Mid-Term Metabolic and Cardiovascular Outcomes

Melina Mata Serrano[1*], Rachel Alfaro Villalobos[2], Reiner Serrano Calderón[3], José Agustín Matamoros Bustamante[4], Ciara María Murillo González[5]

[1]Medical Doctor, Independent Researcher, Cartago, Costa Rica
[2, 5]Medical Doctor, Independent Researcher, San José, Costa Rica
[3]Medical Doctor, San Juan de Dios Hospital, Cartago, Costa Rica
[4]Medical Doctor, San Juan de Dios Hospital, San José, Costa Rica
[*]Corresponding author email: **mematas1488@gmail.com**

International Archives of Integrated Medicine, Vol. 13, Issue 3, March, 2026.
Available online at http://iaimjournal.com/
ISSN: 2394-0026 (P) **ISSN: 2394-0034 (O)**
Received on: 19-2-2026 **Accepted on:** 9-3-2026
Source of support: Nil **Conflict of interest:** None declared.

DOI: **10.5281/zenodo.19276861**

How to cite this article: Melina Mata Serrano, Rachel Alfaro Villalobos, Reiner Serrano Calderón, José Agustín Matamoros Bustamante, Ciara María Murillo González. Metabolic–Bariatric Surgery in Patients with Insulin Resistance and Uncontrolled Arterial Hypertension: Current Selection Criteria and Mid-Term Metabolic and Cardiovascular Outcomes. Int. Arch. Integr. Med., 2026; 13(3): 111-124.

Abstract

Insulin resistance and uncontrolled arterial hypertension represent central components of cardiometabolic disease and are strongly linked to obesity through complex metabolic, inflammatory, neurohormonal, and vascular mechanisms. Dysfunctional adipose tissue, chronic inflammation, and ectopic fat deposition contribute to impaired insulin signaling, endothelial dysfunction, and increased arterial stiffness, thereby promoting both type 2 diabetes mellitus and hypertension. Within this pathophysiological context, metabolic–bariatric surgery has emerged as an effective therapeutic

strategy that extends beyond weight reduction, directly targeting the mechanisms underlying cardiometabolic risk. Traditional eligibility criteria for metabolic–bariatric surgery have relied primarily on body mass index thresholds; however, growing evidence highlights the limitations of this approach in metabolically unhealthy individuals. Contemporary selection strategies increasingly incorporate metabolic markers such as insulin resistance indices, uncontrolled hypertension despite pharmacological therapy, and comprehensive cardiovascular risk stratification, including evidence of target-organ damage. Surgical techniques such as sleeve gastrectomy and Roux-en-Y gastric bypass induce profound hormonal and metabolic adaptations, including enhanced incretin secretion, altered bile acid signaling, and reductions in ectopic fat, leading to early and sustained improvements in insulin sensitivity and glucose homeostasis. Emerging procedures, including one-anastomosis gastric bypass variants, offer additional options for patients with refractory metabolic disease. Mid-term outcomes consistently demonstrate durable improvements in glycemic control, significant rates of diabetes and hypertension remission, favorable changes in lipid profiles, and reductions in systemic inflammation. These metabolic benefits translate into meaningful cardiovascular improvements, including reduced arterial stiffness, regression of left ventricular hypertrophy, and a substantial decrease in major adverse cardiovascular events and mortality. The magnitude of benefit is influenced by baseline metabolic severity, surgical technique, postoperative weight loss, and adherence to long-term lifestyle modification and follow-up. Collectively, current evidence supports metabolic–bariatric surgery as a cornerstone intervention in selected patients with insulin resistance and uncontrolled hypertension, integrating surgical therapy into comprehensive cardiometabolic risk management.

Key words

Ectopic fat; metabolic syndrome; arterial stiffness; endothelial dysfunction; major adverse cardiovascular events; hormonal adaptation.

Introduction

The global burden of obesity, insulin resistance, and uncontrolled hypertension represents a major public health challenge. Obesity currently affects more than 15% of the global adult population and is a key contributor to a wide range of cardiometabolic comorbidities, including hypertension and diabetes mellitus [1]. Its prevalence has nearly tripled since 1975, establishing obesity as one of the leading risk factors for cardiovascular diseases worldwide. According to the World Health Organization, obesity-related conditions now account for more deaths than underweight in most regions of the world, underscoring the magnitude of its global impact [2].

The association between adiposity, insulin resistance, and hypertension is driven by a complex and interrelated pathophysiological network. Excess adipose tissue promotes blood pressure elevation through overactivation of the renin–angiotensin–aldosterone system and the sympathetic nervous system, while simultaneously inducing adipokine imbalance and chronic low-grade inflammation [1]. This dysfunctional adipose tissue environment contributes to impaired insulin signaling and vascular dysfunction, thereby amplifying insulin resistance and sustaining hypertensive states. Chronic inflammation further exacerbates these processes, increasing overall cardiovascular risk and accelerating end-organ damage [3].

Within this context, metabolic–bariatric surgery has emerged as the most effective therapeutic strategy for severe obesity, with benefits that extend well beyond weight reduction. In addition to producing substantial and sustained weight loss, metabolic–bariatric surgery significantly improves insulin sensitivity and promotes remission of arterial hypertension [4]. Clinical

studies have consistently demonstrated marked reductions in both systolic and diastolic blood pressure following surgical intervention, with superior long-term hypertension control compared to non-surgical treatments [5]. Moreover, metabolic–bariatric surgery induces favorable cardiovascular remodeling, including reductions in arterial stiffness and left ventricular hypertrophy, which translate into a lower incidence of major adverse cardiovascular events and reduced all-cause mortality [6]. Importantly, the likelihood of hypertension remission after surgery is modulated by patient-specific factors, such as age and the preoperative burden of antihypertensive therapy, with younger individuals and those requiring fewer medications demonstrating higher remission rates [7].

This article aims to evaluate the role of metabolic–bariatric surgery in patients with insulin resistance and uncontrolled arterial hypertension, focusing on its metabolic and cardiovascular benefits beyond weight loss and its impact on mid-term clinical outcomes.

Methodology

This review on metabolic–bariatric surgery in patients with insulin resistance and uncontrolled arterial hypertension was developed through a structured and comprehensive analysis of the current scientific literature, with the objective of examining clinical, metabolic, and cardiovascular factors that support the use of surgical intervention beyond weight loss. The methodological approach focused on evaluating patient selection criteria, underlying pathophysiological mechanisms, and mid-term metabolic and cardiovascular outcomes associated with different bariatric procedures.

To ensure scientific rigor and reliability, a systematic literature search was conducted using major academic databases, including PubMed, Scopus, and Web of Science, selected for their relevance in the fields of metabolic disease, cardiovascular medicine, endocrinology, and bariatric surgery. A predefined set of inclusion and exclusion criteria was applied. Eligible studies were those published between 2021 and 2026, written in English or Spanish, and addressing key topics such as *Ectopic fat; metabolic syndrome; arterial stiffness; endothelial dysfunction; major adverse cardiovascular events; hormonal adaptation.*Studies lacking peer review, presenting incomplete or insufficient data, or containing duplicated information were excluded.

The search strategy was guided by the following key terms: metabolic–bariatric surgery, insulin resistance, uncontrolled hypertension, cardiometabolic outcomes, cardiovascular risk, and obesity-related hypertension. The initial search yielded 44 relevant references, including original research articles, systematic reviews, meta-analyses, clinical guidelines, and consensus statements from recognized professional societies in endocrinology, cardiology, and bariatric surgery. Each selected publication underwent critical appraisal to extract relevant data on metabolic improvements, hypertension remission rates, cardiovascular structural and functional changes, and predictors of surgical response.

Artificial intelligence tools were incorporated as supportive instruments to assist in the organization, categorization, and synthesis of the selected literature. These tools facilitated thematic clustering of findings and contributed to maintaining logical coherence and continuity throughout the review.

The overall analysis followed a qualitative and comparative methodological framework. The extracted data were organized into thematic sections to evaluate current evidence on selection criteria, compare metabolic and cardiovascular outcomes across surgical techniques, and identify factors influencing mid-term clinical response.

This approach enabled the development of an integrated, evidence-based overview of the role of metabolic–bariatric surgery in this high-risk population, emphasizing its relevance within contemporary cardiometabolic management strategies.

Pathophysiological Basis

Insulin resistance represents a central component of cardiometabolic risk and is strongly influenced by adipokine dysregulation, chronic inflammation, and ectopic fat deposition. Dysfunctional adipose tissue is characterized by altered adipokine secretion and persistent inflammatory signaling, processes that contribute to systemic metabolic impairment and the development of metabolic syndrome (MetS) [8]. In parallel, the accumulation of ectopic fat, particularly within the liver and pancreas, plays a critical role in worsening insulin resistance and constitutes a key pathogenic factor in the progression toward type 2 diabetes mellitus (T2DM) [9].

Beyond its metabolic consequences, insulin resistance is closely interconnected with vascular dysfunction and the development of hypertension. The presence of ectopic fat and the associated inflammatory milieu adversely affect endothelial function and promote increased arterial stiffness, thereby facilitating the onset and persistence of elevated blood pressure. This interaction highlights the bidirectional relationship between metabolic derangements and vascular pathology, in which insulin resistance both contributes to and is amplified by cardiovascular dysfunction [10].

Obesity-related hypertension is driven by multiple neurohormonal and vascular mechanisms. Sympathetic nervous system overactivation and stimulation of the renin–angiotensin–aldosterone system (RAAS) lead to enhanced sodium retention and sustained increases in blood pressure. These processes are further intensified by excess adipose tissue, which disrupts adipokine homeostasis and perpetuates a proinflammatory state, thereby reinforcing hypertensive mechanisms. In addition, obesity is associated with endothelial dysfunction and increased arterial stiffness, both of which play a pivotal role in the pathogenesis of hypertension. Chronic inflammation impairs endothelial responsiveness, while structural vascular changes contribute to reduced arterial compliance, together sustaining elevated vascular resistance [1, 11].

Within this pathophysiological framework, metabolic–bariatric surgery exerts profound metabolic effects through mechanisms that extend beyond weight reduction. Surgical intervention induces significant hormonal adaptations, including enhanced incretin secretion and alterations in bile acid metabolism, which collectively improve insulin sensitivity and glucose homeostasis [12]. These hormonal changes reflect broader adaptations of the gut–brain axis that occur following surgery and contribute to sustained metabolic benefits. Importantly, metabolic–bariatric surgery also produces early improvements in insulin sensitivity and glucose tolerance that are independent of weight loss. These early effects are largely attributed to rapid changes in gut hormone signaling and reductions in ectopic fat deposition, particularly within the liver, underscoring the direct metabolic impact of surgical intervention [13, 14].

Indications and Patient Selection Criteria

Traditionally, metabolic–bariatric surgery has been recommended for individuals with a body mass index greater than 35 kg/m², particularly when obesity-related comorbidities such as type 2 diabetes mellitus and arterial hypertension are present [15]. This BMI-based framework has long served as the cornerstone for surgical eligibility; however, its limitations have become increasingly evident. Reliance on BMI alone fails to adequately capture metabolic risk, especially in metabolically unhealthy patients who may not

meet conventional BMI thresholds yet experience significant cardiometabolic comorbidities and elevated cardiovascular risk [16].

In response to these limitations, metabolic criteria beyond BMI have gained relevance in patient selection for metabolic–bariatric surgery. Markers of insulin resistance, including the homeostatic model assessment of insulin resistance (HOMA-IR) and fasting insulin levels, are increasingly incorporated into clinical decision-making, as they provide a more direct and physiologically meaningful assessment of metabolic dysfunction [17]. In parallel, uncontrolled arterial hypertension has emerged as a key criterion for surgical eligibility. Hypertension that persists above 140/90 mmHg despite the use of multiple antihypertensive agents reflects a high-risk cardiovascular profile and identifies patients in whom surgical intervention may offer substantial metabolic and vascular benefit [18].

Comprehensive cardiovascular risk stratification represents a fundamental component of the preoperative evaluation process. Baseline assessment of cardiovascular status allows for the identification of target-organ damage, with findings such as left ventricular hypertrophy and microalbuminuria serving as markers of advanced cardiometabolic disease and heightened potential benefit from surgical intervention [19]. These parameters contribute to a more refined stratification of patients who are likely to derive meaningful cardiovascular improvements from metabolic–bariatric surgery, extending its role beyond weight reduction alone [7].

Consideration of contraindications and special populations remains essential to ensure surgical safety and optimize outcomes. Absolute contraindications include severe psychiatric disorders and active substance abuse, while relative contraindications often encompass advanced age and established cardiovascular disease [20]. Nevertheless, emerging evidence suggests that age alone should not preclude surgical intervention. Studies have demonstrated that older adults, including those over 50 years of age, can experience significant improvements in components of metabolic syndrome following metabolic–bariatric surgery, supporting its potential benefit even within traditionally higher-risk populations [21].

Surgical Techniques and Their Metabolic Impact

Sleeve gastrectomy is a widely performed metabolic–bariatric procedure that induces metabolic improvement through both restrictive and hormonal mechanisms. The procedure involves the removal of a substantial portion of the stomach, which results in reduced caloric intake and profound alterations in gut hormone secretion. These hormonal changes enhance satiety and improve insulin sensitivity, contributing to better metabolic control [22]. Beyond its restrictive effect, sleeve gastrectomy has been shown to suppress hepatic glucose production and increase hepatic insulin clearance independently of weight loss, indicating that the anatomical and physiological modifications induced by surgery play a direct role in metabolic regulation [23].

These mechanisms translate into clinically relevant improvements in insulin sensitivity and blood pressure control. Sleeve gastrectomy enhances prandial insulin secretion and modifies insulin clearance rates, processes that are fundamental to efficient glucose metabolism [24, 25]. In parallel, the procedure is associated with significant reductions in arterial blood pressure, an effect that is likely mediated by weight loss and overall improvement in metabolic profiles. Nevertheless, the precise pathways through which sleeve gastrectomy exerts its antihypertensive effects remain an area of ongoing investigation [11].

Roux-en-Y gastric bypass is another established surgical technique with well-documented metabolic and cardiovascular benefits. Compared with sleeve gastrectomy, Roux-en-Y gastric bypass is associated with more pronounced improvements in insulin sensitivity and glucose metabolism. These effects are largely attributed to greater alterations in insulin secretion dynamics and insulin clearance, resulting in enhanced glycemic control [24, 25]. In addition to its metabolic advantages, Roux-en-Y gastric bypass confers substantial cardiovascular benefits, including marked reductions in arterial hypertension and favorable changes in lipid profiles, further supporting its role in comprehensive cardiometabolic risk reduction [11].

The benefits of Roux-en-Y gastric bypass are particularly evident in patients with severe insulin resistance. In this subgroup, the procedure leads to more substantial improvements in insulin kinetics and glucose tolerance when compared with sleeve gastrectomy [26]. Its capacity to enhance prandial insulin secretion while reducing insulin clearance contributes to its superior effectiveness in managing advanced metabolic dysfunction [25].

In recent years, emerging and revisional procedures have expanded the surgical options available for the treatment of complex metabolic disease. Techniques such as one-anastomosis gastric bypass and single-anastomosis sleeve ileal bypass have demonstrated significant efficacy, offering substantial weight loss and meaningful metabolic improvements. These procedures are associated with greater reductions in body weight and body mass index, as well as improved control of type 2 diabetes mellitus, when compared with sleeve gastrectomy [27].

These newer surgical approaches are particularly indicated in patients with refractory metabolic disease, in whom conventional procedures may yield suboptimal results. One-anastomosis gastric bypass and single-anastomosis sleeve ileal bypass provide superior metabolic outcomes and improved patient comfort relative to sleeve gastrectomy, making them attractive options in selected cases. Ultimately, the choice of surgical technique should be individualized, taking into account patient-specific characteristics and the severity of underlying metabolic disturbances [27].

Mid-Term Metabolic Outcomes

Bariatric surgery, including Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy, has demonstrated a significant impact on glycemic control and insulin resistance. Surgical intervention is associated with marked improvements in insulin sensitivity, as evidenced by substantial reductions in insulin resistance measured by the homeostatic model assessment. Long-term data indicate that insulin resistance decreases significantly in surgically treated patients compared with non-surgical controls, with these differences persisting over extended follow-up periods of up to twelve years [28]. In parallel, remission of type 2 diabetes has been observed in a considerable proportion of patients following surgery, with complete remission reported in approximately 31% of individuals ten years after the intervention, underscoring the profound metabolic effects of surgical treatment [29].

The durability of these metabolic improvements has been a key focus of mid-term outcome studies. Improvements in insulin sensitivity and glycemic control are generally sustained for several years following surgery, with consistent reductions in fasting plasma glucose and glycated hemoglobin levels documented between two and five years postoperatively [30]. Nevertheless, evidence suggests that diabetes remission rates may decline gradually over time. While early postoperative remission is common, long-term follow-up indicates that approximately 61.8% of patients maintain type 2 diabetes

remission at five years, highlighting both the durability and the potential attenuation of metabolic benefits with prolonged follow-up [31].

Weight loss trajectories play a central role in shaping metabolic outcomes after bariatric surgery. The magnitude of weight reduction achieved postoperatively is closely correlated with improvements in insulin sensitivity and glycemic control. Long-term studies have reported substantial and sustained weight loss following Roux-en-Y gastric bypass, with reductions of up to 24.6% of total body weight observed ten years after surgery. This degree of weight loss is strongly associated with remission of obesity-related comorbidities and contributes significantly to the maintenance of metabolic benefits over time [32]. Consequently, the extent of postoperative weight loss remains a critical determinant of both the achievement and long-term preservation of improved metabolic status [30].

In addition to glycemic control, bariatric surgery exerts favorable effects on lipid metabolism and systemic inflammation. Surgical patients consistently demonstrate improvements in lipid profiles, characterized by reductions in triglyceride levels and increases in high-density lipoprotein cholesterol when compared with non-surgical controls [28]. These changes reflect an overall improvement in atherogenic risk. Furthermore, markers of systemic inflammation, including tumor necrosis factor-alpha, show notable short-term reductions following surgery, indicating a transient attenuation of the inflammatory state associated with obesity. However, some evidence suggests that these anti-inflammatory effects may diminish over time, as certain inflammatory markers tend to return toward baseline levels during long-term follow-up, highlighting the dynamic nature of inflammatory responses after bariatric intervention [4].

Mid-Term Cardiovascular Outcomes

Metabolic–bariatric surgery has demonstrated a substantial impact on blood pressure control, with consistently higher rates of hypertension remission when compared with non-surgical interventions. Clinical studies report remission rates of arterial hypertension of up to 46.9% following procedures such as Roux-en-Y gastric bypass, highlighting the effectiveness of surgical intervention in achieving sustained blood pressure normalization [33]. In parallel with remission, a marked reduction in antihypertensive medication requirements has been observed after surgery. Evidence indicates that medication use may decrease by as much as 80.7% in surgically treated patients, reflecting both improved blood pressure control and reduced pharmacological burden [6, 34].

The sustainability of blood pressure improvement following metabolic–bariatric surgery appears to be influenced by several patient-related and postoperative factors. Younger age at the time of surgery, a lower number of antihypertensive medications before intervention, and greater degrees of postoperative weight loss have been consistently associated with more favorable and sustained blood pressure outcomes [7, 34].

Beyond its effects on blood pressure, metabolic–bariatric surgery induces favorable changes in cardiac structure and function. Reductions in left ventricular mass have been documented following surgical intervention, a finding that is commonly associated with improvements in diastolic function. These structural cardiac adaptations contribute to enhanced overall cardiovascular performance and reflect a reversal of obesity-related cardiac remodeling [11].

Improvements in vascular and endothelial health further support the cardiovascular benefits of metabolic–bariatric surgery. Surgical intervention has been associated with reduced arterial stiffness and enhanced endothelial

function, both of which play a central role in mitigating atherosclerotic progression and lowering long-term cardiovascular risk. These vascular adaptations are integral to the observed improvements in cardiovascular outcomes among surgically treated patients [11].

Collectively, these hemodynamic, cardiac, and vascular effects translate into a meaningful reduction in adverse cardiovascular events and improved prognosis. Metabolic–bariatric surgery is associated with a significant decrease in the incidence of major adverse cardiovascular events, particularly among patients who achieve hypertension remission. Evidence indicates that individuals attaining blood pressure remission after surgery experience approximately a 50% reduction in the risk of major adverse cardiovascular events and mortality compared with those who do not achieve remission [34]. Furthermore, the magnitude of postoperative weight loss is closely linked to cardiovascular risk reduction, emphasizing the critical role of substantial and sustained weight loss in lowering the incidence of major adverse cardiovascular events [35].

Predictors of Response and Non-Response

Baseline metabolic severity plays a central role in determining the magnitude of metabolic and clinical response following metabolic–bariatric surgery. Preoperative levels of insulin resistance, particularly when assessed using the glucose disposal rate, have been identified as significant predictors of postoperative outcomes. Higher preoperative glucose disposal rates are positively correlated with more favorable responses, including greater improvements in type 2 diabetes mellitus, arterial hypertension, and overall weight loss, highlighting the importance of metabolic reserve at the time of intervention [36]. In addition, disease severity scoring systems such as the Insulinoma Severity Score, DiaRem, and advanced DiaRem have been widely used to estimate the likelihood of diabetes remission after surgery. Lower baseline scores consistently correspond to higher remission rates, reinforcing baseline metabolic severity as a critical determinant of postoperative success [37].

The type of surgical procedure performed also significantly influences metabolic outcomes. Different techniques exhibit varying degrees of efficacy in terms of weight reduction and metabolic improvement. Single anastomosis sleeve–ileal bypass has demonstrated particularly favorable results, with substantial weight loss and type 2 diabetes remission reported in up to 77.4% of treated patients [38]. Similarly, one-anastomosis gastric bypass and Roux-en-Y gastric bypass are associated with marked weight loss and significant improvement in obesity-related metabolic diseases. Comparative data indicate that one-anastomosis gastric bypass may achieve greater weight loss outcomes than sleeve gastrectomy, suggesting procedural differences in metabolic impact [39].

Beyond surgical technique and baseline metabolic status, adherence to postoperative lifestyle modification and structured medical follow-up is essential for achieving and maintaining optimal outcomes. Consistent engagement with dietary recommendations, physical activity, and medical monitoring supports sustained weight loss and metabolic control. The assessment of total weight loss percentiles during follow-up has emerged as a practical tool to identify patients at risk for suboptimal response, enabling early intervention and individualized management strategies to improve long-term results [40].

Safety and Perioperative Considerations

Perioperative cardiovascular risk management represents a critical component of care in patients undergoing metabolic–bariatric surgery. Surgical intervention has been consistently associated with a significant reduction in the risk of major adverse cardiovascular events, alongside improved control of arterial hypertension, with

clinically meaningful benefits emerging within the first years following surgery. These cardiovascular risk reductions are largely attributed to sustained weight loss and the improvement of metabolic profiles after surgery, including better glycemic control and favorable changes in lipid metabolism, which collectively contribute to a lower burden of cardiovascular disease [11, 41].

Despite these benefits, metabolic–bariatric surgery is associated with an increased risk of nutritional deficiencies that necessitate long-term surveillance and management. Deficiencies in vitamin D, folic acid, iron, and vitamin B12 are frequently observed after surgery and require systematic monitoring and appropriate supplementation to prevent long-term complications. The extent and nature of these deficiencies may vary according to the surgical technique employed, as different procedures exert distinct effects on nutrient absorption. Consequently, individualized nutritional management strategies are essential to address procedure-specific risks and ensure optimal postoperative nutritional status [42, 43].

The interaction between metabolic–bariatric surgery and ongoing pharmacological therapy also warrants careful consideration. Although surgery leads to significant metabolic improvement, a subset of patients may experience recurrence of type 2 diabetes over time, necessitating the reintroduction of antidiabetic medications. In this context, glucagon-like peptide-1 analogues are recommended due to their efficacy in glycemic control and their additional cardiovascular protective effects. Furthermore, postoperative anatomical and physiological changes can alter the pharmacokinetics of antihypertensive and lipid-lowering agents, underscoring the importance of close clinical monitoring and timely dosage adjustments to maintain therapeutic effectiveness and safety [44].

Conclusions

Insulin resistance and obesity-related hypertension are tightly interconnected through shared metabolic, inflammatory, neurohormonal, and vascular mechanisms, with ectopic fat deposition and adipose tissue dysfunction acting as central drivers of cardiometabolic risk. Metabolic–bariatric surgery directly targets these pathophysiological pathways, producing early and sustained improvements in insulin sensitivity, glycemic control, and blood pressure regulation through hormonal, metabolic, and vascular adaptations that extend beyond weight loss alone.

Contemporary evidence supports a shift from purely body mass index–based selection toward a metabolically driven approach that incorporates insulin resistance markers, uncontrolled arterial hypertension, and comprehensive cardiovascular risk stratification. Surgical technique selection and baseline metabolic severity are critical determinants of response, with procedures such as Roux-en-Y gastric bypass and one-anastomosis variants offering superior metabolic and cardiovascular benefits in patients with severe or refractory disease.

Mid-term outcomes consistently demonstrate durable improvements in metabolic control, hypertension remission, cardiac structure, vascular function, and a significant reduction in major adverse cardiovascular events, particularly among patients achieving substantial and sustained weight loss. These benefits, however, depend on careful perioperative risk management, long-term nutritional surveillance, individualized pharmacologic adjustment, and strict adherence to postoperative follow-up, underscoring metabolic–bariatric surgery as an integral component of comprehensive cardiometabolic care rather than an isolated weight-loss intervention.

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