Post-bariatric hypoglycemia and cardiovascular risk: A systematic review of incidence, risk factors, and management

Hipoglucemia posbariátrica y riesgo cardiovascular: Una revisión sistemática de incidencia, factores de riesgo y manejo

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Abstract

Post-bariatric hypoglycemia (PBH) has emerged as a significant and increasingly recognized long-term metabolic complication following bariatric surgery, particularly Roux-en-Y gastric bypass. This systematic review, synthesizing evidence from 30 studies encompassing over 3,250 patients, reveals a widely variable incidence ranging from 0.2% to over 30%, a disparity largely attributable to differences in diagnostic methods, surgical types, and follow-up durations. The condition is not a uniform entity but is influenced by a constellation of risk factors, most consistently including the type of procedure (with RYGB carrying the highest risk), female sex, rapid and significant weight loss, an exaggerated postprandial incretin response, and a lower preoperative BMI. The management of PBH necessitates a structured, stepwise approach. The foundational strategy is dietary modification, focusing on low-glycemic index carbohydrates and small, frequent meals to mitigate rapid glucose shifts. When lifestyle interventions are insufficient, a range of pharmacological options can be employed, including acarbose to delay carbohydrate absorption, and diazoxide or verapamil to modulate insulin secretion. In severe, refractory cases, surgical revision, while rare, may be considered. The integration of continuous glucose monitoring (CGM) has proven invaluable for both diagnosis and patient education, often uncovering asymptomatic hypoglycemic episodes. Ultimately, PBH is a multifactorial and likely underdiagnosed condition that underscores the complex metabolic alterations after bariatric surgery. Its management demands individualized, multidisciplinary care, and the field would greatly benefit from standardized diagnostic criteria and more robust long-term studies to optimize patient outcomes and clarify its potential implications for broader cardiometabolic health.

Keywords: Post-bariatric hypoglycemia, Bariatric surgery, Risk factors, Treatment, Systematic review

Resumen

La hipoglucemia posbariátrica (HPB) se ha convertido en una complicación metabólica a largo plazo significativa y cada vez más reconocida tras la cirugía bariátrica, en particular el bypass gástrico en Y de Roux. Esta revisión sistemática, que sintetiza la evidencia de 30 estudios con más de 3250 pacientes, revela una incidencia muy variable, que oscila entre el 0,2 % y más del 30 %, una disparidad atribuible en gran medida a las diferencias en los métodos de diagnóstico, los tipos de cirugía y la duración del seguimiento. La afección no es una entidad uniforme, sino que se ve influenciada por una constelación de factores de riesgo, entre los que destacan el tipo de procedimiento (siendo el BGYR el de mayor riesgo), el sexo femenino, la pérdida de peso rápida y significativa, una respuesta incretínica posprandial exagerada y un IMC preoperatorio más bajo. El manejo de la HPB requiere un enfoque estructurado y gradual. La estrategia fundamental es la modificación dietética, centrándose en carbohidratos de bajo índice glucémico y comidas pequeñas y frecuentes para mitigar las fluctuaciones rápidas de la glucosa. Cuando las intervenciones en el estilo de vida son insuficientes, se pueden emplear diversas opciones farmacológicas, como la acarbosa para retrasar la absorción de carbohidratos y el diazóxido o el verapamilo para modular la secreción de insulina. En casos graves y refractarios, se puede considerar la revisión quirúrgica, aunque poco frecuente. La integración de la monitorización continua de la glucosa (MCG) ha demostrado ser invaluable tanto para el diagnóstico como para la educación del paciente, detectando a menudo episodios de hipoglucemia asintomática. En definitiva, la HBP es una afección multifactorial y probablemente infradiagnosticada que subraya las complejas alteraciones metabólicas tras la cirugía bariátrica. Su manejo requiere atención individualizada y multidisciplinaria, y este campo se beneficiaría enormemente de criterios diagnósticos estandarizados y estudios a largo plazo más sólidos para optimizar los resultados de los pacientes y aclarar sus posibles implicaciones para la salud cardiometabólica en general.

Palabras clave: Hipoglucemia posbariátrica, Cirugía bariátrica, Factores de riesgo, Tratamiento, Revisión sistemática

Introduction

Bariatric surgery has firmly established itself as a cornerstone in the management of severe obesity and its associated cardiometabolic diseases, providing not only substantial and sustained weight reduction but also significant improvement or remission of conditions like type 2 diabetes, cardiovascular disease, and metabolic syndrome[1]. The two most prevalent and effective procedures, Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG), dominate the surgical landscape due to their proven long-term outcomes[2]. With the rising prevalence of these interventions, the clinical focus is progressively shifting from immediate postoperative success to the management of long-term metabolic sequelae[3]. A complication that epitomizes this challenge is post-bariatric hypoglycemia (PBH), a condition gaining increasing attention for its potential cardiovascular implications and its profound impact on patient safety and quality of life, particularly after RYGB[4].

Clinically, PBH is characterized by recurrent episodes of postprandial hypoglycemia, typically manifesting one to three hours after meals, especially those rich in carbohydrates[5]. Its reported incidence exhibits remarkable heterogeneity, with estimates ranging from 0.1% to over 70%, a variance heavily influenced by the studied population, the diagnostic methodology—whether based on self-report, structured tests like the oral glucose tolerance test (OGTT) or mixed-meal tolerance test (MMTT), or continuous glucose monitoring (CGM)—and the specific biochemical criteria applied[6]. The underlying pathophysiology, while not completely deciphered, is believed to involve a complex interplay of exaggerated insulin secretion, dysregulated gut hormone responses—notably involving GLP-1 and glicentin—accelerated gastric emptying, and heightened glycemic variability[7]. Several patient- and surgery-specific factors have been implicated in its development, including female sex, younger age, magnitude of weight loss, a history of cholecystectomy, and the use of medications such as antidepressants[8]. Current management is multifaceted, encompassing nutritional strategies, pharmacological agents like acarbose and diazoxide, and, in severe refractory cases, surgical revision; however, the absence of standardized diagnostic and treatment protocols continues to complicate clinical decision-making[9].

Despite a growing corpus of literature on the subject, a comprehensive synthesis of the evidence is urgently needed to clarify the true epidemiological burden of PBH, distill its consistent risk factors, and critically appraise the efficacy of existing therapeutic interventions. This systematic review therefore aims to provide a definitive evaluation of the incidence of PBH across different diag-

nostic modalities, identify the key risk factors predisposing to its development, and summarize the current landscape of clinical management strategies. By integrating findings from available observational and interventional studies, this review intends to inform and refine clinical practice while delineating critical avenues for future research to address this complex metabolic complication.

Study Design and Rationale

This study was conducted as a systematic review in accordance with the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[10]. A protocol was developed a priori to ensure transparency, replicability, and methodological rigor. The review was designed to synthesize the current evidence on the incidence, risk factors, and therapeutic management of post-bariatric hypoglycemia (PBH), a metabolic complication with potential implications for long-term cardiovascular risk due to recurrent glycemic volatility and neuroglycogenic events.

Literature Search Strategy

A comprehensive literature search was executed across four major electronic databases: PubMed, MEDLINE, Embase, and the Cochrane Library, from their inception through August 2023. The search strategy incorporated controlled vocabulary (e.g., MeSH terms) and free-text keywords to capture all relevant studies. Core concepts included “bariatric surgery,” “gastric bypass,” “sleeve gastrectomy,” “Roux-en-Y,” “post-bariatric hypoglycemia,” “postprandial hypoglycemia,” “reactive hypoglycemia,” and “dumping syndrome.” Boolean operators (AND, OR) and truncation were employed to optimize sensitivity and specificity. The search was restricted to human studies published in the English language. To ensure literature saturation, the reference lists of all included articles were manually screened for additional eligible publications.

Eligibility Criteria

Studies were included based on the following pre-defined criteria: (1) original research involving adult human subjects (≥18 years) who had undergone any form of bariatric or metabolic surgery; (2) reporting of quantitative or qualitative data on PBH incidence or prevalence; (3) analysis of factors associated with PBH risk or evaluation of therapeutic strategies for its management; and (4) a follow-up duration of at least one year post-surgery to capture established metabolic outcomes rather than immediate postoperative fluctuations.

Exclusion criteria comprised: case reports, narrative reviews, editorials, conference abstracts, and animal studies. Studies focusing exclusively on the immediate postoperative period (less than 12 months) were also excluded due to the instability of metabolic parameters during that phase.

Study Selection and Data Extraction

The study selection process was managed according to the PRISMA flow diagram. All retrieved records were imported into a reference management software for duplicate removal. Two independent reviewers screened the titles and abstracts of all unique records against the eligibility criteria. The full text of potentially relevant studies was then reviewed independently by the same two reviewers. Any disagreements at either stage were resolved through consensus or by consultation with a third reviewer.

Data from included studies were extracted into a standardized form. The extracted information encompassed: study design, country of origin, sample size, participant demographics (age and sex), type of bariatric procedure performed, PBH diagnostic methods and criteria (e.g., oral glucose tolerance test, mixed-meal tolerance test, continuous glucose monitoring), reported incidence rates, identified risk factors, described therapeutic approaches, and key statistical measures (e.g., odds ratios, confidence intervals).

Data Synthesis

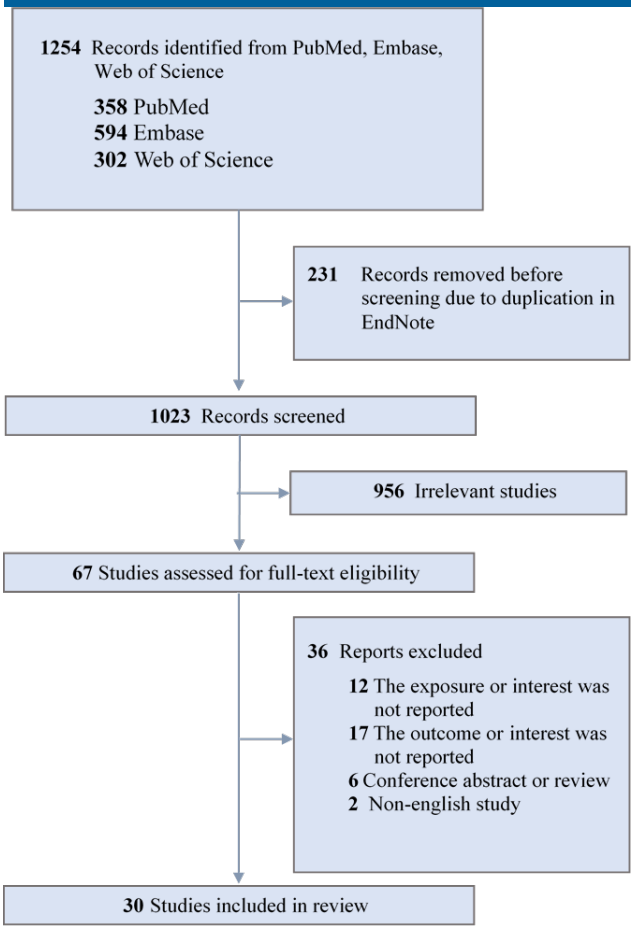
A meta-analysis was deemed unfeasible due to substantial clinical and methodological heterogeneity across the included studies. This heterogeneity pertained to the diagnostic criteria for hypoglycemia, the types of surgical procedures, methods of outcome assessment, and follow-up durations. Consequently, a qualitative and descriptive synthesis was performed. The findings are presented narratively, with incidence rates summarized according to the diagnostic modality used, and key risk factors and therapeutic approaches thematically reviewed.

Results

Study Characteristics

The comprehensive literature search identified 1,254 articles, which were refined to 1,023 after removal of duplicates (Figure 1). Following rigorous screening against pre-defined inclusion criteria, 30 studies were included, representing approximately 3,251 post-bariatric surgery patients. Most studies originated from North America and Europe, with contributions from Asia and South America. Patient mean age ranged from 35 to 55 years, with females constituting 75–90%, consistent with bariatric surgery demographics. Surgical types included Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), and biliopancreatic diversion with duodenal switch (BPD-DS), with RYGB predominating. Detailed study characteristics are summarized in Table 1.

Figure 1. Study Review



Incidence of Post-Bariatric Hypoglycemia

Incidence rates of post-bariatric hypoglycemia (PBH) varied widely depending on the diagnostic approach. Self-reported rates ranged from 3% to 65%, reflecting subjective reporting limitations. Oral glucose tolerance tests (OGTT) indicated incidence between 7% and 60%, whereas mixed-meal tolerance tests (MMTT) showed higher rates, up to 80%. Continuous glucose monitoring (CGM) revealed hypoglycemic episodes in 50% to 75% of patients, frequently detecting asymptomatic events missed by other tests. The differences highlight the impact of diagnostic modality on incidence estimates and suggest PBH is likely underdiagnosed without continuous monitoring. The surgical procedure type greatly influenced risk, with RYGB patients exhibiting higher incidence compared to SG or other surgeries, attributable to anatomical and physiological changes post-RYGB that promote accelerated gastric emptying and exaggerated insulin responses.

Therapeutic Approaches

Management of PBH involved multifaceted strategies. Dietary modification emphasizing frequent, small, low glycemic index carbohydrate meals remained the cornerstone with broad efficacy. Pharmacological agents such as acarbose (alpha-glucosidase inhibitor), diazoxide, and calcium channel blockers modulate glucose absorption or insulin secretion with variable success. Severe, refractory cases occasionally necessitated surgical revision, although evidence supporting this intervention is limited and outcomes vary. Continuous glucose monitoring combined with behavioral education enhanced treatment precision and patient adherence.

Risk Factors for PBH

Key risk factors consistently implicated include RYGB surgery (highest risk), female sex, and younger age. Greater postoperative weight loss, lower baseline BMI, and reduced HbA1c levels correlated with increased PBH risk. Emerging biomarkers such as elevated fasting glicentin and insulin-like growth factor-1 (IGF-1) also demonstrated predictive relevance. A history of cholecystectomy and antidepressant medication usage featured as additional, less well-understood modifiers, suggesting a multifactorial interplay of gut hormones and central glucose regulation mechanisms.

Table 1. Characteristics of Included Studies

Author (Year)	Country	Study Type	Sample Size (N)	Mean Age (Years)	Diagnostic Criteria	Incidence (Cases/N)
Papamargaritis et al (2024)[11]	Greece	Prospective cohort	25	38.7	BG < 3.3 mmol/L at 90, 120 min	8/25
Itariu et al (2024)[12]	Austria	Prospective cohort	36	39.9	BG < 3.3 mmol/L in 2nd hour of OGTT	18/36
Pigeyre et al (2024)[13]	France	Prospective cohort	351	-	BG < 2.8 mmol/L	23/351
Kefurt et al (2024)[14]	Austria	Cohort study	91	41	BG < 3.05 mmol/L	45/91
Lee et al (2024)[15]	USA	Retrospective cohort	450	50.8	≥3 symptoms of postprandial hypoglycemia	154/450
Nannipieri et al (2024)[16]	Italy	Case control	85	-	BG ≤ 2.7 mmol/L	-
Nielsen et al (2024)[17]	Denmark	Cohort study	1429	42	≥72 points on symptom scale	95/1429
Belligoli et al (2024)[18]	Italy	Prospective cohort	186	43	BG ≤ 2.7 mmol/L at any time	61/186
Michaels et al (2024)[19]	USA	Retrospective cohort	3487	43	Whipple's triad	90/3487
Lee et al (2024)[20]	USA	Retrospective cohort	341	50.3	≥3 symptoms of postprandial hypoglycemia	99/341
Poitou et al (2024)[21]	France	Case-control	20	44.3	BG ≤ 3 mmol/L	-
Capristo et al (2024)[22]	Italy	Randomized controlled trial	117	43.1	BG < 3.1 mmol/L	43/117
Lazar et al (2024)[23]	Israel	Cohort study	43	45.8	BG < 3 mmol/L	33/43
Sun et al (2024)[24]	China	Retrospective cohort	122	46	EHSS ≥ 18 points	81/122
Gasser et al (2024)[25]	Switzerland	Cohort study	113	32.8	BG < 3.0 mmol/L	15/113
Brix et al (2024)[26]	Austria	Prospective cohort	281	42	BG < 2.8 mmol/L	72/281
Guarino et al (2024)[27]	Italy	Prospective cohort	35	40	BG ≤ 3.3 mmol/L	11/35
Emous et al (2024)[28]	Netherlands	Cross-sectional	44	-	Postprandial BG < 3.3 mmol/L	36/44
Rebelos et al (2024)[29]	Italy	Cohort study	338	42	Whipple triad within 1–4 h after meal	119/338
van Furth et al (2024)[30]	Netherlands	Retrospective cohort	590	-	≥3 moderate/severe symptoms including neuroglycopenic symptoms	77/590
Lupoli et al (2024)[31]	Italy	Cross-sectional	51	46	TBR 3.0 ≥ 15 min	27/51
Marques et al (2024)[32]	Portugal	Case-control	17	43	Spontaneous symptoms compatible with hypoglycemia	-
Fischer et al (2024)[33]	USA	Prospective cohort	1959	-	≥1 hypoglycemia symptom	255/1959
Ilesanmi et al (2024)[34]	UK	Prospective cohort	10	46.1	TBR 3.0 ≥ 1% or TBR 3.9 ≥ 4%	503/1138 (subset)
Bienvenot et al (2024)[35]	France	Cohort study	1138	50.2	BG < 3.3 mmol/L	-
Zweck et al (2024)[36]	Switzerland	Case-control	35	41.4	BG < 3.4 mmol/L	604/3516
Sjöholm et al (2024)[37]	Sweden	Case-control	2007	-	Diagnosed with hypoglycemia or surrogate outcomes	-
Lu et al (2024)[38]	China	Retrospective cohort	175	47.2	TBR 3.0 ≥ 1% or TBR 3.9 ≥ 4%	-
Lee et al (2024)[39]	USA	Case-control	43	48	BG < 3.3 mmol/L	-
Ye et al (2024)[40]	China	Cross-sectional	39	32.2	BG < 3.3 mmol/L	-
Yu et al (2024)[41]	China	Case-control	52			

Table 2. Incidence of Post-Bariatric Hypoglycemia by Diagnostic Modality

Diagnostic Method	Incidence Range (%)	Number of Studies	Common Diagnostic Criteria	Notes
Self-reported symptoms	3 – 65	10	Patient-reported symptoms	Subjective; may underestimate true incidence
Oral Glucose Tolerance Test (OGTT)	7 – 60	12	Blood glucose < 2.7–3.3 mmol/L at 90-120 min	Biochemical; standardized but may miss asymptomatic cases
Mixed-Meal Tolerance Test (MMTT)	30 – 80	8	Blood glucose < 3.0–3.3 mmol/L post-meal	More physiologic stimulus, detects higher incidence
Continuous Glucose Monitoring (CGM)	50 – 75	7	Time below range (TBR) <3.3 mmol/L, frequent episodes	Detects symptomatic and asymptomatic hypoglycemia

Table 3. Key Risk Factors for Post-Bariatric Hypoglycemia

Risk Factor	Association Strength	Supporting Evidence	Notes
Roux-en-Y Gastric Bypass	Strong (highest risk)	Multiple cohort and case-control studies	Anatomical changes accelerate nutrient transit
Female Sex	Moderate	Several cohorts show higher prevalence	Possible hormonal and beta-cell function effects
Younger Age	Moderate	Identified in various prospective studies	Beta-cell sensitivity may be higher
Greater Weight Loss Post-Surgery	Moderate	Correlated with PBH risk	Enhanced glycemic variability
Lower Preoperative BMI	Weak to Moderate	Some studies note this association	Possibly linked to metabolic reserve
Elevated Fasting Glicentin	Emerging Biomarker	Predictive value in case-control studies	Reflects enteroendocrine response
Elevated IGF-1 Levels	Emerging Biomarker	Reported as predictive in cohorts	Involved in glucose homeostasis
History of Cholecystectomy	Reported in select studies	Observed risk increase	May affect gut hormone release
Use of Antidepressants	Observational	Reported in some cohorts	Central glucose regulation alterations

Table 4. Therapeutic Interventions for Post-Bariatric Hypoglycemia and Outcomes

Intervention	Description	Efficacy	Side Effects / Limitations	References
Dietary Modification	Small, frequent meals with low-glycemic index carbohydrates	First-line, widely effective	Requires significant patient adherence	42, 43
Acarbose	Alpha-glucosidase inhibitor that delays carbohydrate absorption	Reduces postprandial glucose spikes and hypoglycemia	Gastrointestinal side effects (bloating, flatulence, diarrhea)	44, 45
Diazoxide	Opener of ATP-sensitive potassium channels, inhibiting insulin secretion	Used in refractory cases	Fluid retention, hyperuricemia, hirsutism	46
Calcium Channel Blockers	Modulates insulin release from pancreatic beta-cells	Some reported benefit	Hypotension, dizziness, constipation	46
Somatostatin Analogues	Suppresses secretion of insulin and gut hormones (e.g., GLP-1)	Effective, but data is limited	Expensive, gastrointestinal symptoms, gallstone formation	46
Surgical Revision	Reversal or modification of the original bariatric surgery	Reserved for severe, refractory cases	Significant surgical risk, variable long-term outcomes	47
Continuous Glucose Monitoring (CGM)	Provides real-time glucose readings and trend data	Improves glycemic control and detects asymptomatic episodes	Requires patient engagement and technology acceptance	48
Behavioral Education	Counseling on diet, symptom recognition, and management	Improves treatment adherence and outcomes	Dependent on healthcare access and patient literacy	48

Discussion

This systematic review comprehensively summarized the current evidence on the incidence, risk factors, and therapeutic approaches for post-bariatric hypoglycemia (PBH). By analyzing 30 studies involving diverse patient populations and bariatric procedures, this review highlighted the considerable variation in PBH incidence based on diagnostic methods, identified several consistent risk factors contributing to PBH development, and described a range of therapeutic strategies. The findings emphasize PBH as a clinically relevant complication with multifactorial etiology requiring tailored management approaches.

The incidence of PBH reported across studies varies widely, with estimates ranging from as low as 3% to as high as 80%, depending heavily on the diagnostic method employed. This broad variability mirrors findings from previous systematic reviews and underscores

the challenge of accurately determining PBH prevalence[31,49]. Self-reported hypoglycemia tends to yield lower incidence rates, as it relies on subjective symptom recognition, which may underestimate the true burden[50]. In contrast, objective diagnostic methods such as the mixed-meal tolerance test (MMTT) or continuous glucose monitoring (CGM) detect both symptomatic and asymptomatic hypoglycemic episodes, often revealing a higher frequency of PBH[14]. This discrepancy highlights the silent nature of many hypoglycemic events that might go unnoticed without active monitoring[51]. The wide incidence range is further influenced by heterogeneity in patient populations, follow-up durations, and the type of bariatric surgery performed, especially as procedures like Roux-en-Y gastric bypass (RYGB) are more commonly associated with PBH than others. This variation reinforces the urgent need for establishing standardized diagnostic criteria and surveillance protocols, which would enable more consistent epidemiological assessments and facilitate early identification and management of PBH patients.

The analysis of risk factors for PBH revealed consistent associations with specific surgical, demographic, and biochemical variables. RYGB emerged as the bariatric procedure most frequently linked to PBH, supporting previous mechanistic studies indicating that the anatomical alterations in RYGB accelerate gastric emptying and potentiate exaggerated postprandial insulin secretion[52]. This physiological response often leads to rapid glucose absorption followed by hypoglycemia. Female sex and younger age were also identified as significant risk factors, which aligns with prior research suggesting hormonal differences and more robust pancreatic beta-cell responsiveness in these groups[53]. Interestingly, biomarkers such as IGF-1 and fasting glicentin levels showed promise in predicting PBH risk, suggesting an intricate hormonal interplay in glucose regulation post-surgery[12]. Additional risk modifiers, including a history of cholecystectomy and use of antidepressant medications, were identified but are less well understood[30]. These factors may influence gut hormone dynamics or central glucose regulation pathways, pointing to a multifactorial etiology[54,55]. The confluence of these risk factors underscores the complexity of PBH pathophysiology and highlights the importance of personalized risk assessment to guide monitoring and prevention strategies.

Therapeutic approaches for managing PBH remain diverse and often tailored to individual patient characteristics, reflecting the multifaceted nature of the condition. Dietary modifications, including adopting low glycemic index foods and increasing meal frequency to prevent large postprandial glucose spikes, are the first-line interventions and have demonstrated efficacy in symptom reduction[42]. Pharmacological treatments, such as alpha-glucosidase inhibitors (e.g., acarbose), diazoxide, or somatostatin analogs, act through different mechanisms to blunt insulin release or slow carbohydrate absorption, providing symptomatic relief in many cases[44]. However, these drugs can be limited by side effects and variable patient tolerance. Surgical revisions or interventions, such as reversal of bypass or addition of restrictive procedures, are reserved for severe or refractory cases but carry significant risks and inconsistent long-term benefits, making their use controversial[47]. The increasing implementation of continuous glucose monitoring offers real-time insights into glucose fluctuations, allowing for more precise treatment adjustments and patient education [48]. Despite these therapeutic options, the heterogeneity in treatment responses highlights the need for more robust clinical trials to establish standardized and evidence-based management algorithms that can improve outcomes and quality of life for patients with PBH.

Conclusions

This systematic review highlights that post-bariatric hypoglycemia is a prevalent and complex complication following bariatric surgery, particularly after Roux-en-Y gastric bypass. The wide variation in reported incidence reflects differences in diagnostic approaches and patient characteristics, underscoring the need for standardized criteria to improve detection and comparability across studies. Multiple risk factors including surgical type, demographic features, and hormonal biomarkers play crucial roles in PBH development, emphasizing the multifactorial nature of the condition. Therapeutic strategies remain varied, ranging from dietary management to pharmacologic and surgical interventions, but there is a clear need for more rigorous clinical trials to identify optimal, individualized treatments.

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