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ORIGINAL RESEARCH

Microbial Etiology, Antimicrobial Resistance, and Risk Factors of Surgical Site Infections in Gestational Diabetes Mellitus Patients Undergoing Elective Pre-Labor Cesarean Deliveries

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Background: Gestational Diabetes Mellitus (GDM) significantly increases the risk of adverse pregnancy outcomes, including elective pre-labor cesarean deliveries. Postoperative surgical site infections (SSIs) pose a significant concern, underscoring the need for a detailed investigation into their causes and preventative measures. The aim of this study is to systematically identify and analyze the microbial etiology and antimicrobial resistance profiles of pathogens responsible for SSIs in GDM patients undergoing elective pre-labor cesarean deliveries. Additionally, this research aims to elucidate the risk factors contributing to SSIs, with a specific focus on operation duration, amniotic fluid contamination, and genital tract inflammation, and their correlation with the incidence of SSIs.

Methods: A retrospective analysis was conducted at our Hospital between September 2018 and July 2023, involving 150 GDM patients who underwent elective pre-labor cesarean deliveries. Patients were categorized into infected and uninfected groups based on postoperative SSIs. Clinical data were meticulously collected and analyzed using SPSS software (version 27.0). Independent sample t-tests and chi-square tests were employed for statistical analysis.

Results: Microbial profiling revealed that Gram-negative bacteria, primarily E. coli, constituted approximately 59.46% of the isolated strains, exhibiting significant resistance to commonly used antibiotics such as ampicillin and cefotaxime. Elevated levels of biomarkers, including Procalcitonin (PCT) and Hemoglobin A1c (HbA1c), were significantly associated with SSIs. Multivariate logistic regression analysis identified operation time ≥1-hour, amniotic fluid contamination, and genital tract inflammation as significant risk factors.

Conclusion: This study highlights the microbial etiology, resistance patterns, and risk factors for SSIs in GDM cesarean patients, emphasizing the need for tailored preoperative evaluations.

Keywords: gestational diabetes mellitus, surgical site infections, elective pre-labor cesarean delivery, risk factors, microbial etiology

Introduction

Gestational Diabetes Mellitus (GDM), a form of glucose intolerance diagnosed during pregnancy, remains a prevalent complication with an increasing incidence, especially in countries facing demographic shifts and lifestyle changes.[1,2] This condition significantly elevates the risks of specific adverse pregnancy outcomes in the context of GDM, including cesarean deliveries due to poor glycemic control, preterm births resulting from maternal and fetal stress, and macrosomia, which increases the risk of delivery complications and neonatal hypoglycemia. Cesarean sections, a critical surgical intervention in obstetrics, are often indicated for patients with GDM whose glycemic levels remain poorly controlled—persistently elevated despite optimal medical management.[3] Inadequate control of blood glucose levels can significantly increase the risk of complications such as shoulder dystocia, macrosomia, and potential fetal distress.[4,5] These complications often render vaginal delivery too risky when the criteria, including maintaining maternal glucose levels within

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a safe range and ensuring fetal weight is appropriate for vaginal birth, are not met.[6,7] Consequently, such circumstances necessitate opting for a cesarean delivery to avoid further complications and ensure the safety of both mother and child. Although cesarean sections can effectively relieve maternal distress and ensure the safety of both the mother and the fetus, they do come with certain difficulties. A significant issue is the considerable incidence of post-operative surgical site infections (SSIs), which have a profound impact on the prognosis of mothers. To fully understand the complexities and devise strategies to prevent adverse outcomes such as SSIs, an in-depth investigation is crucial. GDM impacts surgical outcomes by altering metabolic, hormonal, and inflammatory responses, which may affect wound healing and infection susceptibility.[8] Additionally, surgical interventions in GDM patients, including the necessity for prolonged surgical times and the challenges of achieving optimal antimicrobial prophylaxis, complicate postoperative recovery. These dynamics underscore the need for a detailed examination of both the pathophysiological impacts of GDM and the surgical factors contributing to higher SSI risks.[9,10]

SSIs post-cesarean is primarily caused by bacterial contamination of the incision and amniotic fluid during surgery.[11] Factors such as disturbances in the reproductive tract's natural microbial flora, often due to bacterial vaginosis or broad-spectrum antibiotics use, further compromise surgical site sterility.[12] In patients with GDM, key immune defenses are impaired, increasing SSI susceptibility. GDM is associated with diminished neutrophil function, reduced phagocytic activity, and altered cytokine profiles, all critical for effective wound healing and infection defense.[11,13,14] These immunological deficits, exacerbated by hyperglycemia, hinder the body's response to microbial invasions at surgical sites.[15] Moreover, GDM-related immune challenges are intensified by prolonged surgical durations and inadequate antibiotic prophylaxis.[16] Therefore, preventing SSIs in GDM patients necessitates a comprehensive approach that addresses these multifactorial risks.

Despite advances in research, significant gaps remain regarding the human innate immune system's role and autoimmunity dynamics in developing SSIs post-cesarean in GDM patients. This study hypothesizes that GDM-related immunomodulation combined with procedural factors significantly escalates SSI risks through altered metabolic, hormonal, and immune responses, impairing wound healing and enhancing infection susceptibility. Our objectives are to systematically evaluate SSI risk factors in GDM patients, including surgical duration, effectiveness of antimicrobial prophylaxis, and impacts of metabolic and hormonal imbalances. We aim to delineate microbial etiology and resistance patterns of pathogens involved, laying a foundation for targeted therapeutic strategies and preventive measures. Additionally, we will explore immune dysregulation mechanisms in GDM, focusing on cytokine profiles and neutrophil function to enhance understanding of SSIs in this high-risk population. The core of this study centers on the SSI epidemic following cesarean deliveries under GDM influence, with a particular focus on combating the rise in antibiotic-resistant pathogens through detailed microbial and resistance profiling. This research addresses the urgent need to mitigate antimicrobial resistance risks in SSIs, offering crucial insights into developing more effective antimicrobial strategies tailored to the unique needs of GDM patients undergoing cesarean sections.

Materials and Methods

Patient Selection and Study Criteria

During a retrospective analysis conducted at our institution between September 2018 and July 2023, we reviewed clinical data from 150 patients with GDM who had undergone cesarean birth. The patients were thereafter divided into two groups depending on the occurrence of post-operative SSIs: 32 in the infected group and 118 in the uninfected group.

To ensure rigorous patient selection and minimize selection bias, eligibility criteria were standardized across the cohort based on the American Diabetes Association's (ADA) standards for GDM. These included fasting plasma glucose levels ≥ 92 mg/dL, 1-hour postprandial glucose ≥ 180 mg/dL, or Hemoglobin A1c (HbA1c) levels ≥ 5.7%. Indications for elective pre-labor cesarean delivery were determined by an obstetric panel according to clinical guidelines that assess factors such as fetal positioning and maternal-fetal health status. The diagnosis of SSIs was based on clinical symptoms —redness, pain, and discharge at the incision site, supported by microbiological evidence of pathogens. Comprehensive clinical records were maintained for all participants to ensure the availability of robust data for analysis.

Inclusion Criteria: Patients diagnosed with GDM as per ADA guidelines and undergoing elective cesarean delivery, confirmed by an obstetric panel based on specified clinical indications, were included. SSI classifications followed the Centers for Disease Control and Prevention (CDC) standards, which consider infection depth, timing, and specific clinical symptoms supported by laboratory evidence.

Exclusion Criteria: Patients with incomplete clinical records, insufficient data on glucose levels or SSI status, or pre-existing diabetes before pregnancy were excluded. Patients with conditions that independently increase the risk of SSIs, such as unmanaged hypertension or immune disorders unrelated to GDM, were also excluded unless these conditions were managed as part of the pregnancy care plan.

This selection process was designed to adhere strictly to clinical guidelines and diagnostic standards to ensure the study's accuracy and reliability. Thorough clinical records were essential for all participants to ensure comprehensive data availability.

Pathogen Culturing and Antibiotic Sensitivity Testing

Following surgical procedures, sterile techniques were employed to collect fluid specimens from the surgical sites of patients meticulously, maintaining aseptic conditions. These specimens were examined using the VITEK-2 Compact Automated Microbiology System by bioMérieux. This state-of-the-art instrument is developed for rapid and precise detection of bacterial infections, providing prompt diagnostic information.

1) Bacterial Validation: Pathogen identification was performed with the VITEK-2 system, aligning with the Clinical and Laboratory Standards Institute (CLSI) 2023 guidelines. This reference is now included to clarify the validation standards employed.
2) Antimicrobial Susceptibility Testing (AST): We utilized the Kirby-Bauer disk diffusion method for AST, adhering to the latest CLSI guidelines. Antibiotic-impregnated disks from Becton Dickinson, USA, were used to assess the efficacy of different antibiotics against isolated bacteria. The selection of antimicrobial agents included cefazolin, ampicillin, and ciprofloxacin, chosen for their broad-spectrum activity against the typical pathogens encountered in surgical site infections post-cesarean.
3) Quality Control Measures: Quality control during AST was ensured by including control strains specified by CLSI in each batch of tests. This practice verifies the efficacy of the antimicrobial disks and guarantees the reproducibility of our results.

This comprehensive approach in pathogen culturing and sensitivity testing allows for informed decisions regarding the most effective antimicrobial therapy, ensuring the precision and reliability of our infection management strategies in the study.

Data Collection and Variables Examined

We conducted extensive preoperative data collection as part of the routine pre-surgical assessment for all patients to identify potential factors that may influence surgery results and postoperative outcomes. The collected data included age, Body Mass Index (BMI), gravidity, and specific biomarkers such as procalcitonin (PCT), HbA1c, and fasting plasma glucose (FPG). These biomarkers were assessed during the final prenatal visit, typically within one week prior to the scheduled cesarean delivery, to reflect the patients' metabolic control and inflammatory status immediately before surgery. Additional data gathered included the duration of surgery, length of incision, intraoperative blood loss, prophylactic use of antimicrobial agents, rectal and vaginal examinations, amniotic fluid contamination, premature rupture of membranes, and genital tract inflammation. This comprehensive data collection aimed to evaluate a wide range of factors potentially impacting surgical and post-surgical outcomes, including the occurrence of SSIs. All data gathering procedures adhered to ethical guidelines and were meticulously documented to ensure the accuracy and reliability of the study's findings.

Statistical Analysis

Statistical analyses were rigorously performed utilizing SPSS software, version 27.0. The data, subjected to normality tests, were divided into quantitative and categorical types. For the quantitative data that conformed to a Gaussian

distribution, statistical significance between groups was assessed using independent sample t-tests. These results were subsequently displayed as mean values accompanied by their respective standard deviations (mean ± SD). On the other hand, categorical data were quantified as frequencies and relative percentages. These were analyzed using chi-square ($\chi 2$) tests to evaluate the independence or association between two or more categorical variables. In the initial stages, univariate analyses were employed to screen relevant variables. Factors exhibiting statistical significance in this primary analysis were subsequently ushered into the multivariate phase. This advanced stage adopted the Logistic regression model, aiming to pinpoint and assess potential risk factors tied to post-cesarean SSIs in GDM patients. Furthermore, to ensure genetic data integrity and to affirm that our sample was representative of the broader population, the Hardy-Weinberg equilibrium test was utilized for gene polymorphism evaluation. Throughout our analysis, a threshold p-value of less than 0.05 was set as the benchmark for discerning statistically significant disparities.

Results

Microbial Etiology of Incision Infections in GDM Cesarean Deliveries

The microbial landscape of SSIs in GDM patients who underwent elective pre-labor cesarean deliveries was meticulously characterized. Our analysis delineated the pathogens into two principal categories: Gram-negative and Gram-positive bacteria. Among the Gram-negative bacteria, E. coli emerged as the most prevalent pathogen, followed by Pseudomonas aeruginosa, Klebsiella pneumoniae, and Enterobacter cloacae. Collectively, these Gram-negative organisms constituted 59.46% of the isolated strains, with E. coli alone accounting for 36.11% of these isolates. On the other hand, Gram-positive bacteria were significantly represented by Enterococcus spp. (including Enterococcus faecalis), S. aureus, S. epidermidis, and coagulase-negative Staphylococcus, together making up 40.54% of the isolates. Notably, S. aureus was identified in 13.89% of the cases, reflecting its substantial presence among the Gram-positive cohort. This comprehensive microbial profiling underscores the diverse etiological landscape of SSIs in GDM patient's post-cesarean section, highlighting the critical need for targeted antibiotic stewardship and infection prevention strategies (Table 1).

Table 1 Distribution of Pathogenic Bacteria in Cesarean Section Incision Infections

Pathogens	Strains (n=36)	Composition (%)
Coagulase-negative Staphylococcus	2	5.56
E. coli	13	36.11
Enterobacter cloacae	1	2.78
Enterococcus faecalis	1	2.78
Enterococcus spp.	3	8.33
Klebsiella pneumoniae	3	8.33
Pseudomonas aeruginosa	4	11.11
S. aureus	5	13.89
S. epidermidis	2	5.56
Serratia marcescens	1	2.78
Streptococcus pyogenes	1	2.78

Abbreviations: E. coli, Escherichia coli; S. aureus, Staphylococcus aureus; S. epidermidis, Staphylococcus epidermidis.

Antimicrobial Resistance Profiles of Major Pathogens Involved in Infection

The Table 2 elucidates the antibiotic resistance patterns among the key pathogens isolated from the incision sites in GDM puerpera post cesarean section. E. coli showed considerable resistance to cefotaxime, ampicillin, and ciprofloxacin. Similarly, Pseudomonas aeruginosa displayed heightened resistance primarily to cefazolin and ciprofloxacin. Among the Gram-positive pathogens, Enterococcus spp. and S. aureus demonstrated significant resistance to ampicillin and penicillin, respectively. Notably, the resistance rates to ampicillin and cephalosporin classes were quite elevated for E. coli and Pseudomonas aeruginosa, while Enterococcus spp. and S. aureus showed higher resistance rates to penicillin and ampicillin. These findings underscore the need for judicious antibiotic usage and resistance surveillance in managing incision infections following cesarean sections in GDM mothers.

Univariate Analysis of Post-Cesarean Section Incision Infection in GDM Puerpera

The univariate analysis conducted provides a comprehensive understanding of the variables contributing to incision infections post-cesarean section in patients diagnosed with GDM. The analysis incorporated a variety of physiological and procedural parameters, including but not limited to, patient age, BMI, the duration of the surgical operation, and intraoperative blood loss. It is noteworthy that factors such as age ≥35 years, prolonged operation time of ≥1 hour, and higher Body Mass Index (BMI ≥25 kg/m²) exhibited a statistically significant association with increased likelihood of incision infection. Additionally, parameters like prophylactic antibiotic use and genital tract inflammation were also found to have significant p-values, suggesting their roles in modulating the risk of postoperative infection. Levels of specific biomarkers such as FPG, PCT, and HbA1c were also considered in the analysis. Elevated levels of these biomarkers were significantly associated with incision infections, reinforcing the need for rigorous preoperative evaluation and monitoring. The findings emphasize the multifactorial nature of post-cesarean incision infections in GDM patients, thereby suggesting a need for a multidimensional approach in preoperative assessment and planning to minimize associated risks (Table 3).

Multivariate Analysis of Post-Cesarean Section Incision Infection in GDM Puerpera

The multifactorial logistic regression analysis revealed significant associations between several variables and the occurrence of incision infection post-cesarean section in patients with GDM. Notably, an operation time of 1 hour or more, amniotic fluid contamination, and genital tract inflammation were associated with significantly increased odds of developing an infection. Conversely, the prophylactic use of antibiotics was associated with reduced odds. Furthermore, elevated levels of PCT and HbA1c were observed to be relevant factors in predicting incision infection. To quantify these associations, OR and their 95% CI were calculated. For instance, patients who

Table 2 Antimicrobial Resistance Distribution Among Key Pathogens in Incisional Infections Post Cesarean-Section

	E. Coli	Pseudomonas Aeruginosa	Enterococcus Spp.	S. Aureus
Cefazolin	7 (18.42%)	3 (33.33%)	–	–
Cefuroxime	4 (10.53%)	1 (11.11%)	–	–
Ceftazidime	4 (10.53%)	1 (11.11%)	–	–
Cefotaxime	5 (13.16%)	1 (11.11%)	–	–
Ampicillin	12 (31.58%)	–	2 (40.00%)	3 (33.33%)
Ciprofloxacin	6 (15.79%)	3 (33.33%)	2 (40.00%)	2 (22.22%)
Penicillin	–	–	1 (20.00%)	2 (22.22%)
Erythromycin	–	–	–	2 (22.22%)

Abbreviations: E. coli, Escherichia coli; S. aureus, Staphylococcus aureus.

Table 3 Univariate Analysis of Factors Associated with Incision Infection in GDM Puerpera After Cesarean Section

Factors	Infected (n=32)	Non-Infected (n=118)	χ2 / U	P-value
Prophylactic Use of Antibiotics [n(%)]	14(43.75)	116(98.31)	3.51	0.016
Primipara [n(%)]	22(68.75)	76(64.41)	0.19	0.561
Operation Time (≥1h) [n(%)]	12(37.5)	37(31.36)	3.79	0.013
Length of Incision (≥8 cm) [n(%)]	10(31.25)	32(27.12)	2.05	0.085
Intraoperative Blood Loss (≥500 mL) [n(%)]	10(31.25)	30(25.42)	2.69	0.062
Body Mass Index (≥25 kg/m²) [n(%)]	18(56.25)	77(65.25)	1.93	0.073
Age (≥35 years) [n(%)]	21(65.63)	75(63.56)	4.34	0.013
Procalcitonin [ng/mL, M(P25, P75)]	0.37(0.29, 0.43)	0.28(0.24, 0.33)	3.79	<0.001
Premature Rupture of Membranes [n(%)]	12(37.5)	35(29.66)	3.45	0.016
Hemoglobin A1c [%, M(P25, P75)]	7.6(7.19, 8.03)	7.12(6.8, 7.45)	3.51	<0.001
Genital Tract Inflammation [n(%)]	9(28.13)	22(18.64)	5.45	0.016
Fasting Plasma Glucose [mmol/L, M(P25, P75)]	6.42(5.9, 7.18)	6.12(5.7, 6.65)	1.17	0.065
Anal/Vaginal Examination (≥3 times) [n(%)]	14(43.75)	47(39.83)	3.51	0.015
Amniotic Fluid Contamination [n(%)]	7(21.88)	16(13.56)	2.76	0.036

underwent an operation lasting 1 hour or more had 2.3 times greater odds of infection compared to those with shorter operation times. Similarly, patients with amniotic fluid contamination were approximately three times as likely to develop an infection. Moreover, it was observed that increased levels of PCT and HbA1c, which are indicative of systemic inflammation and poor glycemic control, respectively, were statistically significant factors contributing to the likelihood of post-operative incision infection (Table 4). This comprehensive analysis highlights

Table 4 Multivariate Analysis of Post-Cesarean Section Incision Infection in Puerpera with GDM

Factors	β Value	SE Value	Wald Value	P-value	OR Value	95% CI
Prophylactic use of antibiotics	−0.70	0.50	3.75	0.03	0.38	0.130~0.89
Operation time ≥ 1h	0.72	0.53	3.54	0.04	1.98	1.12~3.25
Anal/vaginal examination ≥ 3	0.69	0.52	3.47	0.04	1.91	1.16~5.19
Amniotic fluid contamination	0.97	0.71	3.74	0.03	2.66	1.06~6.51
Premature rupture of membranes	0.81	0.61	3.58	0.04	2.21	1.09~3.56
Increased PCT	0.17	0.08	9.01	0.00	1.04	1.06~2.98
Increased HbA1c	0.27	0.18	4.34	0.02	1.17	1.17~2.36
Genital tract inflammation	0.99	0.62	4.99	0.01	2.72	1.12~4.73
Age ≥35 years	0.23	0.16	3.78	0.02	1.02	1.26~7.68

Abbreviations: GDM, Gestational Diabetes Mellitus; β, Beta; SE, Standard Error; Wald χ^2, Wald Chi-Square; OR, Odds Ratio; CI, Confidence Interval; PCT, Procalcitonin; HbA1c, Hemoglobin A1c.

the necessity for rigorous preoperative assessments and interventions, particularly focusing on modifiable factors such as operation time and prophylactic antibiotic use, to mitigate the risk of incision infections in this vulnerable population.

Discussion

The antibiotic resistance patterns identified in this study have critical implications for the management of SSIs in patients with GDM undergoing cesarean deliveries. The high rates of resistance to commonly used antibiotics such as cefotaxime, ampicillin, and ciprofloxacin among E. coli, and the resistance observed in Pseudomonas aeruginosa to cefazolin and ciprofloxacin, challenge the effectiveness of standard prophylactic antibiotic regimens. This necessitates a reconsideration of current antimicrobial strategies to prevent postoperative infections in this vulnerable population. Tailoring antibiotic prophylaxis based on local antibiograms could significantly enhance treatment outcomes and minimize the emergence of further resistance. Additionally, the observed resistance patterns underscore the urgency of integrating antibiotic stewardship programs into obstetrical care to optimize antibiotic usage and improve patient safety. The findings from this study highlight the need for ongoing surveillance of antimicrobial resistance and the development of novel therapeutic approaches to manage and prevent SSIs effectively in GDM patients.

The findings from our study not only corroborate previous research indicating an increased risk of SSIs in GDM patients but also provide new insights into specific risk factors such as operation time, amniotic fluid contamination, and elevated biomarkers like PCT and HbA1c. Our study highlights the substantial role of prolonged surgical times and poor glycemic control as predictors of SSIs, aligning with studies that suggest hyperglycemia exacerbates infection risks by impairing immune function. Furthermore, our findings on antimicrobial resistance patterns enrich the existing literature by documenting the prevalent resistance in commonly used antibiotics, underscoring the need for tailored antibiotic protocols based on local resistance data. These insights are crucial for developing more effective preventive strategies and could significantly influence clinical guidelines for managing GDM patients undergoing cesarean sections. Moreover, the detailed microbial profiling presented in this study lays the groundwork for future research aimed at exploring targeted therapeutic interventions, potentially leading to improved outcomes in this high-risk patient population.

The extensive characterization of the microbial landscape in SSIs among GDM patients in our study highlights a significant prevalence of both gram-negative and gram-positive bacteria, with notable dominance of E. coli and S. aureus.[17] However, when compared to microbial profiles from non-GDM patients undergoing similar cesarean deliveries, the data suggests that GDM may influence the diversity and resistance patterns of pathogens.[18] Literature indicates[19,20] that the altered glucose metabolism in GDM can create a favorable environment for specific pathogens, potentially explaining the higher prevalence of E. coli observed in our study. In non-GDM populations, the microbial distribution often shows a more balanced prevalence between gram-negative and gram-positive bacteria, with less pronounced antibiotic resistance.[21,22] This differential pattern underscores the need for targeted antimicrobial strategies in GDM patients, who may be more susceptible to infections from highly resistant strains.[23] Future studies should focus on directly comparing these microbial profiles in GDM versus non-GDM cesarean deliveries, to better understand the impact of metabolic changes on SSIs and to tailor prevention and treatment strategies accordingly.

An important finding of our study is the heightened antibiotic resistance displayed by certain bacterial species. Escherichia coli and Pseudomonas aeruginosa have demonstrated significant resistance to ampicillin and cephalosporins, whilst Enterococcus and Staphylococcus aureus have exhibited resistance to penicillin and ampicillin. The presence of these resistance patterns highlights the importance of regularly conducting bacterial culture and antimicrobial susceptibility tests in order to choose the most suitable antibiotics to use.[24,25] Amniotic fluid contamination and the frequency of vaginal inspections were identified as significant factors influencing the likelihood of post-cesarean infections in individuals with GDM. The amniotic fluid frequently contains fetal waste products that can contaminate the surgical site, leading to local responses or infections. However, regular vaginal inspections raise the chances of bacteria entering the uterus, which in turn increases the risk of SSIs.

The current study utilized multivariate logistic regression analysis to investigate different parameters influencing the occurrence of post-cesarean section incision infection in individuals with GDM. The findings are remarkable in multiple aspects. Extended surgical durations were found to be a notable risk factor for incision infection. Specifically, patients

with GDM who underwent surgery lasting an hour or more had a 2.302-fold higher risk of developing an infection.[26] This discovery is consistent with the existing literature that shows a direct association between longer surgical length and increased risk of infection in several surgical fields. Furthermore, the preventive administration of antibiotics was discovered to reduce the likelihood of infection, most likely due to its ability to boost the immune system and decrease vulnerability to infections that may occur during surgery.[27] Additionally, it was discovered that performing many rectal or vaginal inspections increases the probability of postoperative incisional infections, resulting in a 2.226-fold increased risk. These tests are necessary for monitoring the health of both the mother and the fetus, but they also have the drawback of increasing the risk of exposure to disease-causing microorganisms.

Our study emphasized the consequences of amniotic fluid contamination, which was linked to a 3.093-fold rise in the risk of infection in post-cesarean section incisions.[28] This provides evidence that the presence of amniotic fluid contamination indicates the presence of infection within the uterus, which in turn increases the likelihood of infection after surgery. In addition, there is a strong association between premature rupture of membranes (PROM) and a 2.573-fold increase in the chance of incision infection.[29] This increased risk is due to the heightened susceptibility to infections that occurs after PROM. Concurrent inflammation of the vaginal tract in individuals with GDM resulted in a 3.162-fold higher risk of infection in the incision after cesarean delivery. This increased risk is likely owing to the presence of cellular infections generating inflammation and the potential entry of these infections into the surgical incision. There was a correlation between infection risk and serum levels of biomarkers such as PCT and HbA1c. Each unit increase in these parameters resulted in a 1.215-fold and a 1.363-fold increase in risk, respectively. Elevated PCT levels indicate existing infection and inflammation, exacerbated by the surgical intervention, while higher HbA1c levels suggest poorer glycemic control, which is conducive to bacterial growth and consequently, higher postoperative infection risks.[30,31]

We have integrated a comparative analysis of SSIs in various surgical settings, emphasizing the prevalence, types, and antimicrobial resistance patterns of pathogens. This comparison highlights critical insights into the unique challenges and management strategies across different surgical disciplines. Building on the global perspective provided by Fiore et al,[32] who address multidrug-resistant pathogens in abdominal SSIs, our study narrows the focus to GDM patients undergoing cesarean deliveries. We specifically explore the prevalence and resistance patterns of pathogens like E. coli, which are crucial for developing targeted antimicrobial therapies tailored to this demographic. This provides a granular understanding that is pivotal for optimizing treatment protocols in GDM-related SSIs. Similarly, the findings from Atif et al,[33] detailing the resistance of organisms such as Pseudomonas aeruginosa and Klebsiella species in thoracic SSIs, resonate with our observations of Gram-negative bacterial resistance in cesarean sections. Our study extends these discussions by linking such resistance profiles to pregnancy-specific risk factors, such as amniotic fluid contamination, thereby enriching the contextual framework for managing SSIs in pregnant patients. Furthermore, insights from Skender et al[34] on the heightened resistance to commonly used antibiotics in orthopedic SSIs, particularly Staphylococcus aureus, provide a valuable comparison. Our research adds depth by incorporating metabolic control factors, like HbA1c levels, which influence SSI risks and outcomes in GDM patients. This comparative analysis not only aligns with broader surgical infection control practices but also emphasizes the importance of tailored preoperative assessments and antibiotic prophylaxis, adapting these strategies to address the specific needs and challenges faced by GDM patients. By drawing on these comparative studies, our discussion enriches the understanding of SSIs across surgical fields, offering a broader validation of our findings and highlighting the need for specialized approaches to infection management in diverse surgical contexts.

This study has several limitations that warrant mention. Firstly, the cross-sectional design restricts our ability to make causal inferences between the identified factors and post-cesarean section incision infection in GDM patients. Longitudinal or prospective studies are needed to substantiate the observed associations and better address temporal relationships. Secondly, the sample size, limited to a single medical center, may not adequately represent the broader population, thus limiting the generalizability of our findings. Thirdly, while we utilized multivariate logistic regression models to adjust for potential confounders, the possibility of unmeasured or residual confounding remains, as not all relevant variables may have been captured or measured with precision. Additionally, the study did not account for variations in surgical technique or the skill level of the operating clinicians, which are significant factors that could influence the risk of postoperative infection. Moreover, our analysis focused only on a selected set of biomarkers (PCT and HbA1c); the inclusion of other

inflammatory and metabolic markers could provide a more comprehensive understanding of the underlying mechanisms and their interactions in GDM-associated SSIs. Finally, the reliance on clinical records for data collection could introduce information bias, particularly if the accuracy and completeness of the records varied across cases. Addressing these limitations in future research will be crucial to enhancing the robustness and applicability of the findings.

Future research should employ longitudinal designs to elucidate causal relationships between GDM and SSIs and expand across multiple centers to enhance generalizability. Incorporating diverse biomarkers like C-reactive protein and interleukins will deepen understanding of GDM-related pathophysiology. Detailed documentation of surgical techniques and clinician expertise is crucial for developing targeted training and improving surgical outcomes. Clinically, personalized antimicrobial strategies and interdisciplinary care pathways are essential for optimizing perioperative management and reducing SSIs in GDM patients.

Conclusions

In conclusion, this study provides a detailed analysis of the microbial etiology and antimicrobial resistance patterns in SSIs among GDM patients undergoing elective cesarean sections. Our findings reveal a high prevalence of Gram-negative bacteria, particularly E. coli and Pseudomonas aeruginosa, with significant resistance to commonly used antibiotics such as cefotaxime and ciprofloxacin. Additionally, Gram-positive bacteria, including S. aureus and Enterococcus spp., exhibited notable resistance to penicillin and ampicillin. The study identifies critical risk factors for SSIs, such as prolonged operation time, amniotic fluid contamination, genital tract inflammation, elevated PCT, and HbA1c levels. These results emphasize the necessity for tailored preoperative risk assessments and highlight the importance of adopting personalized antibiotic stewardship strategies to mitigate infection risks and improve clinical outcomes in this vulnerable population.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Taizhou Hospital of Zhejiang Province (20180827). In studies using human subjects, all procedures followed the ethical guidelines set down by the institutional and/or national research committee, the Helsinki declaration of 1964 and its subsequent revisions, or analogous ethical guidelines. Each individual participant in the study or their legal guardians gave their informed permission.

Consent for Publication

Written informed consent for publication was obtained from all patients and their families included in this retrospective analysis. This consent included confirmation that participants were informed and agreed that their data could be used for research purposes.

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Disclosure

The authors declare that they have no competing interests in this work.

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