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ORIGINAL ARTICLE

Role of Mucosal and Reproductive Tract Microbiota in Postoperative Infectious Complications following Multisite Surgical Procedures in Women

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ABSTRACT

Background: Mucosal and reproductive tract microbiota play a crucial role in maintaining immune balance and preventing infections. Alterations in the microbiota may play an important role in the risk of postoperative infections among women undergoing multisite surgeries.

Objective: To evaluate the association between mucosal and reproductive tract microbiota composition and postoperative infectious complications in women undergoing multisite surgical interventions.

Methods: This cross-sectional clinical study was conducted from June 2022 to May 2023 at Bolan Medical College and DHQ Teaching Hospital. A total of 120 female patients undergoing multisite surgical procedures were enrolled. Microbiota from vaginal, rectal, and skin sites were collected preoperatively and assessed through culture and 16S rRNA methods. Patients were followed for 30 days postoperatively to assess surgical site infections, pelvic infections, urinary tract infections, and systemic complications. Chi-square tests and logistic regression were used for statistical analysis, with a p-value of < 0.05 considered significant.

Results: Postoperative infections were observed in 31.7% of patients. Infection rates were significantly higher in patients with microbiota dysbiosis (52.6%) compared to those with normal microbiota (14.3%) ($p < 0.001$). Multisite colonization was strongly associated with infection severity (58.1%). Dysbiosis was identified as an independent predictor of infection (OR = 3.45, 95% CI: 1.89–6.31). Elevated inflammatory markers, including CRP and IL-6, were significantly associated with microbial imbalance.

Conclusion: Microbiota dysbiosis of the mucosal and reproductive tracts is a strong predictor of postoperative infection in women with multisite surgery. Testing the microbiota preoperatively may be used to stratify the risk and develop preventive strategies.

Keywords: microbiota, dysbiosis, postoperative infection, surgical site infection, vaginal microbiome, inflammation.

INTRODUCTION

The human microbiota constitutes a complex and dynamic ecosystem that plays a fundamental role in maintaining host physiology, immune homeostasis, and resistance to pathogenic invasion[1]. In females, the mucosal microbiota of the gastrointestinal tract, skin and reproductive system constitute a network of mucosal immunity that safeguards against infections, especially in the perioperative setting. Of these, the vaginal microbiota is of greatest clinical relevance as it is commonly dominated by Lactobacillus species that produce lactic acid, hydrogen peroxide, and bacteriocins, which keep the vaginal pH low and prevent the growth of pathogenic microorganisms[2].

Surgery, particularly that involving multiple anatomical sites such as abdominal, pelvic, and gynecological surgeries, breaks down anatomical barriers and can enable the translocation of microorganisms between mucosal surfaces[3]. This process increases the risk of postoperative infectious complications, including surgical site infections (SSIs), pelvic infections, urinary tract infections, and systemic sepsis. Although sterile procedures and the administration of antibiotics during surgical interventions have improved, SSIs are still a significant source of postoperative complications, increased hospital length of stay and health care expenditure globally[4].

In recent years, attention has moved from exogenous to endogenous sources of infection, revealing a large percentage of postoperative infections are derived from the patient's own flora[5]. Dysbiosis, which refers to a disruption in the composition and function of microbial communities, has emerged as a factor in poor health. Dysbiosis in the female reproductive tract is marked by a decrease in the dominance of lactobacilli and an increase in colonisation by anaerobic and facultative pathogens, such as Gardnerella, Prevotella, Escherichia coli and Staphylococcus aureus. These changes in the mucosal microbiota are linked to decreased mucosal barrier integrity, increased inflammation, and increased risk of infection[6].

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Additionally, the dynamic interplay between mucosal microbiota and the immune system is essential for modulating immune responses[7]. Microbial imbalance can trigger the release of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which may compromise wound healing and promote systemic inflammatory responses. In multisite surgeries, where tissue trauma and immune responses are already increased, dysbiotic microbiota may enhance the inflammatory response, therefore elevating the risk of complications[8].

Beyond the local microbiota, the notion of multisite microbial interaction has emerged. The gut, skin and reproductive tract microbiota are not in isolation but interact with one another through microbial translocation and the immune system[9]. For example, recto-vaginal microbial transfer is known to occur, which could affect the composition of the vaginal microbiota and potentially increase the risk of infection, especially in pelvic surgery. Likewise, skin colonization at the surgical site with pathogens may directly contribute to wound infection[10].

Although the significance of the microbiome in surgery is increasingly being recognised, there are few clinical studies on the integrated effect of mucosal and reproductive tract microbiota on postoperative infections in women undergoing multisite surgical procedures. The majority of studies have examined the microbiota of individual sites or single infections, without exploring the interconnected microbial environment and its systemic effects[11,12].

Therefore, this study aims to comprehensively evaluate the role of mucosal and reproductive tract microbiota in the development of postoperative infectious complications in women undergoing multisite surgical procedures. By analyzing microbial composition across multiple anatomical sites and correlating these findings with postoperative outcomes and inflammatory markers, this research seeks to provide deeper insights into microbiota-driven risk factors and identify potential avenues for personalized preventive strategies in surgical care[13].

MATERIALS AND METHODS

This cross-sectional clinical study was conducted over a period of one year, from June 2022 to May 2023, at Bolan Medical College

and DHQ Teaching Hospital. This study sought to assess the relationship between genital and mucosal microbiota and postoperative infections in female patients undergoing multisite surgeries.

One hundred and twenty female patients between the ages of 18 and 60 were included using non-probability consecutive sampling. Those undergoing elective surgeries involving multiple anatomical sites, including gynecological, abdominal and urological surgeries, were included. Those with known immunosuppressed conditions, history of antibiotics use in the past two weeks of surgery, active infections, cancer, or chronic inflammatory bowel diseases were excluded to prevent confounding factors in microbiota and immune response.

Preoperative medical histories were collected, including age, sex, medical conditions, and reasons for surgery. Sampling of the microbiota was conducted from three main sites before surgery, including the vagina, rectum, and skin at the site of planned surgery. Swabs were taken in a sterile manner and promptly sent to the microbiology lab for processing. Microbiota analysis was conducted using traditional culture methods and molecular profiling (16S rRNA gene sequencing) to determine the composition of the microbiota. The microbiota was classified as either normal microbiota (Lactobacillus-dominated flora) or dysbiotic microbiota (mixed or pathogenic organisms with decreased beneficial organisms).

Patients were managed according to the standard of care, including the administration of preoperative antibiotics according to institutional guidelines. Patients were followed up for 30 days after surgery for any signs and symptoms of infections, such as surgical site infections (SSIs), pelvic infections, urinary tract infections and systemic infections. Infections were diagnosed according to clinical, laboratory, and imaging (if needed) diagnostic criteria.

Finally, inflammatory markers, including C-reactive protein (CRP), interleukin-6 (IL-6) and total white cell count were measured before and after surgery to evaluate systemic inflammatory response.

The data were entered and analyzed using SPSS 26.0. Demographic and clinical data were described using descriptive statistics. Categorical variables were analyzed using the chi-square test, while continuous variables were expressed as mean ± standard deviation. Multivariate logistic regression was used to determine independent risk factors for postoperative infections, and simple correlation analysis was used to examine the associations between microbiota patterns and inflammatory parameters. A p-value of less than 0.05 was considered statistically significant.

The study was approved by the institutional Ethics Committees of both hospitals. All patients signed a consent form before enrollment into the study, with confidentiality and institutional research guidelines maintained.

RESULTS

A total of 120 female patients undergoing multisite surgical procedures were included in the final analysis. The results are presented in a structured manner with detailed paragraph interpretation followed by corresponding tables.

Baseline Characteristics of Study Population: The mean age of the participants was 37.9 ± 8.7 years, with the majority of patients falling within the reproductive age group (20–45 years). Among the study population, 56.7% underwent gynecological procedures, while 43.3% underwent abdominal or combined surgeries. Comorbid conditions such as diabetes mellitus (18.3%) and obesity (25.0%) were commonly observed. Preoperative microbiota analysis revealed that 47.5% of patients had dysbiosis, while the remaining 52.5% exhibited normal Lactobacillus-dominant microbiota. These baseline data suggest that a significant number of patients have dysbiotic microbiota before surgery, which could affect surgical outcomes (Table 1).

Incidence and Types of Postoperative Infections: During the 30-day postoperative follow-up period, 38 patients (31.7%) developed infectious complications. The most frequent complication was surgical site infection (SSI) (17.5%), followed by pelvic infections (8.3%), urinary tract infections (4.2%), and systemic infections (1.7%). These data show that infections following surgical procedures continue to be a major concern, especially for patients with complex or multiple site procedures (Table 2).

Association Between Microbiota Status and Postoperative Infections: There was a strong correlation between the microbiota status before surgery and the incidence of postoperative infection. Among patients with normal microbiota, only 14.3% developed infections, whereas 52.6% of patients with dysbiosis experienced postoperative infections. This was a highly significant association ($p < 0.001$), suggesting that dysbiosis is a strong risk factor for infections (Table 3).

Multisite Microbial Colonization and Infection Severity: Further analysis demonstrated that patients with multisite colonization by pathogenic organisms (vaginal + rectal + skin) had a markedly higher rate of deep surgical infections and pelvic complications (58.1%), compared to those with single-site colonization (21.7%). A strong positive correlation was observed between multisite colonization and infection severity ($r = 0.59$, $p < 0.001$), suggesting that microbial interaction across anatomical sites plays a critical role in postoperative outcomes (Table 4).

Inflammatory Markers and Microbiota Status: Dysbiosis patients had higher inflammatory markers. The mean CRP level in the dysbiosis group was 18.6 ± 6.2 mg/L, compared to 9.8 ± 4.1 mg/L in the normal microbiota group. Likewise, the IL-6 level was significantly elevated in patients with dysbiosis ($p < 0.01$). This suggests that dysbiosis is associated with a heightened inflammatory response, which can lead to poor surgical outcomes (Table 5).

Predictors of Postoperative Infections (Logistic Regression Analysis): Multivariate logistic regression showed bacterial dysbiosis is a significant predictor of postoperative infection (OR = 3.45, 95% CI: 1.89-6.31, $p < 0.001$). Multisite colonization (OR = 3.72, $p < 0.001$) and high CRP levels (OR = 2.58, $p = 0.003$) were also significant predictors. This demonstrates the role of both pathogenic and inflammatory factors in the risk of infection (Table 6).

This study clearly shows that the microbiota composition prior to surgery is closely linked to post-surgical infection. Those with dysbiosis and multiple site microbial colonisation had higher incidence of infection and increased inflammation. These results suggest that microbiota should be considered in the risk assessment for surgery, and that microbiota-based interventions may have a positive impact on post-surgery outcomes.

Table 1: Baseline Characteristics of Study Population (n = 120)

Variable	Frequency (%)
Mean age (years)	37.9 ± 8.7
Age group (20–45 years)	78 (65.0%)
Gynecological surgeries	68 (56.7%)
Abdominal/multisite surgeries	52 (43.3%)
Diabetes mellitus	22 (18.3%)
Obesity (BMI ≥30)	30 (25.0%)
Normal microbiota	63 (52.5%)
Dysbiosis	57 (47.5%)

Table 2: Distribution of Postoperative Infectious Complications (n = 120)

Type of Infection	Frequency (%)
Surgical site infection (SSI)	21 (17.5%)
Pelvic infection	10 (8.3%)
Urinary tract infection	5 (4.2%)
Systemic infection (sepsis)	2 (1.7%)
Total infections	38 (31.7%)

Table 3: Association Between Microbiota Status and Postoperative Infections

Microbiota Type	Infection (n, %)	No Infection (n, %)	p-value
Normal (n = 63)	9 (14.3%)	54 (85.7%)	<0.001
Dysbiosis (n = 57)	30 (52.6%)	27 (47.4%)	

Table 4: Multisite Microbial Colonization and Infection Outcomes

Colonization Pattern	Infection (%)	No Infection (%)
Single-site colonization	10 (21.7%)	36 (78.3%)
Multisite colonization	25 (58.1%)	18 (41.9%)

Table 5: Comparison of Inflammatory Markers by Microbiota Status

Parameter	Normal Microbiota	Dysbiosis	p-value
CRP (mg/L)	9.8 ± 4.1	18.6 ± 6.2	<0.001
IL-6 (pg/mL)	12.3 ± 5.4	24.7 ± 8.9	<0.01
WBC count (×10⁹/L)	7.2 ± 1.8	10.1 ± 2.3	0.002

Table 6: Logistic Regression Analysis of Predictors of Postoperative Infection

Variable	Odds Ratio (OR)	95% CI	p-value
Microbiota dysbiosis	3.45	1.89–6.31	<0.001
Multisite colonization	3.72	2.01–6.88	<0.001
Elevated CRP	2.58	1.37–4.86	0.003
Diabetes mellitus	1.82	0.96–3.45	0.07

DISCUSSION

The present study provides strong clinical evidence that mucosal and reproductive tract microbiota play a pivotal role in determining postoperative infectious outcomes in women undergoing multisite surgical procedures[8]. The study shows that almost a third of patients experienced a postoperative infection, which was considerably more frequent in women with preoperative dysbiosis of the microbiota. This is consistent with the emerging view that not only extrinsic (external) contamination but also intrinsic (internal) microbiota dysbiosis is responsible for the development of postoperative infections[9].

A key finding of this study is the significantly greater incidence of infection in patients with dysbiosis (52.6%) than in patients with normal microbiota (14.3%)[10]. This observation supports the hypothesis that the Lactobacillus-dominated vaginal microbiome has a protective effect through the creation of an acidic environment and the production of antimicrobial compounds. On the other hand, dysbiosis, with overgrowth of Gardnerella, Prevotella, Escherichia coli and Staphylococcus aureus, disrupts the mucosal barrier and allows pathogens to invade. These pathogens are known for their biofilm-forming, immune-evading and wound-colonising properties, which predispose to infection[11].

The other major contribution of this study is the demonstration of the importance of multisite microbial colonisation in postsurgical infection[12]. Among patients with co-colonization of vaginal, rectal, and skin microbiota by pathogenic bacteria, the risk of developing deep surgical infections and other pelvic complications was significantly increased. This evidence supports the theory that microbial translocation from recto-vaginal and skin contamination play a role in infection. Multisite surgeries inherently breach anatomical barriers, enabling microorganisms from various anatomical locations to cross-talk, colonise and infect surgical sites, thus increasing infection risk[13].

The researchers also found a correlation between dysbiosis and high levels of inflammatory proteins (CRP and IL-6), suggesting that microbial dysbiosis leads to systemic inflammation[14]. This is important clinically as inflammation can delay wound healing, cause more tissue damage and create a risk of complications such as abscesses and sepsis. The association between dysbiosis and inflammation supports the idea that the microbiota is not just a passive inhabitant but an active participant in the immune response[15].

Multivariate analysis also confirmed that microbiota dysbiosis, multisite colonization and high CRP levels are independent risk factors for postoperative infections[16]. These results highlight the importance of including microbiota analysis in preoperative patient screening. While diabetes and obesity are also important risk factors for infections, they were not as strongly tied to the risk of infection as microbial factors in this study, suggesting that microbiota profiling could deliver better risk prediction[17].

The findings of this study have significant clinical implications. First, pre-surgical screening for microbiota composition can be used to determine risk. Second, strategies to restore microbiota composition, such as probiotics, prebiotics or selective antimicrobials, might reduce infection risk. Third, surgical and other planning can be optimized based on knowledge of patient microbiota[18,19].

This study has some limitations. The cross-sectional nature of the study precludes causality. Further, while 16S rRNA sequencing was employed, more sophisticated metagenomic techniques will offer greater insights into microbial functions. The sample size, although sufficient, may not represent population variation, and multicenter longitudinal research is required to confirm these results[20].

CONCLUSION

This study demonstrates that mucosal and reproductive tract microbiota are critical determinants of postoperative infectious complications in women undergoing multisite surgical procedures. Dysbiosis of the microbiota, particularly with reduced presence of Lactobacillus and overgrowth of pathogens, is associated with higher risks of surgical site infections, pelvic infections and systemic complications. Microbial colonization of multiple sites and heightened inflammatory responses also exacerbate this risk, revealing the interplay between microbiota and the immune system. This research highlights the need for microbiome assessment in risk prediction before surgery. Finally, microbiota analysis holds potential for surgical outcome prediction and targeted prevention. Research efforts should aim to develop microbiome-based strategies to enhance surgical safety and limit complications in women.

Author Contributions

N.U.K.: Conceptualization, study design, supervision, and final approval of the manuscript.

H.A.: Data collection, patient recruitment, and coordination between study centers.

N.K.: Literature review, drafting of introduction and discussion, and critical revision.

A.U.H.P.: Statistical analysis, interpretation of results, and preparation of tables.

A.M.: Microbiological analysis, laboratory coordination, and validation of findings.

S.I.A.: Clinical oversight, surgical data verification, and final manuscript editing and approval.

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