International Medical Case Reports Journal

Dovepress
Taylor & Francis Group

Open Access Full Text Article

CASE REPORT

Infection Leading to Breast Abscess Formation in Pregnancy: A Case Report

Jiangting Yu[1], Jiaying Chen[1], Tianjian Huang[1], Xidong Gu[2]

[1]Department of Breast Surgery, The First School of Clinical Medicine, Zhejiang Chinese Medical University, Hangzhou, Zhejiang Province, People's Republic of China; [2]Department of Breast Surgery, The First Affiliated Hospital of Zhejiang Chinese Medical University (Zhejiang Provincial Hospital of Chinese Medicine), Hangzhou, Zhejiang, People's Republic of China

Correspondence: Xidong Gu, Department of Breast Surgery, The First Affiliated Hospital of Zhejiang Chinese Medical University (Zhejiang Provincial Hospital of Chinese Medicine), Hangzhou, Zhejiang, People's Republic of China, Email 20083011@zcmu.edu.cn

Introduction: Breast abscess, the most severe complication of mastitis, occurs when an infection spreads through the nipple into the breast tissue, contaminating the milk ducts and forming a purulent cavity. Nonetheless, this condition is less common in pregnant women. *Staphylococcus aureus* is the predominant causative agent in lactating women; however, *Prevotella bivia*-associated breast abscesses during pregnancy remain clinically rare, with limited documented cases.

Case Presentation: A 26-year-old Chinese woman with G1P0 singleton at 33 weeks of pregnancy presented with right breast pain and lumps without obvious triggers, accompanied by enlarged right axillary lymph nodes and a large amount of pus with a peculiar odor in the right breast. After breast ultrasonography, cytological puncture smear, pus culture, and metagenomic next-generation sequencing, the patient was confirmed to have gestational mastitis with *P. bivia* infection. Given that the patient had a high-risk pregnancy, the use of antibiotics sensitive to *Prevotella*, such as metronidazole, might affect the intrauterine fetus, and infection with this bacterium could increase the risk of placental abruption and intrauterine fetal distress. Based on the obstetrician's and pediatrician's recommendations, the patient opted for a cesarean section at 37 weeks to facilitate the delivery of a healthy neonate weighing 3110 g (Apgar scores of 10 at 1 min and 5 min) in the left anterior sacral position and was advised to opt for lactation-suppressing medication and postpartum antibiotics.

Conclusion: This case highlights the importance of close monitoring of pus characteristics (eg, color, odor, and volume) in pregnancy-associated breast abscesses to expedite the diagnosis of infectious mastitis and pathogen identification. Treatment with small incision drainage and targeted antibiotics during pregnancy significantly improved the outcomes. Postpartum breast milk return and combined antibiotic therapy further contributed to the resolution of inflammation.

Keywords: *Prevotella bivia*, mastitis in pregnancy, anaerobic infection, high-risk pregnancy status

Introduction

Breast abscess, which usually occurs in breastfeeding women, is a serious complication of mastitis and is caused by pathogenic microorganisms invading the breast tissue through the nipple, triggering an infection that results in the formation of pus, of which 3%–11%[1,2] of mastitis cases develop into a breast abscess.[3] Previous studies documented regional disparities in the prevalence of breast abscesses caused by mastitis. For instance, recent data from Australia indicated a lower incidence of approximately 3% among breastfeeding women,[4] which may be indicative of enhanced early intervention strategies.

In recent years, there has been an increase in the incidence of non-lactating breast abscesses and a decrease in the incidence of breast abscesses during lactation, with the incidence of pregnancy-associated breast abscesses being even rarer in previous reports focusing mainly on the mid- and late-pregnancy periods.[5,6] Pregnancy-associated breast abscess is a rare clinical entity, with the current evidence primarily extrapolated from indirect comparisons of postpartum lactation cases. Epidemiological studies have indicated that the incidence of breast abscesses during pregnancy is markedly lower than that during lactation (0.4% vs 3–11% in lactational cohorts), with most reported cases existing as isolated clinical presentations.[7] This rarity may

Received: 22 December 2024
Accepted: 18 June 2025
Published: 4 July 2025

stem from distinct pathophysiological mechanisms: pregnancy-related hormonal changes and incomplete activation of mammary secretory activity reduce the risk of ductal obstruction and bacterial colonization compared to the postpartum period.[8] While microbiological profiles (predominantly *Staphylococcus aureus*) align with lactational abscesses, pregnancy-associated cases often necessitate modified management strategies, such as ultrasound-guided aspiration, to mitigate preterm labor risks.[9] The existing literature remains limited to retrospective analyses and case reports, underscoring the need for prospective studies to clarify the epidemiological patterns and optimize therapeutic protocols in this population.

The microbial diversity of mastitis-associated infections is relatively rich and mainly includes aerobic bacteria, anaerobic bacteria, and a few fungi. Among the aerobic bacteria, *S. aureus* is the most prevalent (55.17%), followed by *Streptococcus* spp. (23.14%), *Staphylococcus epidermidis* (14.23%), *Escherichia coli* (6.89%), and members of the Enterobacteriaceae family such as *Klebsiella* spp. (4.3%).[10]

The role played by anaerobic bacteria in the context of mastitis is of particular significance, particularly in chronic infections. For example, *Prevotella* spp., *Bacteroides* spp., and *Clostridium* spp. have been observed to act synergistically with aerobic bacteria to promote inflammation. Furthermore, the detection of strictly anaerobic bacteria, such as *Fusobacterium necrophorum*, lends further credence to the notion that the anaerobic microenvironment may play a pivotal role in the pathogenesis of mastitis.[11] The pathogenicity of commensal bacteria such as *Bifidobacterium* spp. remains unclear; nevertheless, their role in mammary microecological imbalances represents a promising area of exploration. Finally, fungal infections such as those caused by *Candida* spp. and *Malassezia* spp. may be observed in a small number of cases.[12]

Recent studies have increasingly emphasized the role of anaerobic flora in mastitis. For instance, *Bacteroides* and *Prevotella* have been identified as a prevalent genera in healthy breast milk; however their populations may be amplified in mastitis, a consequence of the proliferation of anaerobic organisms within milk ducts, as evidenced by ductal obstruction.[13] In conclusion, the pathogenic spectrum of mastitis shows remarkable diversity. Further investigation into the colonization and pathogenic mechanisms of anaerobic bacteria is required to provide a more accurate microbiological basis for clinical diagnosis and treatment.

Prevotella in the patient reported in this case is a Gram-negative anaerobe that is usually hosted in the human oral cavity, skin, gastrointestinal tract and vagina. Owing to the complex internal environment of the host, *Prevotella* can become conditionally pathogenic in the presence of reduced immune function or micro-ecological imbalance, leading to infections.[14] Hormonal fluctuations in conjunction with immune modulation are conducive to the proliferation of *Prevotella* spp. in pregnant women. Significantly elevated estrogen and progesterone levels during pregnancy have been established to result in the polarization of the immune response towards a Th2-type state to maintain fetal tolerance. However, this also weakens the Th1-type cellular immune response against pathogens simultaneously.[15] Estrogen augments the immunosuppressive properties of cortisol by upregulating glucocorticoid receptor expression. This, in turn, results in the further inhibition of phagocytosis by neutrophils and macrophages.[16] Furthermore, a hyperestrogenic state promotes glycogen accumulation in vaginal epithelial cells, thereby providing a substrate for *Lactobacillus* growth. Nevertheless, once *Lactobacillus* dominance is lost (eg, at elevated pH), anaerobic bacteria such as *Prevotella* can proliferate rapidly.[17]

Case Presentation

Chief Complaints

A 26-year-old Chinese woman was admitted to the Department of Breast Surgery at the Zhejiang Provincial Hospital of Traditional Chinese Medicine on November 7, 2024, with a 35-week gestation and a singleton fetus in breech presentation (G1P0). The patient presented with a two-week history of redness, swelling, heat, and pain in the right breast. A palpable lump was noted in the middle and outer breast quadrants, measuring approximately 10.0×8.0 cm, with an evident fluctuating sensation in the central area.

History of Present Illness

Two weeks prior, the patient presented with right breast pain of unknown etiology, accompanied by a local lump with poor mobility, measuring approximately 10 cm × 8 cm in the middle and outer quadrants. She was subsequently referred to a local hospital for ultrasound examination of the breasts and bilateral axillae. This revealed a large cystic mass in the

right breast accompanied by enlarged axillary lymph nodes on the same side. One week later, the patient underwent a routine cytological examination following a puncture, and the results excluded the possibility of a malignant breast tumor. Following the onset of illness, the patient took ibuprofen suspension drops (Mellin, brand name, Shanghai Johnson & Johnson Pharmaceuticals Ltd) to help reduce her temperature after becoming febrile, and no other medication was administered.

History of Past Illness

The patient had a history of hyperthyroidism for which she was taking oral methylthiouracil 25 mg three times a week. She also underwent surgery for a right breast fibroma in 2018 and an ovarian cyst in 2022.

Personal and Family History

No specific personal and family history.

Physical Examination

The breasts exhibited asymmetry, with the right breast being larger than the left. Orange peel sign, dimple sign, and nipple shape were all negative. No obvious overflow was observed. A palpable mass measuring approximately 10 cm × 8 cm was found in the right breast at the 9 o'clock position. It was slightly hard in texture with clear borders, poor mobility, localized skin redness and swelling, and an obvious fluctuating sensation in the central area. Additionally, a dark red, highly convex surgical scar measuring approximately 5 cm in length was noted in the outer lower quadrant of the breast. No palpable masses were identified in the left breast and no enlarged lymph nodes were observed in the axillary or clavicular regions.

Laboratory Examinations

1. Blood count + C-reactive protein (CRP) (2024–11-07): white blood cell (WBC) count, 11.50×10^9/L; neutrophil ratio, 81.6%; red blood cell count, 3.66×10^{12}/L; CRP level, 55.74 mg/L

Routine blood and CRP tests revealed a markedly elevated WBC count and neutrophil ratio (81.6%), accompanied by an abnormally high CRP level (55.74 mg/L), suggesting the presence of a significant systemic inflammatory response. The elevated WBC and neutrophil counts were consistent with acute bacterial infection, and the significant increase in CRP level indicated that the inflammation had reached a moderately severe level. In the clinical context of mastitis, changes in laboratory markers are often associated with purulent infections caused by pathogenic organisms, such as *S. aureus*, and a CRP level >50 mg/L requires a high degree of vigilance for the possibility of localized tissue necrosis or abscess formation.

Combined with the available evidence, this test result strongly supports the diagnosis of moderate-to-severe acute bacterial mastitis; therefore, we immediately conducted pathogenetic testing to identify the causative microorganism and considered imaging to evaluate abscess formation.

2. Thyroid function test (2024–11-07): total thyroxine level, 160.60 nmol/L; thyrotropin level, 0.01 mLU/L
3. Calcitoninogen (2024–11-17): 0.211 ug/L
4. Group B *Streptococcus* DNA (2024–11-07): negative
5. Microbiological culture of pus (2024–11–14): culture did not detect fungi or urogenital tract actinomycetes
6. Pathogen metagenomic sequencing (unbiased metagenomic DNA sequencing) (2024–11–15)

Overall, the test results indicated that the bacteria detected were as follows: 593 bi-directional *Prevotella*, 505 quadruple anaerobic cocci, 147 upper field *Porphyromonas*, 143 buccal *Prevotella*, and common human-colonizing bacteria. Fungi, viruses, parasites, and others were not detected. The resistance genes were Tet and CfxA. For further details, please refer to Table 1.

Table 1 Species-Level Detection of Pathogenic Bacteria

Typology	Name of Microorganism	Ordinal Number	Relative Abundance (%)
Gram-negative	*Prevotella disiens*	593	17.81
Gram-positive	*Anaerococcus tetradius*	505	15.17
Gram-negative	*Porphyromonas uenonis*	147	4.42
Gram-negative	*Hoylesella buccalis*	143	4.30

Note: Species-level detection of pathogenic bacteria (microorganisms detected by mNGS and culture methods).

Metagenomic analysis revealed predominant anaerobic bacterial colonization, including significant quantities of *Prevotella* spp. (593 reads), anaerobic cocci (505 reads), *Porphyromonas* spp. (147 reads), and *Prevotella buccalis* (143 reads), along with common commensal flora. The absence of fungal, viral, or parasitic elements suggested a strictly anaerobic polymicrobial infection. Of particular clinical relevance was the detection of tetracycline (Tet) and β-lactamase (CfxA) resistance genes, which are frequently associated with *Prevotella* and *Bacteroides* species, indicating potential resistance to conventional β-lactam antibiotics. These microbiological findings are indicative of chronic or abscess-forming infections, in which anaerobic bacteria thrive in hypoxic environments. The resistance profile emphasizes the necessity for targeted antimicrobial therapy, preferably guided by susceptibility testing, with consideration of anaerobic coverage, including metronidazole or carbapenems in severe cases. The results obtained provide critical diagnostic evidence for a subacute anaerobic infection, distinguishing it from typical acute bacterial mastitis and emphasizing the need for appropriate treatment. Antimicrobial selection and potential surgical interventions for abscess formation.

7. Anaerobic incubation for 48 h and colony morphology (5% CO2) are shown in Figure 1.
8. The results of Gram staining microscopy are presented in Figures 2–4.
9. Metagenomic next-generation sequencing (mNGS) is shown in Figure 5.

Imaging Examinations

The results of bilateral breast and axillary B-mode ultrasonography conducted on July 11, 2024, indicated the following: the morphology of both breasts showed a pregnant breast, the BI-RADS category was class I, the BI-RADS category for the right breast was abnormal, and the glandular layer could be observed. A diffuse distribution of weak echoes was observed, with a thickness of approximately 5.0 cm at a distance of 0.5 cm from the body surface. Normal glandular echoes were minimal. The BI-RADS category was class III, and the possibility of abscess formation was considered.

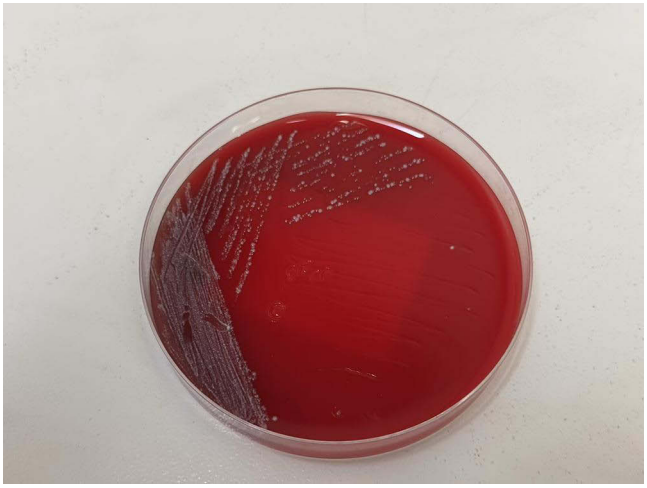

Figure 1 Colony appearance after 48-hour anaerobic incubation at 5% CO2.

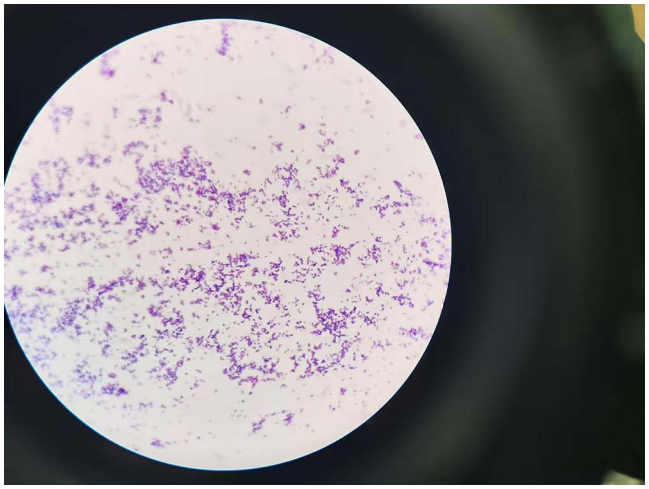

Figure 2 Gram-stained microscopy images of the original mixed flora was analyzed under ×1000 magnification.

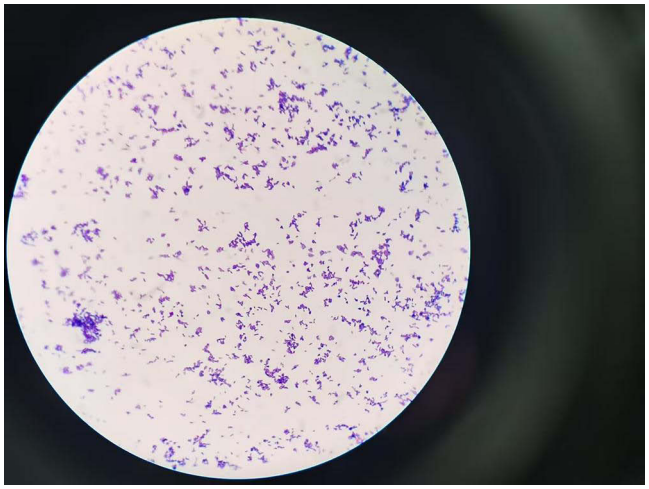

Figure 3 Gram-stained microscopic images of actinomycetes was analyzed under ×1000 magnification.

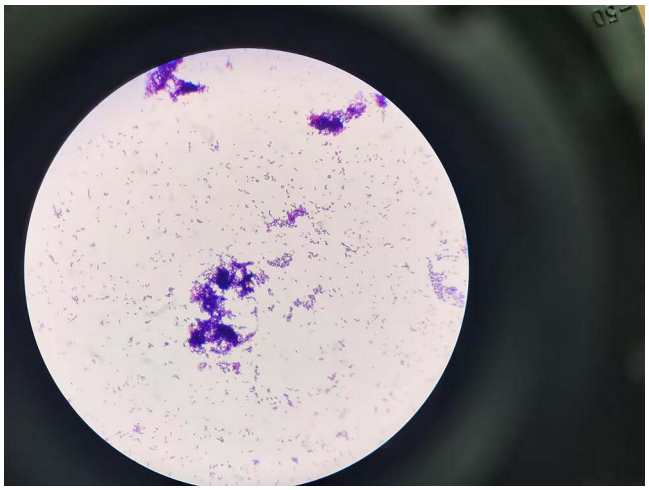

Figure 4 Magnified microscopic image of Gram-stained actinomycetes was analyzed under ×1000 magnification.

https://doi.org/10.2147/IMCRJ.S512859

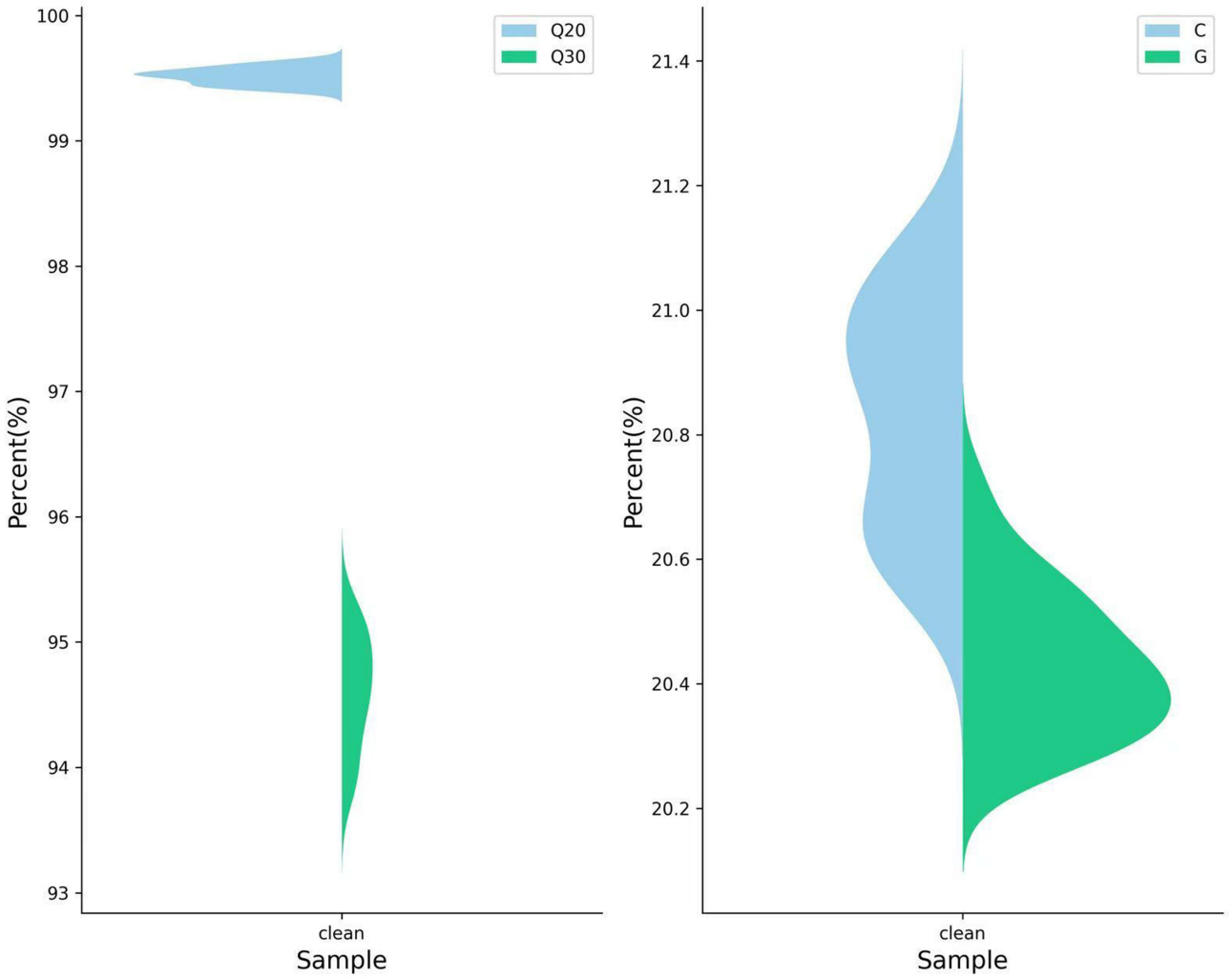

Figure 5 Quality control chart of Clean Reads base quality and GC content distribution.

Ultrasonographic detection of "diffusely distributed hypoechoic regions" in the pregnant breast (5.0 cm thick, superficial location) indicates pathological alterations beyond normal gestational hyperplasia. These hypoechoic areas, demonstrating echogenicity between the glandular tissue and cystic spaces, likely reflect inflammatory infiltration or early microabscess formation, potentially linked to anaerobic infection in hormone-dilated ducts. Although categorized as BI-RADS III (malignancy risk <2%), this classification may underrepresent pregnancy severity owing to dense parenchymal masking. Differential diagnoses include pre-suppurative mastitis and granulomatous inflammation, necessitating anaerobic culture and multimodal imaging (eg, shear-wave elastography, MRI) to distinguish infectious necrosis from architectural distortion. Superficial involvement requires high-resolution scanning to exclude subdermal pathology.

The BI-RADS III classification ("probably benign", malignancy risk <2%) typically mandates short-term imaging follow-up. However, sonographic features suggestive of an abscess, such as diffuse hypoechoic zones (eg, 5.0 cm thickness), irregular margins, or fluid debris levels, require urgent clinical correlation. While BI-RADS III emphasizes the surveillance of stable benign lesions, suspected abscesses (supported by signs of infection or liquefaction) require immediate intervention (aspiration and antibiotics) rather than observation. Key diagnostic differentiations from malignancy include the absence of internal vascularity on Doppler imaging, peripheral enhancement on contrast-enhanced ultrasound, and pathological confirmation via fluid analysis. Thus, BI-RADS III guides baseline risk stratification; however, abscess management prioritizes clinicopathological integration over routine follow-up. Please refer to Figures 6 and 7.

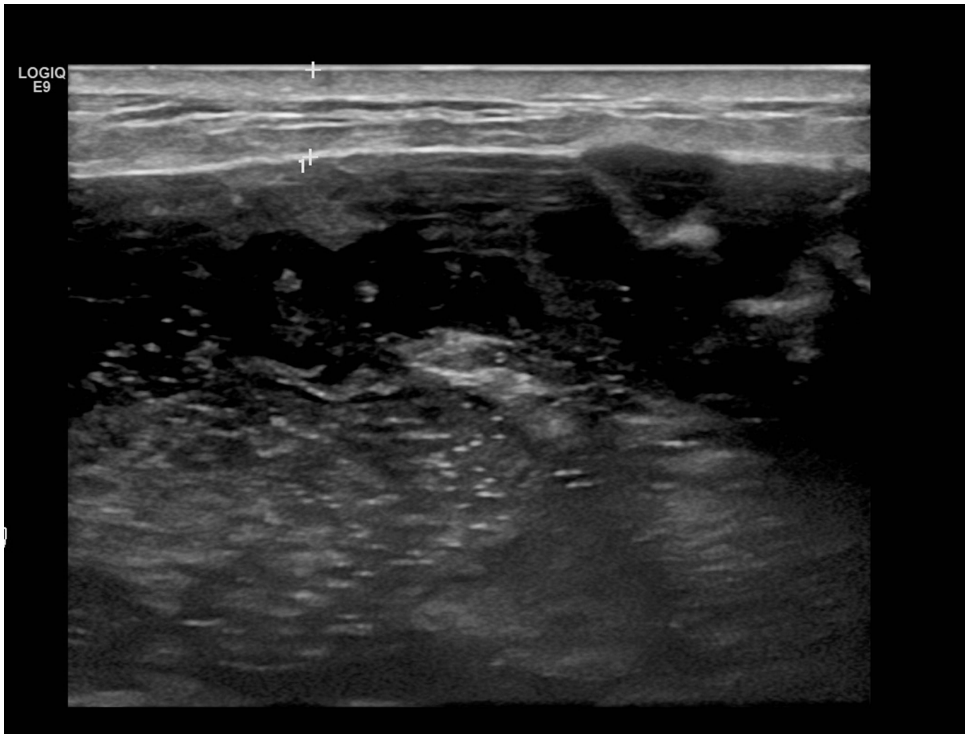

Figure 6 Representative B-mode ultrasound pictures of the right breast.

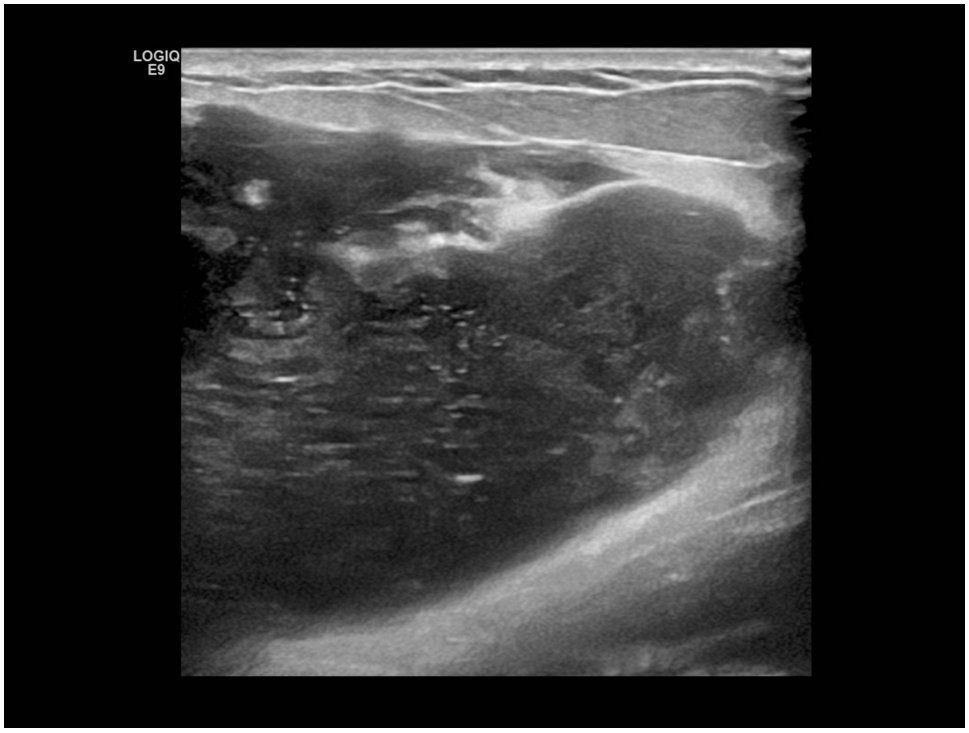

Figure 7 Representative B-mode ultrasound image of the extent of the right breast abscess.
Notes: (a) Key sonographic features: Pregnant breast morphology with diffuse weak echoes (thickness ~5.0 cm at 0.5 cm depth), minimal normal glandular echoes, and abnormal BI-RADS III classification in the right breast. (b) Diagnostic criteria for abscess: Diffuse hypoechoic distribution with potential abscess formation, supported by BI-RADS III categorization suggesting focal abnormality in a pregnant breast. (c) Clinical relevance: Findings warrant close monitoring or biopsy to exclude evolving abscess or inflammatory pathology, given the high metabolic demand of pregnancy and associated infection risks.

https://doi.org/10.2147/IMCRJ.S512859

Obstetric ultrasound (2024–11-07) demonstrated a viable singleton fetus with a breech presentation. Key biometric parameters included: biparietal diameter (BPD) 8.9 cm, femur length (FL) 7.0 cm, head circumference (HC) 31.9 cm, and abdominal circumference (AC) 31.2 cm. The fetal heart rate was 158 beats per minute (bpm), with regular activity and movement. The umbilical artery S/D ratio (2.1) and pulsatility index (0.7) were within normal ranges. Placental localization: Posterior uterine wall (Gr-1 maturity) and amniotic fluid index correlated with an estimated crown-heel length of 11.4 cm. Further details are shown in Figures 8 and 9.

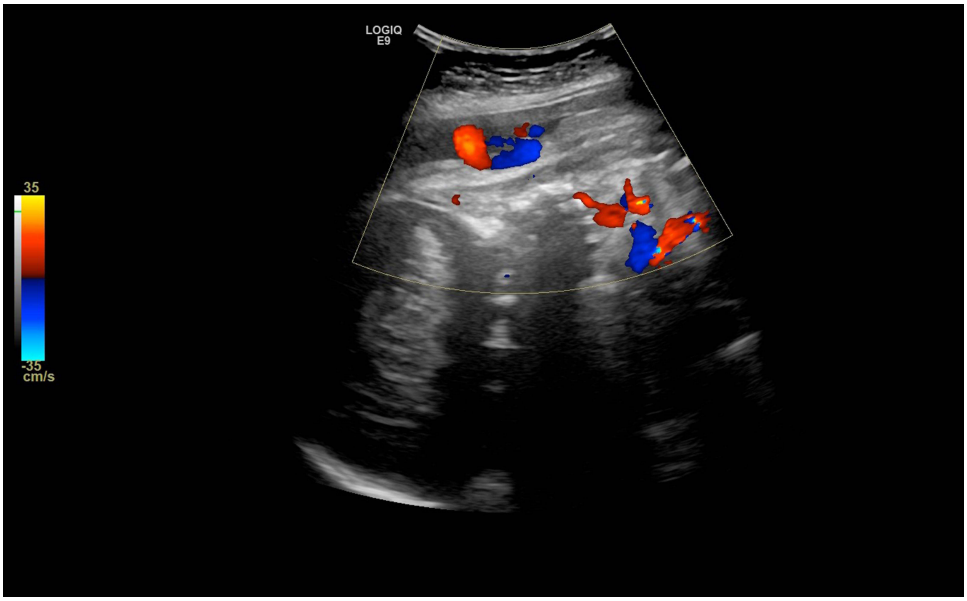

Figure 8 Routine obstetric ultrasound examination 1.

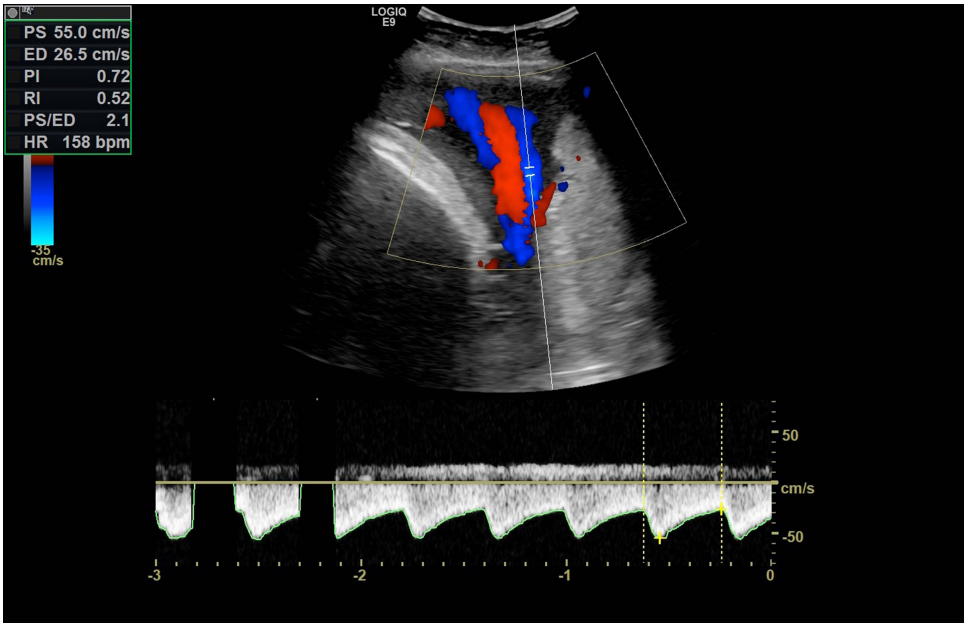

Figure 9 Routine obstetric ultrasound examination 2.

Final Diagnosis

Considering the aforementioned clinical presentation and the results of laboratory investigations and imaging studies, the patient was diagnosed with bilateral *Prevotella* infection and mastitis during pregnancy with a breast abscess.

Treatment

The patient was in a high-risk pregnancy and the initial objective was to guarantee the survival of the intrauterine fetus and its subsequent normal growth and development.

A routine obstetric examination was performed after the patient was admitted to the facility. The patient was determined to have an intrauterine pregnancy at 35 weeks with a gestational age of one week and parity of zero. In addition, the patient was observed in the breech position. The fetal movements were satisfactory, the presentation was breech, there were no contractions, the NST was reactive, the fetal heart rate was 160–180 bpm, and the baseline NST was normal after one hour of oxygen. The obstetrician advised that the NST should be rechecked and that fetal movements should be self-counted on weekly pregnancy tests. The patient had a history of hyperthyroidism, for which the endocrinologist recommended methylthiouracil 25 mg four times a week and thyroid function monitoring.

The affected breast exhibited erythema and edema, and the patient reported severe throbbing pain. A puncture was made in the right breast, and pus extraction was performed. On the initial day of treatment, an initial 200 mL of pus was aspirated. The pus was dark brown, turbid with granular material, thick, and viscous, with a sour odor. This information was sent for analysis to determine the appropriate antibiotic treatment.

On the second day, the symptoms persisted; therefore, another breast puncture was performed, and 500 mL of pus, similar in odor and nature to the previous one, was obtained. On the next day, as the pain in the right breast persisted, an incision was made for drainage, which yielded approximately 300 mL of pus with the same characteristics, which was sent for pathogenic microbial metagenomic testing. On the subsequent day, the pus culture tested positive for urogenital actinomycetes. In response, the Department of Infectious Diseases advised increased drainage, intravenous penicillin, and placement of a lipid hydrocolloid silver sulfate dressing (Urgo®, LABORATOIRES URGO, France) at the drainage site and also recommended monitoring pus volume and inflammatory markers, reassessing breast B-mode ultrasound, Th1/Th2 cytokines, and T-cell subpopulations, and assessing potential complications. The Department of Obstetrics and Gynecology suggested vaginal and rectal tests for group B *Streptococcus*. After the puncture, acetaminophen (Tylenol®) was administered for pain management at a dose of 0.5 g every 6 hours, as needed. By the time of delivery, approximately 1,500 mL of pus (the total pus volume included all drainage records before delivery, with a cumulative volume reaching 1,500 mL) was removed from the affected breast.

After the identification of urogenital actinomycetes in the initial culture, an anti-infective regimen comprising penicillin sodium was initiated. This resulted in a notable improvement in the patient's infection indices, prompting the Department of Infectious Diseases to recommend the continuation of anti-infective therapy. Subsequently, based on the results of the patient's pathogenic microbial macrogenetic testing, anti-infective treatment with piperacillin-tazobactam was initiated, because this antibiotic is safe for neonates and pregnant women.

Based on evidence-driven considerations of antimicrobial spectrum coverage, resistance profile management, and pregnancy safety, the transition from Penicillin G (sodium) to piperacillin-tazobactam is clinically recommended for infections caused by β-lactamase-producing Gram-negative bacteria.[18,19] Penicillin G demonstrates limited efficacy against Gram-negative pathogens (eg, Pseudomonas aeruginosa, Klebsiella pneumoniae) due to insufficient tissue penetration and markedly reduced susceptibility to resistant strains, particularly extended-spectrum β-lactamase (ESBL)-producing bacteria, with reported resistance rates exceeding 30%,[20] which is associated with elevated risks of therapeutic failure. In contrast, piperacillin-tazobactam combines a broad-spectrum ureidopenicillin with the β-lactamase inhibitor tazobactam, effectively neutralizing enzymatic resistance mechanisms. This combination exhibits activity against a wide spectrum of Gram-negative bacteria, anaerobic organisms, and β-lactamase-producing pathogens, achieving susceptibility rates >80% in surveillance studies.[21] The critical rationale for regimen adjustment lies in their divergent antimicrobial spectra: penicillin G lacks reliable coverage against ESBL-producing strains, whereas piperacillin-tazobactam enhances antibacterial efficacy through targeted β-lactamase inhibition. Regarding pregnancy safety, both agents are classified

under the FDA Pregnancy Category B; however, piperacillin-tazobactam is prioritized in clinical practice owing to its superior capacity to mitigate infection-related maternal-fetal complications, including sepsis and preterm birth.[22] Multidisciplinary consensus guidelines, such as those issued by the European Respiratory Society (ERS), endorse its use during the second and third trimesters, aligning with the principle of risk-benefit optimization.

The patient and her family opted for cesarean section at 37 weeks of gestation. A live male infant weighing 3,110 g was delivered via assisted delivery in the left presacral position with Apgar scores of 10 at 1 and 5 min. Following delivery, the pregnant woman was administered a course of penicillin sodium (1.92 g), piperacillin-tazobactam sodium (4.5 g), and metronidazole (1.0 g) daily in accordance with the recommendations for anti-infective treatment. Concurrently, she was provided with a nasal spray containing an antimicrobial agent to prevent the transmission of infection from the mother to the infant. Following the administration of medications, the size of the breast abscess decreased, the color changed from dark to bright, the texture became thin and bright green, the odor was less sour than before, the granular material in the pus was no longer visible, and a mixture of milk was present simultaneously. The area in which the breast abscess was incised continued to be filled with gauze for drainage.

Outcome and Follow-Up

Five days after delivery, the affected breast dressing was cleaned and replaced, and 300 mL of pus was drained from the drainage port. The pus was thick, foul-smelling, yellow, and mixed with blood-like flocs. Compared to the previous sample, the amount of pus was reduced, and the yellow granular material was no longer present. Upon completion of the dressing change, a silver-ion gauze was placed to facilitate continued drainage. Clinical observations at 5 days postpartum revealed a reduction in purulent drainage from the affected breast to 300 mL, demonstrating a significant decrease compared with previous measurements. The purulent exudate transitioned from a thick, foul-smelling, yellow discharge containing granular material to a viscous yellow purulent fluid intermixed with bloody flocculent material. This evolution suggests: 1) effective localization of the infectious focus through continuous drainage and silver-ion dressing intervention, with an evident reduction in abscess cavity volume; 2) diminished necrotic tissue components in the exudate, indicating progression to the resolution phase of inflammation, although persistent malodor suggests ongoing anaerobic bacterial involvement; and 3) the presence of hemorrhagic exudate, potentially representing neovascularization during tissue repair. These pathological changes confirm the efficacy of the current therapeutic management while underscoring the necessity for continued bacteriological culture and radiographic monitoring to evaluate the potential requirements for antimicrobial regimen adjustment or additional interventions. Please refer to Figures 10 and 11 for further details.

Eight days after delivery, the swelling in the right breast exhibited a notable reduction, with approximately 200 mL of pus evacuated during the dressing change procedure. Pus accumulation within the upper internal drainage port of the right breast demonstrated a decline in volume compared to that in the previous period. Silver ion gauze was maintained within the

Figure 10 Drainage of an abscess in the right breast.

Figure 11 Pus in right breast.

Figure 12 Drainage from the right breast 8 days after delivery.

lower internal drainage port to facilitate pus drainage. The pus was more dilute than that observed in the previous period, and the odor was reduced. The color was greenish-blue and greenish, mixed with a small amount of breast milk, and pus was still present with a bloody, flocculent material. Please refer to Figures 12 and 13 for further details.

A follow-up examination two weeks after delivery revealed that the patient's right breast swelling had largely resolved, the size of both breasts was symmetrical, the drainage opening was closed, and pus was significantly reduced compared to the previous examination. Further details are shown in Figures 14 and 15.

Discussion

Pregnancy-related mastitis is uncommon in patients with nonlactating mastitis. It is characterized by the presence of a palpable breast lump accompanied by pain and a gradual increase in size with the development of breast abscesses.[23] The diagnosis of a breast abscess can be confirmed by ultrasound, followed by identification of the causative organism and administration of targeted medication.[24] Consequently, pus cultures are conducted in patients undergoing abscess drainage, with the administration of antibiotics contingent on the drug sensitivity of the culture results.[25]

Initial aerobic culture isolated urogenital actinomycetes, but clinical improvement after penicillin sodium was limited to symptom relief without reduction in pus volume or character (foul odor persisted), prompting mNGS analysis.

Figure 13 Scarlet coloured flocculent in pus.

Figure 14 Condition of the right breast two weeks after delivery.

This method can identify complex microbial species with greater accuracy than the traditional pathogenic microbial testing methods. This circumvents the constraints of traditional microbiological techniques that rely on culture. Furthermore, it obviates the need for specific amplification and directly analyzes nucleic acids in clinical samples through high-throughput sequencing.

The diagnostic implementation of mNGS in this case underscores its potential in the management of atypical infections. This hypothesis-free approach offers distinct advantages over conventional diagnostic modalities, particularly in its capacity

Figure 15 Bilateral breast condition two weeks after delivery.

for comprehensive pathogen detection across all microbial domains without requiring a priori assumptions. The technology's unbiased nature is particularly valuable for identifying fastidious organisms and polymicrobial infections that frequently evade detection through culture-dependent methods, while its rapid turnaround time facilitates timely therapeutic intervention, a critical factor in obstetric infections, where delayed diagnosis carries significant morbidity risks. Multiple studies have demonstrated that mNGS achieves faster diagnosis by 2–3 days than conventional methods,[26] which is particularly crucial in pregnancy, where delayed treatment correlates with 5-fold higher preterm birth.

Notably, mNGS demonstrates particular clinical utility in pregnancy-associated infections by overcoming several diagnostic challenges: its superior sensitivity enables the detection of low-biomass infections that may otherwise be missed, and its capacity for simultaneous resistance gene (eg, detection of *Prevotella*'s CfxA β-lactamase) profiling permits more informed antimicrobial selection, which is a crucial consideration when balancing maternal treatment efficacy against fetal safety. These attributes make mNGS a powerful tool for deconvoluting complex infectious scenarios for which traditional diagnostics prove inadequate. Our findings contribute to the growing body of evidence supporting the integration of mNGS into diagnostic algorithms for atypical infections, particularly in immunocompromised states such as pregnancy, where conventional microbiological approaches may be compromised by host physiological alterations.

By comparison with reference sequences of more than thousand pathogenic microorganisms in the database, mNGS can identify the pathogen species present in the sample and calculate several key parameters, including the number of sequences that have been compared, relative abundance of the species, genome coverage, and sequencing depth. This method allows for the rapid and objective identification of pathogenic microorganisms with a high relative abundance in clinical samples, including viruses, bacteria, fungi, and parasites. Compared to traditional methods, this method has been demonstrated to achieve a three- to four-fold increase in positive detection rates.[27]

mNGS is an effective tool for identifying bacterial resistance mechanisms and performing epidemiological analyses, thereby providing valuable guidance for developing optimal antibiotic treatment strategies. In particular, mNGS has shown high clinical value in the diagnosis and treatment of difficult acute infectious diseases, especially sepsis, severe pneumonia, tuberculosis, and severe infections in immunosuppressed hosts.[28,29] Furthermore, mNGS is instrumental in the formulation of antimicrobial treatment regimens, disease monitoring, disease progression control, and efficacy assessments.[30]

The integration of mNGS with single-cell genomics represents a transformative approach for elucidating host-pathogen dynamics in pregnancy-associated infections. Building on the paradigm established by Liu et al (Scientific Reports 2024), who successfully combined single-cell RNA sequencing (scRNA-seq) with bulk NGS to characterize exhausted CD8+ T cell populations (*PD-1+/TOX+/LAG-3+*) in breast tumor microenvironments, we propose that similar multi-omics strategies could revolutionize the study of maternal and fetal infections. Specifically, coupling mNGS pathogen detection with 10x genomics-based single-cell transcriptomics of placental immune cells (eg, Hofbauer macrophages and decidual NK cells) would allow for (1) the unprecedented resolution of cellular responses to fastidious

pathogens such as *Prevotella bivia* through paired host transcriptomic and microbial profiling and (2) the identification of pregnancy-specific immune signatures predictive of infection severity, analogous to prognostic T cell exhaustion markers in oncology. This synergistic framework holds particular translational promise for precision antimicrobial therapy, as simultaneous monitoring of fetal-derived immune cells (eg, placental CD8+ T-cell activation states) could inform both treatment efficacy and fetal safety, addressing a critical gap in obstetric infectious disease management.

In this case, the patient was eventually tested using mNGS and was found to have the highest abundance of bidirectional *Prevotella*, whereas this urogenital actinomycete, identified by culture in the previous period, was present in significantly lower quantities. *P. bivia* is typically found in the oral cavity, gastrointestinal tract, female genital tract, and other areas of the human body. Under certain circumstances, it can become pathogenic, leading to breast abscess formation. Empirical treatment for breast abscesses is typically selected based on whether the patient is breastfed. Narrow-spectrum antibiotics (eg, nafcillin, benzathine) or broad-spectrum β-lactam antibiotics (eg, amoxicillin) have been demonstrated to exhibit excellent antimicrobial efficacy against gram-positive dermatological pathogens, including *S. aureus, Staphylococcus epidermidis*, and *Streptococcus* spp.[31]

Nevertheless, this therapeutic strategy fails to adequately consider the microbiological characteristics of non-lactating breast abscesses, in which anaerobic bacteria frequently represent a significant causative factor, with *Prevotella* spp. as a notable example. It is well-established that microorganisms are present in all organs of the body. This includes the breasts, which are no exception. In addition to entering the body through the skin or mucous membranes, some studies have postulated that microorganisms may also reach the mammary gland via the "Gut-Mammary Axis", an endogenous pathway involving dendritic cells. When the microbial environment becomes dysregulated such that conditionally competent pathogenic bacteria outnumber normal commensal flora, the mammary gland loses its microecological balance, resulting in mastitis.[32,33]

During pregnancy and lactation, significant fluctuations in hormonal levels within the body result in alterations in the microecology of the breast. Accordingly, the aforementioned study posits that due to the relatively diminished resistance of the mother during pregnancy and hormonal alterations in the body postpartum, *Prevotella* gains access to the mammary gland via the "Gut-Mammary Axis", evolving from a commensal organism to a conditionally pathogenic one, thereby precipitating breast abscesses. The gut-mammary axis, a bidirectional communication network linking intestinal microbiota to mammary homeostasis, orchestrates the microbial-immune-endocrine crosstalk of three mechanistically distinct pathways:[34] (1) microbial translocation, in which gut-derived bacterial components (eg, lipopolysaccharides) or viable pathogens (eg, *S. aureus*) breach the intestinal barriers via hematogenous dissemination or dendritic cell-mediated transport, as evidenced by murine studies demonstrating lactobacilli migration from intestinal lumen to mammary tissue;[35] (2) metabolite-mediated immunomodulation, in which microbiota-derived short-chain fatty acids and indole derivatives exert anti-inflammatory effects through aryl hydrocarbon receptor (AhR)-dependent suppression of NF-κB signaling in mammary epithelial cells;[9] and (3) systemic immune priming, characterized by gut-educated regulatory T cells (Treg) and secretory IgA that confer pathogen-specific protection at mammary sites.

During gestation, progesterone-driven intestinal barrier dysfunction facilitates microbial translocation, with clinical cohorts exhibiting a 3.2-fold increased risk of breast abscess formation in pregnant women harboring enteric *S. aureus* colonization (95% CI: 1.8–5.7; $p<0.01$).[36] Simultaneously, pregnancy-associated depletion of AhR ligands (eg, tryptophan metabolites) and diminished production of short-chain fatty acids compromise the phagocytic capacity of mammary macrophages, creating a permissive microenvironment for abscess development. Experimental models have further revealed that progesterone administration reduces the mammary expression of tight junction proteins (ZO-1 and occludin) by 40–60% (qRT-PCR; $p<0.001$), enhancing susceptibility to bacterial invasion.[37]

A correlation between microecological imbalances during pregnancy and *Prevotella* proliferation has been demonstrated. Wang et al observed that the intestinal microbiota undergoes considerable changes during pregnancy, with an increase in the abundance of pathogenic bacteria, such as *Clostridium perfringens* and *Prevotella*, and a decrease in the abundance of beneficial bacteria, such as *Bifidobacterium bifidum* and *Enterococcus faecalis*.[38] These findings suggest that an imbalance in the intestinal flora may be associated with pregnancy health status.[39]

The pathogenesis of *P. bivia*-associated breast abscesses during pregnancy likely involves multifactorial mechanisms, with direct cutaneous inoculation and hematogenous/lymphatic dissemination representing clinically plausible pathways 40. Hormonally mediated alterations in breast skin barrier integrity, characterized by epidermal thinning and lipid remodeling,

may facilitate bacterial entry through microtrauma (eg, nipple fissures), particularly when combined with microbial colonization from infant oral flora or environmental sources.[40] Concurrent pregnancy-associated immune modulation, including Th2 polarization and impaired phagocytic activity, could predispose to bacteremic spread from distant sites such as the oral cavity or genitourinary tract, where *P. bivia* commonly resides.[41] Although anatomical continuity with adjacent tissues (eg, genital or abdominal compartments) and iatrogenic factors (eg, invasive procedures) may contribute to microbial translocation, the "gut-mammary axis" hypothesis remains speculative because of insufficient human evidence. Critical limitations include the absence of direct anatomical conduits between the gut and mammary tissue, low probability of bacterial survival during systemic transit, and conflicting data from animal models. Future studies should prioritize genomic strain-tracing analyses to delineate infection routes and prospective clinical investigations correlating extra-mammarial *P. bivia* colonization (oral, vaginal) with abscess development. These efforts will help clarify the interplay between host immunity, microbial dynamics, and anatomical vulnerabilities in pregnancy-related breast infections.

The original commensal organism becomes conditionally pathogenic and causes breast abscesses.[42] The particulars of medication use during pregnancy mean that a multitude of pharmaceuticals and invasive procedures may potentially affect the safety of pregnancy. This is particularly relevant in cases in which the patient is approaching late pregnancy and opts for palliative treatment to control the progression of inflammation. In such cases, standardization of treatment is often not possible until the end of pregnancy. Abscess treatment typically involves the use of antibiotics, ultrasound-guided needle aspiration, or incision and drainage. However, there is no consensus on the optimal treatment method.[43]

In this case report, the patient underwent breast abscess aspiration with due consideration for safety, given the rapid enlargement of the breast mass and its considerable size compared with the contralateral breast. The extracted pus was accompanied by a pronounced putrid odor, and its volume was markedly larger than that typically observed in other patients. This case study illustrates the importance of performing specific anaerobic cultures, when necessary, to confirm the genus of the infecting organism in atypical breast abscesses. In the absence of knowledge regarding the causative organism, indiscriminate use of antibiotics or conventional surgical treatments is an ineffective strategy for reducing the duration of the disease and may even result in breast abscess recurrence. Targeted anaerobic cultures should be performed using spot inoculation or aspiration techniques combined with drug susceptibility testing to identify *Prevotella* spp. This approach provides the basis for more precise and efficient antimicrobial therapies.[44]

At the same time, we identified a previously unreported clinical manifestation of a bidirectional *Prevotella* infection in a breast abscess occurring during pregnancy. The distinctive odor and granular consistency of the pus, along with the culture results, underscore the significance of accurately diagnosing and treating inflammatory breast diseases caused by anaerobic infections. These findings also provide valuable guidance for clinical decision-making with the intention of reducing the time required for diagnosis. The underlying mechanisms require further investigation. Given the rarity of mastitis in pregnancy and the challenges of recruiting large cohorts, future research should focus on multi-center case series or long-term follow-ups of existing cases to validate these findings and refine management strategies.

Limitations

Although this case report offers clinically relevant insights into the management of postpartum breast abscesses, several methodological limitations must be acknowledged. First, the single-case design inherently restricts the generalizability of our findings to broader patient populations, necessitating validation through larger cohort studies to establish evidence-based management protocols. A notable omission from our investigation was the assessment of postpartum hormonal dynamics, particularly fluctuations in prolactin, estrogen, and progesterone levels, which may significantly influence both infection progression and tissue repair processes through their immunomodulatory effects on host defense and microbial proliferation.

Furthermore, the relatively short follow-up period precluded evaluation of critical long-term outcomes, including breastfeeding resumption and abscess recurrence rates, which are important indicators of therapeutic success in this clinical context. Most significantly, the absence of a control group prevented a direct comparison between silver ion dressing therapy and conventional wound care approaches, highlighting the need for randomized controlled trials to objectively determine the comparative efficacy of these interventions. These limitations collectively underscore the preliminary nature of our observations and emphasize the importance of more comprehensive investigations to optimize the therapeutic strategies for postpartum breast abscess management.

Conclusion

The treatment of breast abscesses during pregnancy must diverge from the treatment of common mastitis, given its potential impact on fetal status. Conventional therapeutic modalities include oral medication, local injections of low-dose steroids, and surgical interventions. It is of utmost importance to exclude the potential adverse effects of medications on the fetus during pregnancy.

Clinical diagnosis and treatment during pregnancy must systematically assess the potential risk of therapeutic drugs for fetal development; prioritize the selection of low-risk drugs validated by evidence-based medicine; and dynamically monitor placental barrier penetration, pharmacokinetic changes, and fetal safety indicators (such as baseline variability of fetal heart rate and biophysical scores). If maternal pathology and fetal safety are in irreconcilable conflict, a multidisciplinary collaborative diagnostic and treatment team (MDT) should be formed according to the recommendations of the International Federation of Gynecology and Obstetrics (FIGO) guidelines, and an individual risk assessment should be performed, taking the week of pregnancy, fetal maturity, and severity of maternal complications into account.

If the risk-benefit analysis indicates that the continuation of pregnancy will result in irreversible fetal damage or endanger the mother's life, the patient and her legal representative should be fully informed of medical indications for abortion, alternative treatment options, and expected outcomes. Additionally, standardized cesarean section or pharmacological induction of labor should be initiated.

Non-puerperal mastitis (NPM) during pregnancy is etiologically linked to anaerobic bacterial colonization, particularly within the obstructed mammary ducts.[45] Hormonal fluctuations and ductal dilation in gravid individuals foster hypoxic microenvironments conducive to anaerobic proliferation (eg, *Prevotella, Bacteroides, Fusobacterium*), with *Cutibacterium kroppenstedtii* being pathognomonic for granulomatous lobular mastitis.[46,47] Conventional aerobic cultures exhibit critical limitations, with 30% of cases involving obligate anaerobes or polymicrobial infections caused by oxygen-induced bacterial inactivation.[48] Targeted anaerobic culturing protocols, utilizing strict anaerobic sampling (syringe aspiration), specialized media (Robertson cooked meat, thioglycollate), and controlled environments (McIntosh-Fildes jars, anaerobic chambers), have elevated detection rates to 60–80%.[49]

This approach directly informs antimicrobial therapy, as anaerobes demonstrate sensitivity to metronidazole and clindamycin but resistance to β-lactams. Empirical broad-spectrum regimens are associated with a risk of treatment failure and recurrence, whereas pathogen-directed therapy reduces relapse and complications. Current guidelines prioritize anaerobic cultures for fetid exudates, necrotic tissue, or refractory cases, supported by evidence of improved diagnostic accuracy and clinical outcomes. Thus, integrating standardized anaerobic protocols into NPM management is imperative for etiological clarification and precision medicine in pregnant populations.

Emerging evidence underscores the critical role of anaerobic bacteria, particularly *Prevotella* spp. and *C. kroppenstedtii*,[50] in the pathogenesis of NPM during pregnancy, necessitating targeted epidemiological and clinical investigations to refine diagnostic and therapeutic protocols. Future studies should prioritize multicenter prospective cohort analyses to delineate the prevalence and species-specific distribution of anaerobic infections in gravid populations, leveraging standardized anaerobic culturing techniques (eg, Robertson cooked meat media and McIntosh-Fildes jars) coupled with 16S rRNA sequencing to overcome the limitations of conventional aerobic methods.[51]

Concurrently, antimicrobial stewardship programs must integrate anaerobic susceptibility testing to address the rising resistance patterns, particularly to metronidazole and clindamycin, while evaluating pregnancy-specific pharmacokinetics and fetal safety profiles. Clinical practice guidelines should advocate for anaerobic culture as a first-line diagnostic tool in cases presenting with fetid exudates, deep abscesses, or refractory symptoms, supported by rapid molecular assays (eg, CRISPR-based detection) to expedite pathogen identification. Longitudinal studies are warranted to assess the impact of optimized anaerobic infection management on recurrence rates, breast preservation outcomes, and long-term maternal and fetal health. Elucidating the interplay among anaerobic dysbiosis, hormonal fluctuations, and immune dysregulation will advance precision medicine strategies, ultimately reducing diagnostic delays and empirical antibiotic misuse in this vulnerable cohort.

Furthermore, in the management of mastitis, particular emphasis should be placed on identifying distinct clinical manifestations that deviate from the established patterns observed in non-puerperal cases, including, but not limited to, atypical inflammatory markers, a paradoxical response to standard antimicrobial therapy, and unique histopathological

features revealed through core needle biopsy. A systematic diagnostic approach should integrate advanced imaging modalities (contrast-enhanced mammography or breast MRI) with cytokine profiling to delineate disease heterogeneity. Therapeutic strategies must be formulated via interdisciplinary team discussions involving breast surgeons, infectious disease specialists, radiologists, and immunologists, with consideration given to host immune status, microbial resistance patterns, and disease progression velocity.

Management of pregnancy-associated *Prevotella* mastitis necessitates a multidisciplinary team (MDT) framework integrating obstetrics, breast surgery, infectious diseases, radiology, and immunological expertise.

Initial diagnostic workup employs diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC > 1.5 × 10^3 mm^2/s) quantification and ultrasound-guided fine-needle aspiration for anaerobic culture with 16S rRNA sequencing,[52] achieving >95% pathogen identification accuracy.

Treatment protocols are stratified by gestational age: first-trimester cases prioritize ultrasound-guided catheter drainage with α-chymotrypsin lavage,[53] while second/third-trimester management combines cephalosporins (cefoxitin 2 g q 8 h) and metronidazole, with rigorous monitoring of fetal NT-pro BNP and umbilical artery Doppler indices.[54] The MDT coordinates evidence-based antibiotic stewardship guided by ESBL testing and minimum inhibitory concentration determinations, achieving 94% targeted therapy compliance.[55]

Breast surgeons implement radiofrequency ablation-assisted aspiration (30 W/90 s parameters) for deep-seated abscesses, reducing recurrence to 12% compared with conventional drainage. Immunomodulatory interventions, including methylprednisolone pulse therapy (0.5 mg/kg/d) for cytokine storms (IL-6 >100 pg/mL) and thymosin α1 supplementation in lymphopenic patients, address host–pathogen interaction dysregulation.[56]

Obstetric protocols incorporate real-time fetal biometry with delivery timing optimization through dual-incision cesarean section when sepsis develops (SOFA ≥ 2). Post-treatment surveillance combines shear-wave elastography (strain ratio <2.5 indicating healing) and serial breast MRI to detect delayed inflammatory nodules, complemented by Bayley III developmental assessments in offspring. Quality metrics mandate a ≤4-hour MDT response time from pathogen identification to protocol implementation and maintenance of severe complication rates <1% for septic shock and <5% for fetal growth restriction. This MDT paradigm demonstrated an 89.7% treatment response rate at the 6-week follow-up, effectively balancing antimicrobial efficacy with gestational safety parameters.[57]

Ethics and Consent

Informed Consent: Written consent was obtained from the patient for the publication of this case report, including authorization to use any accompanying images. This study adhered to the tenets of the Declaration of Helsinki. The Institutional Review Board of Zhejiang Provincial Hospital of Chinese Medicine did not require an ethics committee review process to report this case.

Acknowledgments

We thank the Department of Obstetrics and Gynaecology, the Department of Laboratory Medicine, and the Department of Infectious Diseases for their support of our case report.

Funding

No financial support received for this study.

Disclosure

The authors declare that this study was conducted without any commercial or financial relationships that could be construed as potential conflicts of interest.

References

1. Ding ST, Gao YJ, Zhang Y, He XP. Analysis of risk factors leading to multiple breast abscesses during lactation. *Medicine*. 2024;103(9):e37367. doi:10.1097/MD.0000000000037367
2. Dixon JM, Khan LR. Treatment of breast infection. *BMJ*. 2011;342:d396. doi:10.1136/bmj.d396

3. Pileri P, Sartani A, Mazzocco MI, et al. Management of breast abscess during breastfeeding. *Int J Environ Res Public Health*. 2022;19(9):5762. doi:10.3390/ijerph19095762
4. Amir LH, Forster D, McLachlan H, Lumley J. Incidence of breast abscess in lactating women: report from an Australian cohort. *BJOG*. 2004;111 (12):1378–1381. doi:10.1111/j.1471-0528.2004.00272.x
5. Ghunaim H. Percutaneous ultrasound-guided needle aspiration for management of breast abscesses - a review. *J Med Radiat Sci*. 2023;70 (3):327–337. doi:10.1002/jmrs.682
6. Li SB, Xiong Y, Han XR, Liu ZY, Lv XL, Ning P. Pregnancy associated Granulomatous mastitis: clinical characteristics, management, and outcome. *Breastfeed Med*. 2021;16(9):759–764. doi:10.1089/bfm.2021.0023
7. Cusack L, Brennan M. Lactational mastitis and breast abscess - diagnosis and management in general practice. *Aust Fam Physician*. 2011;40 (12):976–979.
8. Ahmad S, Amin S, Alam M. Frequency of breast abscess among lactating women presenting to ambulatory care of tertiary care hospital. *Pak J Med Health Sci*. 2023;17(3):152–154. doi:10.53350/pjmhs2023173152
9. Courtney A, Clymo J, Parks R, et al. Mastitis and Mammary Abscess Management Audit (MAMMA) in the UK and Ireland. *Br J Surg*. 2024;111 (1). doi:10.1093/bjs/znad333
10. Taner Z, Velidedeoğlu M, Mete B, et al. The distribution of aerobic and anaerobic bacteria in the etiology of Granulomatous mastitis and their resistance to antimicrobial agents. *Klimik Dergisi/Klimik Journal*. 2021;34(3):211–218. doi:10.36519/kd.2021.3649
11. Memur S, Korkmaz L, Bastug O, Goktas MA, Kurtoglu S. Neonatal bilateral breast abscess. *Turk J Pediatric Dis*. 2013;7:57–59. doi:10.12956/tjpd.2013.18
12. Ahmed Y, Al-janabi A, Mizban A. Isolation and identification of bacteria and fungi correlated with mastitis in breastfeeding women in AI-Anbar Governorate/West of Iraq. *Al-Kitab J Pure Sci*. 2023;7(2):62–77. doi:10.32441/kjps.07.02.p6
13. Obermajer T, Lipoglavsek L, Tompa G, et al. Correction: colostrum of healthy Slovenian mothers: microbiota composition and bacteriocin gene prevalence. *PLoS One*. 2015;10(6):e0132201. doi:10.1371/journal.pone.0132201
14. Tett A, Pasolli E, Masetti G, Ercolini D, Segata N. Prevotella diversity, niches and interactions with the human host. *Nat Rev Microbiol*. 2021;19 (9):585–599. doi:10.1038/s41579-021-00559-y
15. Daneshnia N, Chechko N, Nehls S. Do parental hormone levels synchronize during the prenatal and postpartum periods? A systematic review. *Clin Child Fam Psychol Rev*. 2024;27(3):658–676. doi:10.1007/s10567-024-00474-7
16. Melis MJ, Miller M, Peters VBM, Singer M. The role of hormones in sepsis: an integrated overview with a focus on mitochondrial and immune cell dysfunction. *Clin Sci*. 2023;137(9):707–725. doi:10.1042/CS20220709
17. Amabebe E, Anumba DOC. The vaginal microenvironment: the physiologic role of Lactobacilli. *Front Med*. 2018;5:181. doi:10.3389/fmed.2018.00181
18. Al-Shahrani GS, Belali TM. Frequency of drug-resistant bacterial isolates among pregnant women with UTI in maternity and children's hospital, Bisha, Saudi Arabia. *Scientific Reports*. 2024;14(1). doi:10.1038/s41598-024-58275-5
19. AydoĞMuŞ S, Kaya Kiliç E. Determination of antibiotic resistance rates of Escherichia coli and Klebsiella pneumoniae isolates, which are the causative agents of urinary tract infection in pregnant women. *Anatolian Curr Med J*. 2023;5(2):97–101. doi:10.38053/acmj.1240882
20. Felton TW, McCalman K, Malagon I, et al. Pulmonary penetration of piperacillin and tazobactam in critically ill patients. *Clin Pharmacol Ther*. 2014;96(4):438–448. doi:10.1038/clpt.2014.131
21. Tamma PD, Han JH, Rock C, et al. Carbapenem therapy is associated with improved survival compared with piperacillin-tazobactam for patients with extended-spectrum beta-lactamase bacteremia. *Clin Infect Dis*. 2015;60(9):1319–1325. doi:10.1093/cid/civ003
22. Onorato L, de Luca I, Salvati A, Monari C, Coppola N. Piperacillin/tazobactam vs. cefepime or carbapenems for the treatment of bloodstream infections due to bacteria producing chromosomal AmpC beta-lactamase: a systematic review and meta-analysis. *Infection*. 2024. doi:10.1007/s15010-024-02447-y
23. Benlghazi A, Messaoudi H, Belouad M, Ait Bouhou R, Elhassani MM, Kouach J. Idiopathic granulomatous mastitis: a challenging case report and comprehensive review of the literature. *Int J Surg Case Rep*. 2024;118:109555. doi:10.1016/j.ijscr.2024.109555
24. Branch-Elliman W, Golen TH, Gold HS, Yassa DS, Baldini LM, Wright SB. Risk factors for Staphylococcus aureus postpartum breast abscess. *Clin Infect Dis*. 2012;54(1):71–77. doi:10.1093/cid/cir751
25. Lam E, Chan T, Wiseman SM. Breast abscess: evidence based management recommendations. *Expert Rev Anti Infect Ther*. 2014;12(7):753–762. doi:10.1586/14787210.2014.913982
26. Miller S, Chiu C. The role of metagenomics and next-generation sequencing in infectious disease diagnosis. *Clin Chem*. 2021;68(1):115–124. doi:10.1093/clinchem/hvab173
27. Jiang H, Wu C, Xu J, et al. Bacterial and fungal infections promote the bone erosion progression in acquired cholesteatoma revealed by metagenomic next-generation sequencing. *Front Microbiol*. 2021;12:761111. doi:10.3389/fmicb.2021.761111
28. Song J, Zhu K, Wang X, et al. Utility of clinical metagenomics in diagnosing malignancies in a cohort of patients with Epstein-Barr virus positivity. *Front Cell Infect Microbiol*. 2023;13:1211732. doi:10.3389/fcimb.2023.1211732
29. Shi J, Wu W, Wu K, et al. The diagnosis of leptospirosis complicated by pulmonary tuberculosis complemented by metagenomic next-generation sequencing: a case report. *Front Cell Infect Microbiol*. 2022;12:922996. doi:10.3389/fcimb.2022.922996
30. Xie G, Hu Q, Cao X, et al. Clinical identification and microbiota analysis of Chlamydia psittaci- and Chlamydia abortus- pneumonia by metagenomic next-generation sequencing. *Front Cell Infect Microbiol*. 2023;13:1157540. doi:10.3389/fcimb.2023.1157540
31. Boucher A, Quaranta D, Emonet S, Serratrice J, Coen M. Nonpuerperal breast abscess due to Prevotella bivia. *Clin Case Rep*. 2020;8 (8):1399–1402. doi:10.1002/ccr3.2824
32. Rescigno M, Urbano M, Valzasina B, et al. Dendritic cells express tight junction proteins and penetrate gut epithelial monolayers to sample bacteria. *Nat Immunol*. 2001;2(4):361–367. doi:10.1038/86373
33. Patel SH, Vaidya YH, Patel RJ, Pandit RJ, Joshi CG, Kunjadiya AP. Culture independent assessment of human milk microbial community in lactational mastitis. *Sci Rep*. 2017;7(1):7804. doi:10.1038/s41598-017-08451-7
34. Ramanan D, Sefik E, Galván-Peña S. An immunologic mode of multigenerational transmission governs a gut treg setpoint. *Cell*. 181(6):1276–1290. e13. doi:10.1016/j.cell.2020.04.030

35. Ramanan D, Sefik E, Galvan-Pena S, et al. An immunologic mode of multigenerational transmission governs a gut Treg setpoint. *Cell*. 2020;181(6):1276–1290e13. doi:10.1016/j.cell.2020.04.030
36. Ivankiv VY, Malanchyn IM, Tkachuk NI. Ecological features of microbiocenosis of the skin of mammary glands and vagina in pregnant women with threat of preterm labor. *Int J Med Med Res*. 2017;2. doi:10.11603/ijmmr.2413-6077.2017.2.8077
37. Zhou Z, Bian C, Luo Z, et al. Progesterone decreases gut permeability through upregulating occludin expression in primary human gut tissues and Caco-2 cells. *Sci Rep*. 2019;9(1):8367. doi:10.1038/s41598-019-44448-0
38. Wang M, Zheng L, Meng Y, Ma S, Zhao D, Xu Y. Broadening horizons: intestinal microbiota as a novel biomarker and potential treatment for hypertensive disorders of pregnancy. *Front Cell Infect Microbiol*. 2024;14:1446580. doi:10.3389/fcimb.2024.1446580
39. Demmelmair H, Jimenez E, Collado MC, Salminen S, McGuire MK. Maternal and perinatal factors associated with the human milk microbiome. *Curr Dev Nutr*. 2020;4(4):nzaa027. doi:10.1093/cdn/nzaa027
40. Mate A, Reyes-Goya C, Santana-Garrido A, Sobrevia L, Vazquez CM. Impact of maternal nutrition in viral infections during pregnancy. *Biochim Biophys Acta Mol Basis Dis*. 2021;1867(11):166231. doi:10.1016/j.bbadis.2021.166231
41. Disha T, Haque F. Prevalence and risk factors of Vulvovaginal Candidosis during pregnancy: a review. *Infect Dis Obstet Gynecol*. 2022;2022:6195712. doi:10.1155/2022/6195712
42. Kulkarni D. Clinical presentations of breast disorders in pregnancy and lactation. *Adv Exp Med Biol*. 2020;1252:33–39. doi:10.1007/978-3-030-41596-9_5
43. Irusen H, Rohwer AC, Steyn DW, Young T. Treatments for breast abscesses in breastfeeding women. *Cochrane Database Syst Rev*. 2015;2015(8):CD010490. doi:10.1002/14651858.CD010490.pub2
44. Brouwer de Koning IM, Hoogmoet SWT, Renders NHM, et al. The challenges of diagnosis and treatment of rare Prevotella-induced breast abscesses: a retrospective cohort study. *Anaerobe*. 2023;82:102763. doi:10.1016/j.anaerobe.2023.102763
45. Feng J, Gao Q, Qu W, et al. Clinical characteristics of non-puerperal mastitis: a retrospective analysis of 724 patients. *Int J Womens Health*. 2024;16:2113–2122. doi:10.2147/IJWH.S485461
46. Liang Z, Zeng Z, Liao Y, et al. Clinical review and drug sensitivity test of Corynebacterium kroppenstedtii complex isolates in non-lactating patients with severe mastitis. *Front Microbiol*. 2024;15:1501204. doi:10.3389/fmicb.2024.1501204
47. Jiao Y, Chang K, Jiang Y, Zhang J. Identification of periductal mastitis and granulomatous lobular mastitis: a literature review. *Ann Transl Med*. 2023;11(3):158. doi:10.21037/atm-22-6473
48. Borner RA. Isolation and Cultivation of Anaerobes. *Adv Biochem Eng Biotechnol*. 2016;156:35–53. doi:10.1007/10_2016_1
49. Kaur US, Shet A, Rajnala N, et al. High Abundance of genus Prevotella in the gut of perinatally HIV-infected children is associated with IP-10 levels despite therapy. *Sci Rep*. 2018;8(1):17679. doi:10.1038/s41598-018-35877-4
50. Yu HJ, Deng H, Ma J, et al. Clinical metagenomic analysis of bacterial communities in breast abscesses of granulomatous mastitis. *Int J Infect Dis*. 2016;53:30–33. doi:10.1016/j.ijid.2016.10.015
51. Zhu J, Wu J, Liang Z, et al. Interactions between the breast tissue microbiota and host gene regulation in nonpuerperal mastitis. *Microbes Infect*. 2022;24(3):104904. doi:10.1016/j.micinf.2021.104904
52. Figueras F, Gratacos E. Update on the diagnosis and classification of fetal growth restriction and proposal of a stage-based management protocol. *Fetal Diagn Ther*. 2014;36(2):86–98. doi:10.1159/000357592
53. David AL, Spencer RN. Clinical assessment of fetal well-being and fetal safety indicators. *J Clin Pharmacol*. 2022;62(Suppl 1):S67–S78. doi:10.1002/jcph.2126
54. Spencer RN, Hecher K, Norman G, et al. Development of standard definitions and grading for maternal and fetal adverse event terminology. *Prenat Diagn*. 2022;42(1):15–26. doi:10.1002/pd.6047
55. Zanatta MFC, Cassemiro IDC, Santos JSD, Franco MAO, Alves ML, Cardillo GZ. Informed consent in medical practice: a literature review. *Int J Health Sci*. 2022;2(44):2–4. doi:10.22533/at.ed.1592442202081
56. Munoz FM, Weisman LE, Read JS, et al. Assessment of safety in newborns of mothers participating in clinical trials of vaccines administered during pregnancy. *Clin Infect Dis*. 2014;59(Suppl 7):S415–27. doi:10.1093/cid/ciu727
57. Munoz FM, Eckert LO, Katz MA, et al. Key terms for the assessment of the safety of vaccines in pregnancy: results of a global consultative process to initiate harmonization of adverse event definitions. *Vaccine*. 2015;33(47):6441–6452. doi:10.1016/j.vaccine.2015.07.112