Original Article

Ultrasound-guided microwave ablation of granulomatous mastitis: An effective therapeutic tool

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Background: Granulomatous mastitis is a chronic inflammatory breast condition characterized by non-caseating granulomas in the breast tissue, often requiring multidisciplinary approaches for accurate diagnosis and effective management. This study aimed to evaluate the efficacy and safety of ultrasound-guided microwave ablation (MWA) for the treatment of granulomatous mastitis compared with surgical excision.

Methods: This retrospective study analyzed the clinical outcomes of 65 consecutive patients with granulomatous mastitis treated with ultrasound-guided MWA (MWA group) and 60 patients treated surgically (surgery group) during the same period. Outcomes compared between the two groups included immediate effects, clinical cure rates, postoperative complication rates, recurrence rates, BREAST-Q satisfaction scores, and breast cosmetic score outcomes. Correlated variables were subsequently incorporated into a multivariate binary logistic regression model.

Results: (I) The MWA group was superior to the surgery group in terms of operation time, intraoperative blood loss (IBL), postoperative pain, and hospital stay ($P<0.05$). (II) There were no significant differences in cure rate (98.5% *vs.* 98.3%) recurrence rate (9.2% *vs.* 11.7%), and BREAST-Q satisfaction score (66.8±5.5 *vs.* 66.1±4.4) between the two groups ($P>0.05$). The incidence of postoperative complications in the MWA group was significantly lower than that in the surgery group (4.6% *vs.* 16.7%, $P<0.05$). (III) The breast cosmetic score in the MWA group was significantly higher than that in the surgery group ($P<0.05$). (IV) Multivariate logistic regression analysis revealed that therapy method (MWA or surgery) and breast cosmetic score were significantly associated with complication rate.

Conclusions: Ultrasound-guided MWA is safe and effective in the treatment of granulomatous mastitis, which can be used as an alternative treatment method.

Keywords: Ultrasound guidance; microwave ablation (MWA); granulomatous mastitis; surgical procedures

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Introduction

Idiopathic granulomatous mastitis (IGM) is a chronic inflammatory breast condition predominantly affecting young to middle-aged women with a history of childbirth and lactation. In recent years, the incidence of IGM has risen (1). Despite its unknown etiology, possible contributing factors include milk stasis, infection, autoimmune responses, and hyperprolactinemia (2,3). Besides, several infectious agents have been isolated from granulomatous mastitis using metagenomics (4). This suggests that IGM results from an interaction between the specific bacteria that may otherwise be non-pathogenic. Clinically, IGM presents nonspecifically as masses, pain, and fever, making early diagnosis challenging (5). Prolonged disease duration often leads to fistula formation and breast deformity, impacting patients' quality of life (6). Current treatment strategies for IGM are controversial (7,8); most commonly, conservative treatments such as antibiotics, hormones, or immunosuppressants are employed, either alone or in combination with surgery (9,10). However, immunosuppressive therapies can lead to drug resistance and adverse side effects (11,12), whereas surgical interventions carry the risks of recurrence and compromise breast function and aesthetics (8,9,13). Given these limitations, there is an urgent need for minimally invasive alternatives that balance efficacy with reduced morbidity. Microwave ablation (MWA) has been shown to be effective in treating both benign and malignant thyroid tumors (14,15), and its application in the ablation of benign and malignant breast tumors, as well as plasma cell mastitis, has shown promising outcomes (16-19). Despite these advances (20,21), evidence for MWA in IGM remains scarce, leaving its potential role in this challenging condition underexplored.

Previous studies have largely overlooked the critical issue of how patient preference-driven treatment selection—a key factor in real-world clinical decision-making—may introduce confounding biases that affect outcome assessments (20,21). To address this knowledge gap, our study aimed to innovatively incorporate patient preference into the treatment allocation process while rigorously controlling for potential confounders through multivariate regression analysis. This dual approach not only enhances the ecological validity of our findings but also provides a more realistic evaluation of treatment outcomes in clinical practice settings where patient-centered care is paramount.

Given the clinical demand for minimally invasive yet effective therapies, this study aimed to evaluate ultrasound-guided MWA as a viable alternative to surgery, with a focus on efficacy, safety, and patient-reported outcomes. By addressing this gap, our findings may expand the therapeutic arsenal for this challenging condition. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1856/rc).

Methods

Participants

A total of 65 patients with IGM who underwent ultrasound-guided MWA from Fujian Nan'an City Hospital between April 2019 and May 2023 were selected for this study. Additionally, 60 patients who received surgical treatment during the same period were also included. Based on the treatment modality, the patients were divided into two groups: the MWA group and the surgery group. Participants were grouped according to their own preferences. The MWA group comprised 60 patients aged between 25 and 50 years. The surgery group consisted of 30 patients aged between 28 and 50 years. The inclusion criteria were as follows: (I) age older than 18 years; (II) presence of clinical symptoms and signs, along with lesions identified by ultrasound or other imaging modalities; (III) histological confirmation of IGM diagnosis via ultrasound-guided biopsy; and (IV) did not receive treatment for hyperprolactinemia or related immune manifestations. The exclusion criteria were as follows: (I) severe coagulopathy; (II) pregnancy or lactation; (III) acute infectious diseases; (IV) severe chronic diseases; and (V) contraindications to immunosuppressive agents. This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. This study was approved by the Ethics Committee of Fujian Nan'an City Hospital (approval No. 2024045), and all patients provided written informed consent.

Treatment methods

After confirming the diagnosis of IGM, patients were prescribed oral prednisone (20 mg/day) for 1 week. Following surgery, patients continued oral prednisone (20 mg/day) for another week.

Ultrasound-guided MWA

Before the procedure, ultrasound was used to determine the size, extent, echogenicity, shape, and boundary of the lesions, and color Doppler flow imaging was employed to

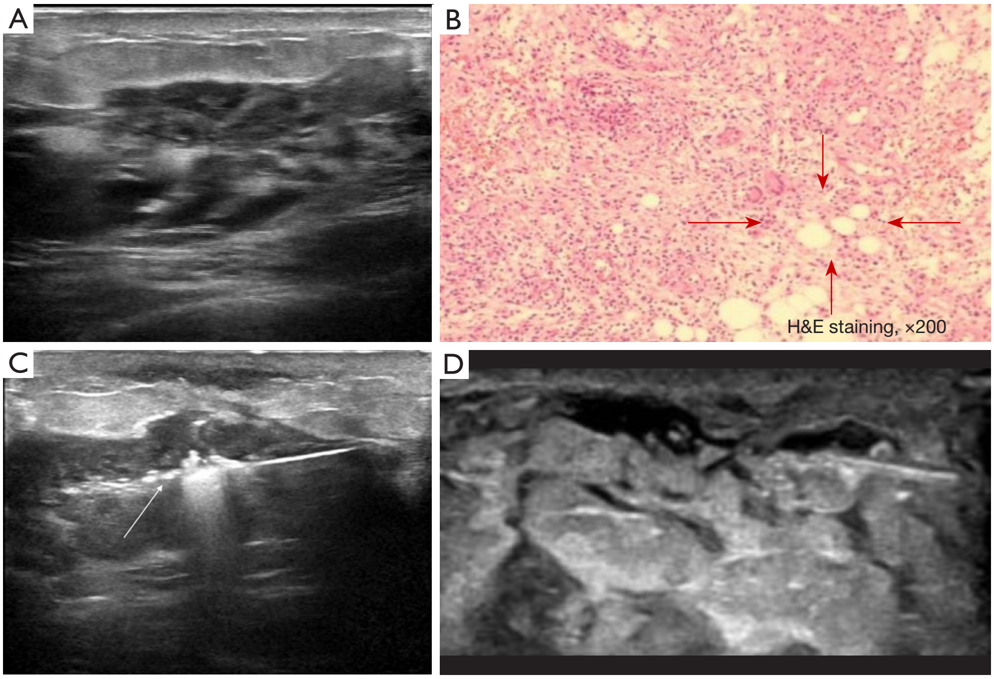

Figure 1 Ultrasound images before and during MWA and pathological images before MWA. (A) Primary IGM lesion prior to MWA. (B) Pathological image showing granulomatous inflammation before MWA. The arrow indicates an area of granulomatous inflammation. The lesions were distributed around mammary lobules, with the stroma showing extensive infiltration of both acute and chronic inflammatory cells. Focal microabscess formation was observed, accompanied by multinucleated giant cell aggregation. H&E staining, ×200. (C) During MWA (arrow indicates changes in echogenicity after MWA). (D) Glucose-water isolation performed on adjacent skin before MWA. H&E, hematoxylin and eosin; IGM, idiopathic granulomatous mastitis; MWA, microwave ablation.

assess blood flow and distribution when necessary. Based on these findings, the sonographer and surgeon jointly developed an individualized ablation plan, determining the puncture site, needle depth, ablation range, number of puncture treatments, and treatment dose. Patients were positioned supine, with routine disinfection and draping. Under ultrasound guidance, the MWA needle was inserted into the lesion, and the ablation power and time were set at 30 W (*Figure 1*). For smaller lesions, a single or multipoint ablation strategy was used, whereas for larger lesions, a mobile ablation strategy was employed. The ablation range encompassed the entire lesion and extended beyond its margins by at least 5 mm. Glucose-water isolation technology was utilized to protect adjacent structures such as the skin, areola, and retro-mammary space.

Surgical treatment

Patients were placed supine, and the appropriate surgical incision was chosen based on the size and location of the lesion to ensure complete removal.

Patients were followed up every 3 months with physical examination and ultrasound examination until 24 months post-treatment (*Figure 2*).

Observation indicators

The following parameters were observed and recorded: operation time, intraoperative blood loss (IBL), postoperative pain (assessed using a visual analog scale), length of hospital stay, cure rate, recurrence rate, postoperative complications (including incision infection, subcutaneous hematoma, breast deformity, sinus formation, fat liquefaction, skin ulcer, nipple deformity, and lactation disorders).

Clinical cure was defined as meeting the following criteria 6 months after the procedure: (I) no detectable lesion by ultrasound or only residual traces of treatment; (II) absence of clinical symptoms and signs; and (III) no requirement for additional ablation, surgical treatment, or pharmacotherapy.

Recurrence was defined as follows: (I) detection

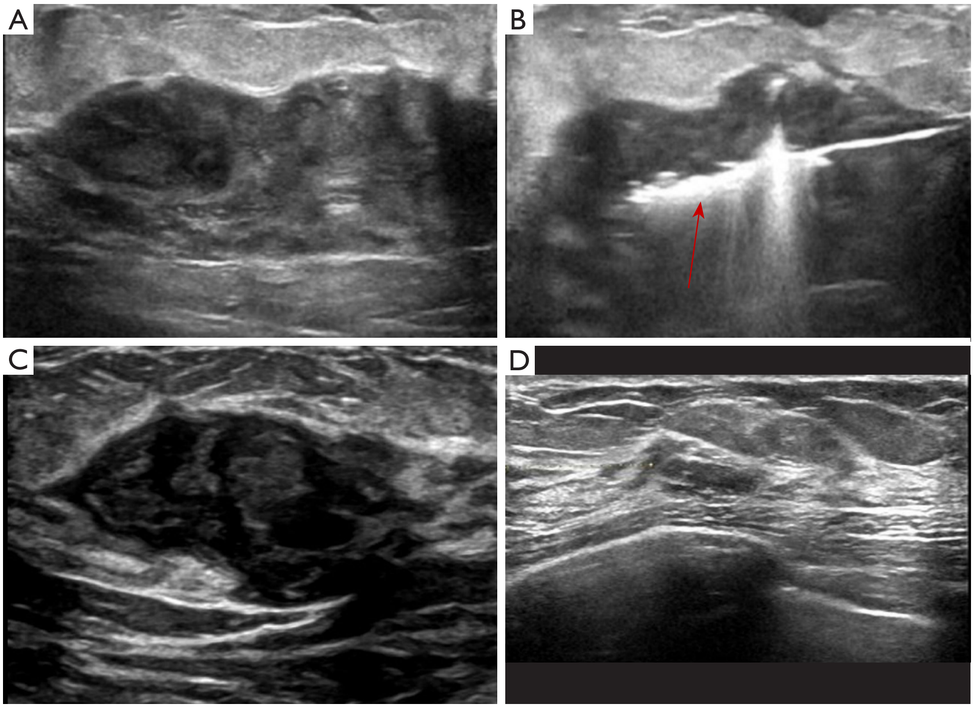

Figure 2 Ultrasound images before MWA, during MWA, and post-MWA follow-up. (A) Primary IGM lesion prior to MWA; (B) during MWA (arrow indicates lesions covered by hypoechoic signals after MWA); (C) 3 months post-ablation, the lesions show significant shrinkage; (D) 6 months post-ablation, the lesions are markedly smaller than before, with only residual scar tissue remaining. IGM, idiopathic granulomatous mastitis; MWA, microwave ablation.

of persistent lesions by ultrasound with persisting or unimproved symptoms; and (II) need for retreatment or development of new lesions elsewhere in the body post-treatment.

The BREAST-Q satisfaction questionnaire and a modified breast cosmetic score were administered before and 6 months after the procedure. The modified breast cosmetic score was adapted from the thyroid cosmetic score method (22,23). Score 0: not palpable, not visible; Score 1: palpable, not visible; Score 2: palpable and visible; Score 3: obvious; Score 4: deformed or disfigured breasts or nipples.

The patient's postoperative pain score is assessed using a numerical rating system divided into four levels: 0 indicates no pain; 1–3 represents mild pain (pain-free at rest but occurring during movement, without sleep disturbance); 4–6 indicates moderate pain (persistent pain at rest affecting sleep); and 7–10 signifies severe pain (intense continuous pain accompanied by sweating and sleep deprivation, where 7 denotes sleep-disrupting pain, 8 represents persistent pain with sweating, 9 indicates unbearable pain, and 10 reflects excruciating pain described as "worse than death").

Statistical analysis

The software SPSS 20.0 (IBM Corp., Armonk, NY, USA) was used to analyze the data. Measurement data not conforming to a normal distribution were expressed as medians (interquartile ranges), whereas normally distributed data were expressed as means ± standard deviations ($\bar{x}$±s). The *t*-test was used for intergroup comparisons. Count data were expressed as rates (%) and compared using the χ^2 test. Univariate ordinal logistic regression analysis significant variables and potential clinical predictors identified through empirical observation were included in multivariate logistic regression analysis. Missing data were handled using complete-case analysis, where only participants with fully observed data were included in the statistical analyses. A P value <0.05 was considered statistically significant.

Results

Comparison of preoperative clinical baseline data between the MWA group and surgical group

Except for the age, breast cosmetic score, and preoperative

Table 1 Comparison of preoperative clinical baseline data between MWA group and surgical group

Characteristics	MWA group (n=65)	Surgical group (n=60)	t/χ^2	P value
Age (years)	33.9±4.9	39.3±6.1	5.442	<0.001
Maximum diameter (mm)	30.1±10.6	35.0±9.6	2.699	0.402
Lesion number	2.4±1.0	2.4±1.2	0.241	0.810
Lesion distribution			1.180	0.554
Left side	19	23		
Right side	33	26		
Both sides	13	11		
Lesion location			3.442	0.064
Single quadrant	35	42		
Multiple quadrants	30	18		
Skin involvement	21	17	0.233	0.629
Abscess formation	31	22	1.553	0.213
Sinus track formation	1	1	0.003	0.954
Breast cosmetic score	2.8±0.4	2.4±0.4	–5.793	<0.001
Preoperative pain score	3.2±0.2	3.6±0.3	7.382	<0.001
Autoimmune manifestations	29	22	0.816	0.366
Hyperprolactinemia	31	23	1.114	0.291

Quantitative variables are expressed as mean ± standard deviation. MWA, microwave ablation.

Table 2 Comparison of indexes related to the immediate effect of treatment between MWA group and surgical group

Indexes	MWA group (n=65)	Surgical group (n=60)	t	P value
Operation time (min)	37.9±9.1	91.2±10.0	31.237	<0.05
Perioperative bleeding (mL)	39.8±8.3	205.3±17.4	67.082	<0.05
Degree of postoperative pain (score)	2.39±0.4	3.2±0.4	11.194	<0.05
Hospital stays (day)	6.22±1.5	3.4±0.6	13.487	<0.05

Quantitative variables are expressed as mean ± standard deviation. MWA, microwave ablation.

pain score, there were no statistically significant differences in preoperative clinical baseline data between the two groups of IGM-treated patients. These data were comparable, as detailed in *Table 1*.

Comparison of indexes related to the immediate effect of treatment between the MWA group and surgical group

The operation time, IBL, postoperative pain, and length of hospital stay were significantly lower in the MWA group compared to the surgical group ($P<0.05$), as shown in *Table 2*.

Comparison of cure rate, recurrence rate, complication rate, postoperative breast cosmetic score, and BREAST-Q satisfaction score between the MWA group and surgical group

There was no significant difference in the cure rate, recurrence rate, and BREAST-Q satisfaction score of IGM patients between the two groups ($P>0.05$). However, the incidence of postoperative complications was significantly lower in the MWA group compared to the surgical group ($P<0.05$). Additionally, the breast cosmetic score was

Table 3 Comparison of cure rate, recurrence rate, complication rate, breast cosmetic score, and BREAST-Q satisfaction score between the MWA group and surgical group

Indexes	MWA group (n=65)	Surgical group (n=60)	t	P value
Cure rate (%)	98.5	98.3	0.003	0.954
Recurrence rate (%)	9.2	11.7	0.199	0.656
Complication rate (%)	4.6	16.7	4.863	0.027
BREAST-Q satisfaction score	66.8±5.5	66.1±4.4	0.725	0.470
Breast cosmetic score	2.8±0.4	2.4±0.4	−5.793	<0.001

Quantitative variables are expressed as mean ± standard deviation. MWA, microwave ablation.

Table 4 Results of multivariable ordinal logistic regression for predicting complication risk

Predictor Variable	β	SE	Z	Wald χ^2	P value	OR	95% CI
Therapy method	−3.647	1.282	−2.845	8.097	0.004	0.026	0.002–0.321
Lesion distribution	0.945	0.697	1.357	1.840	0.175	2.572	0.657–10.075
Lesion location	−0.880	1.232	−0.714	0.510	0.475	0.415	0.037–4.638
Maximum diameter	−0.005	0.044	−0.114	0.013	0.909	0.995	0.913–1.085
Lesion number	−0.166	0.418	−0.396	0.157	0.692	0.847	0.373–1.924
Breast cosmetic score	3.325	1.114	2.985	8.910	0.003	27.799	3.132–246.700
Skin involvement	1.412	0.869	1.625	2.642	0.104	4.103	0.748–22.513
Abscess formation	0.328	0.988	0.332	0.110	0.740	1.388	0.200–9.626

CI, confidence interval; OR, odds ratio; SE, standard error.

significantly better in the MWA group compared to the surgical group (P<0.001).

Multivariable logistic regression analysis for predicting cure rates, recurrence rate, and complications

The results showed that therapy method (MWA or surgery) and breast cosmetic score were significantly associated with complication rate (P<0.05). Lesion distribution was significantly associated with recurrence rate (P<0.05). No association was found between treatment method and cure/recurrence rates (both P>0.05) (see *Tables 3-6* for details).

Discussion

The findings of this study demonstrate that ultrasound-guided MWA outperforms surgery in several key aspects, including operation time, IBL, postoperative pain levels, and length of hospital stay. Moreover, the cure rate and recurrence rate achieved with MWA are equivalent to those obtained with surgical intervention, whereas the incidence of complications is notably lower. These outcomes align with the literature, supporting the safety and efficacy of MWA in treating IGM (20). The favorable ablation outcomes may be attributed to the following factors: Firstly, effectiveness of MWA. MWA works by inducing thermal coagulation necrosis of the lesion tissue through microwave energy, achieving the therapeutic goal. Numerous studies have established that thermal ablation techniques, including MWA, yield comparable outcomes to surgical treatment in managing breast and thyroid tumors (16-20). Secondly, benefits of ultrasound guidance. Ultrasound guidance facilitates precise lesion localization and monitoring, enabling the avoidance of major blood vessels and the delineation of the ablation area and treatment plan. Real-time monitoring during the procedure ensures thorough and targeted ablation. Thirdly, detection and treatment of occult lesions. Given the intricate branching pattern of the breast ducts and the multifocal nature of IGM lesions, ultrasound guidance and intraoperative imaging

Table 5 Results of multivariable ordinal logistic regression for predicting recurrence risk

Predictor variable	β	SE	Z	Wald χ^2	P value	OR	95% CI
Therapy method	−1.110	0.995	−1.116	1.245	0.264	0.330	0.047–2.315
Lesion distribution	2.150	0.937	2.294	5.262	0.022	8.581	1.368–53.581
Lesion location	−0.285	1.135	−0.251	0.063	0.802	0.752	0.081–6.955
Maximum diameter	0.000	0.037	0.003	0.000	0.998	1.000	0.930–1.075
Lesion number	−0.237	0.454	−0.523	0.274	0.6001	0.789	0.324–1.919
Breast cosmetic score	0.687	0.863	0.796	0.634	0.426	1.988	0.366–10.787
Skin involvement	0.670	0.804	0.834	0.696	0.404	1.955	0.405–9.449
Abscess formation	0.717	0.835	0.858	0.737	0.391	2.048	0.398–10.533

CI, confidence interval; OR, odds ratio; SE, standard error.

Table 6 Results of multivariable ordinal logistic regression for predicting cure rate

Predictor variable	β	SE	Z	Wald χ^2	P value	OR	95% CI
Therapy method	−3.429	5.457	−0.628	0.395	0.530	0.032	0.000–1,431.535
Lesion distribution	−1.756	2.349	−0.747	0.558	0.455	0.173	0.002–17.274
Maximum diameter	−0.347	0.331	−1.048	1.098	0.295	0.707	0.369–1.353
Lesion number	0.564	1.796	0.314	0.099	0.753	1.758	0.052–59.378
Breast cosmetic score	2.013	3.991	0.504	0.254	0.614	7.484	0.003–18,690.843
Skin involvement	1.860	4.835	0.385	0.148	0.700	6.426	0.000–83,790.729
Abscess formation	3.927	3.571	1.100	1.209	0.271	50.759	0.046–55,608.232

CI, confidence interval; OR, odds ratio; SE, standard error.

allow for the timely identification and treatment of occult lesions. In conclusion, ultrasound-guided MWA offers a safe and effective alternative treatment modality for IGM, with outcomes comparable to those of traditional surgical approaches. This minimally invasive technique preserves breast aesthetics and function, thereby enhancing patient satisfaction. MWA represents a promising option for patients requiring treatment for IGM.

The results of this study demonstrated that ultrasound-guided MWA treatment offers fewer complications and superior cosmetic outcomes compared to traditional surgical approaches. These advantages may be attributed to several factors: Firstly, MWA is minimally invasive, requiring only ultrasound-guided percutaneous insertion of the MWA needle without the need for skin incisions or excision of breast tissue, thus minimizing impact on breast morphology. Secondly, the procedure is characterized by a shorter operating time, reduced IBL, lower postoperative pain, and faster patient recovery. Additionally, the use of glucose-water isolation technology during MWA effectively isolates the skin, areola, and retro-mammary space, thereby decreasing the incidence of complications. Lastly, the treatment is reproducible, allowing for retreatment of recurrent or residual lesions if necessary.

The MWA, radiofrequency ablation, and cryoablation demonstrate distinct technical and clinical characteristics. MWA generates heat through dielectric hysteresis by inducing rapid oscillation of water molecules under electromagnetic fields, offering superior advantages including a broader ablation zone and minimal heat-sink effect, making it particularly suitable for hypervascular inflammatory lesions. Its capability for simultaneous multi-probe deployment ensures efficient treatment of irregularly shaped pathologies (20). In contrast, radiofrequency ablation relies on frictional heating from alternating electrical currents, resulting in relatively constrained ablation volumes with compromised efficacy in fibrotic tissues and near major vasculature due to impedance limitations (24). Cryoablation induces cellular destruction through rapid freeze-thaw cycles, achieving precise margin control while potentially leaving residual inflammatory tissue untreated and frequently causing significant post-procedural edema (25). Collectively, MWA emerges as the promising modality for diffuse inflammatory conditions, owing to its exceptional tissue penetration depth and consistent thermal distribution profile that ensure reliable therapeutic outcomes.

Notwithstanding these benefits, ultrasound-guided MWA does have limitations. For instance, there is a risk of incomplete ablation in cases involving larger or deeper lesions. Moreover, the technique demands a high level of skill from the operator, including proficiency in ultrasound guidance and MWA. Furthermore, although surgical intervention and steroid therapy are commonly employed in the management of these conditions, related study has demonstrated that inflammation can resolve after treating hyperprolactinemia (26). Consequently, it is still important to explore the underlying causes of the condition to ensure comprehensive patient care.

Compared with surgery, MWA offers several advantages: less trauma, minimal impact on breast shape, and shorter operation time. Patients also show a greater willingness to participate in MWA compared to surgery. Therefore, based on the principle of beneficence and ethical principles, patients will be grouped according to their preferences. To mitigate potential confounding effects, we performed adjusted multivariable logistic regression analysis. The results demonstrated that the association between treatment modality and complication risk remained statistically significant after controlling for covariates [adjusted odds ratio (OR) =0.026, 95% confidence interval (CI): 0.002–0.321, P=0.004], indicating minimal confounding influence on this relationship.

Our study has several limitations that should be acknowledged. First, the homogeneity of our patient population in terms of racial/ethnic composition and regional healthcare practices may limit the extrapolation of findings to other demographic settings. Multicenter studies with diverse populations are needed to validate our results. Second, the non-randomized design and patient preference-based allocation may introduce selection bias, yet be mitigated by multivariate adjustment. Third, technical challenges in ablating complex lesions (e.g., multifocal or retroareolar) require specialized expertise that may not be universally available. Future multicenter studies should focus on the following: (I) establishing standardized MWA protocols for different lesion subtypes; and (II) conducting rigorous cost-effectiveness analyses comparing this approach with conventional medical therapies.

Conclusions

Ultrasound-guided MWA provides a safe and effective alternative for treating granulomatous mastitis, offering the advantages of minimal invasiveness and rapid recovery. However, strict control of indications is essential. Clinicians should carefully consider the pros and cons of different treatment modalities based on individual patient circumstances to select the most appropriate management strategy. Further large-scale, multicenter clinical trials are warranted to confirm the long-term efficacy of ultrasound-guided MWA.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-1856/rc

Data Sharing Statement: Available at https://qims.amegroups.com/article/view/10.21037/qims-24-1856/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1856/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. This study was approved by the Ethics Committee of Fujian Nan'an City Hospital (approval No. 2024045), and all patients provided written informed consent.

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