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Original Article

Clinical efficacy analysis of ultrasound-guided microwave ablation for nodular goiters

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Abstract: Purpose: To investigate the clinical efficacy and influence on thyroid function of ultrasound-guided microwave ablation (UGMWA) in patients with nodular goiter. Methods: A retrospective analysis was conducted on the clinical data of 162 patients with nodular goiter admitted to Beijing United Family Hospital and Beijing Tiantan Hospital, Capital Medical University from January 2021 to December 2022. According to the surgical treatment plan, they were divided into the control group (conventional surgical methods, n=78) and the experimental group (UGMWA, n=84). Thyroid function indicators, surgical time, visual analog scale (VAS) pain scores, complications, and cosmetic effects were compared between the two groups. Results: All patients recovered and were discharged after treatment. Three months postoperatively, both groups showed lower levels of free triiodothyronine (FT3) and free thyroxine (FT4) compared to pre-surgery levels, while levels of thyroid-stimulating hormone (TSH) were higher. However, compared with the control group, the experimental group had higher FT3 and FT4 levels and lower TSH levels (all $P < 0.05$). Additionally, patients in the experimental group had shorter surgical time, less intraoperative blood loss, and lower VAS pain scores than those in the control group. Moreover, the postoperative cosmetic effect scores were higher in the experimental group than in the control group (all $P < 0.05$). Finally, there was no statistically significant difference in the incidence of complications between the two groups ($P=0.523$). Conclusion: UGMWA for the treatment of nodular goiters can expedite surgical time, protect thyroid function, reduce postoperative pain scores, and improve cosmetic effects with certain safety.

Keywords: Nodular goiter, thyroid function, ultrasound-guided, clinical efficacy, cosmetic effects

Introduction

The thyroid is a crucial organ responsible for regulating metabolism, influencing heart rate, and controlling body temperature. However, thyroid nodules are prevalent, with more than half of the adult population affected, and this percentage is even higher in some regions [1-4]. This widespread prevalence has made thyroid nodules a significant public health concern that cannot be ignored.

Research has shown that thyroid nodules result from a combination of multiple factors, such as environment, lifestyle, and dietary habits. At present, surgery remains the primary treatment modality for thyroid nodules [6]. However, due to the thyroid's superficial location, postoperative wounds may affect the local aesthetics, especially in female patients. Microwave ablation (MVA) is a minimally invasive surgery that belongs to the category of thermal ablation. It involves inserting an ablation electrode into the target tissue precisely under ultrasound guidance. The microwave energy generated by electromagnetic waves induces cell degeneration and necrosis of the lesion, thereby eliminating the nodules. Additionally, it is less invasive and more aesthetically pleasing, satisfying the aesthetic demands of some patients. Recently, ultrasound-guided microwave ablation (UGMWA) has been increasingly used in the treatment of nodular goiters and has achieved good clinical outcomes. However, existing studies are limited to single-indicator studies, making it difficult to comprehensively evaluate the clinical efficacy of minimally invasive techniques for treating thyroid nodules [7, 8]. Therefore, this study aims to explore the

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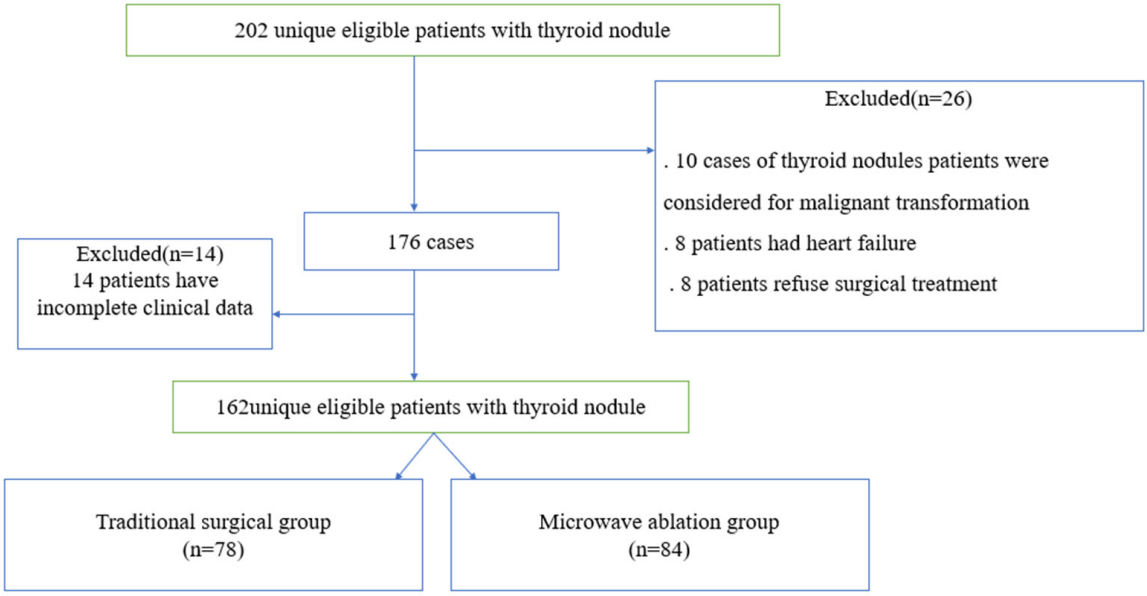

Figure 1. Flowchart of patient inclusion.

clinical effectiveness of UGMWA in patients with nodular goiters, intending to provide more evidence-based guidance for clinical treatment decisions.

Materials and methods

General information

A retrospective analysis was conducted on the clinical data of 162 patients with nodular goiters admitted to *Beijing United Family Hospital and Beijing Tiantan Hospital, Capital Medical University,* from January 2022 to December 2023. Patients were free to choose the treatment option, surgery or UGMVA, after hearing a full standardized explanation from the doctors. Based on their treatment, the patients were divided into a control group (conventional surgical methods, n=78) and an experimental group (UGMVA, n=84), and the flowchart of patient inclusion is shown in **Figure 1**. This study was approved by the Beijing United Family Hospital and Beijing Tiantan Hospital, Capital Medical University's ethics committee (Approval Number: BJUEC2024-03-015-K15).

Inclusion criteria: 1. Age > 18 years old; 2. No history of neck surgery; 3. Meeting the relevant diagnostic criteria for nodular goiter; 4. Unilateral nodular goiter; 5. Histopathologically diagnosed as benign lesions. Exclusion criteria: 1. Preoperative surgical contraindications, such as coagulation abnormalities; 2. Consideration of malignant lesions; 3. Impaired cardiopulmonary function; 4. Presence with psychiatric disorders or other conditions that impede normal communication.

Sample size calculation

The sample size ratio of the two groups was designed as 1:1. This study utilized a parallel controlled design, with participants allocated to either the control group or the experimental group. A review of the literature on similar designs showed that the mean VAS score in the control group (μ1) is 5.7, and the mean VAS score in the experimental group (μ2) is 4.9, with a standard deviation (σ) of 1. Considering a 10% dropout rate, and assuming that the probability of a Type I error (α) in this study is 0.05, and that the power of the study (1-β) is 80%, the sample size required for this study was estimated using the following formula:

$$n1 = n2 = \frac{2(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times \sigma^2}{(\mu 1 - \mu 2)^2}$$

Then by substituting the above values in the formula with μ1 of 5.7, μ2 of 4.9, σ of 1, α of 0.05, and β of 0.2, the final sample size was calculated to be approximately 25 subjects for each group. Therefore, all 162 patients were

enrolled to increase the reliability of the results of the study.

Methods

Patients in the control group underwent conventional chest circumferential incision. After general anesthesia, a 5.0 cm incision was made about 1 finger width above the suprasternal notch. After hemostasis, the thyroid gland was explored, and the extent of thyroidectomy was determined based on preoperative examination results. After completion of the surgery and hemostasis, patients were transferred to the anesthesia recovery room and then to the general ward after they regained consciousness.

Patients in the experimental group underwent microwave ablation for thyroid goiter. The equipment used included a high-frequency microwave ablation machine, thyroid microwave ablation needles, and a Philips four-dimensional ultrasound diagnostic instrument. Patients were placed in a supine position with shoulder pads and head tilted back on the operating table. The procedure began with routine disinfection, followed by towel spreading and the administration of local anaesthesia with 2% lidocaine. Under ultrasound guidance, the perithyroidal area was infiltrated with anesthesia. During this progress, attention was paid to separating the thyroid gland from internal jugular vein, trachea, and recurrent laryngeal nerve.

A 0.1 cm incision was made in the affected area of the neck and a 14-16-gauge GS tissue biopsy needle was inserted to obtain the tissue for pathologic examination. Under ultrasound guidance, the ablation needle was precisely inserted into the thyroid nodule, and stepwise ablation by layer was performed from the lower and posterior margin toward the upper and anterior margin. The thermal power was set to 25-30 w (at a temperature of 80-100°C) [9, 10]. When microbubbles appeared within the nodule, the orientation of the needle tip was carefully adjusted to ensure complete ablation. For nodules with cystic component, the cystic fluid was thoroughly aspirated with a syringe before ablation. For cysts ≥ 3.5 cm in diameter, cyst fluid was extracted and replaced with anhydrous ethanol before microwave ablation. Immediately after ablation, contrast-enhanced ultrasound (CEUS) was performed to confirm complete nodal ablation.

Outcome measures

Primary outcome measures: The levels of free triiodothyronine (FT3), free thyroxine (FT4) and thyroid stimulating hormone (TSH) were recorded and compared between the two groups of patients before treatment (in the early morning on the day following admission) and three months after discharge. Specifically, 3 ml of fasting peripheral venous blood collected from patients in the early morning was centrifuged at a radius of 13.5 cm and 3,000 r/min for 12 min, and the serum was collected to determine the levels of FT3, TSH, and FT4 by chemiluminescent assay. The treatment effective rate = the number of (effective + improvement) cases/total cases × 100%.

Postoperative pain scores: The visual analog scale (VAS) was used to assess the patients' pain level on the first postoperative day. A higher score indicates a higher level of pain [11]. Cosmetic outcome assessment at six months and one year postoperatively: The Observer Scar Assessment Scale (OSAS) and the Patient Scar Assessment Scale (PSAS) were used to evaluate cosmetic outcomes, with total scores ranging from 5 to 50 and 6 to 60, respectively. The Vancouver Scar Scale (VSS) was also evaluated, with a total score ranging from 0 to 14. Lower scores on these scales indicate better cosmetic outcomes [12].

Secondary outcome measures: The intraoperative blood loss, operation time, hospital stay and complication rate of the two groups were recorded and counted. The complications in this study included neck discomfort, incision infection, recurrent laryngeal nerve injury and hypothyroidism during hospitalization.

Statistical analysis

SPSS 22.0 software was used for data analysis. The measurement data were expressed as mean ± SEM. T-test was used for comparison of the measurement data with normal distribution; specifically, paired sample T-test was used for intra-group comparison and independent sample T-test was used for inter-group comparison. Rank sum test (Mann-Whitney U) was used to compare data not normally distributed. The count data was expressed as a rate (%), and the comparison of the count data was performed using the χ^2 test. $P < 0.05$ indicated that the difference was statistically significant.

Table 1. Comparison of general data between the two groups

Group	Gender (male/female)	Age	BMI	Hypertension	Nodule diameter (cm)	Nodule location (left/right)	Ultrasonic TIRADS classification (I/II; III/IVa)	
Experimental group (n=84)	60/24	46.8±6.1	23.5±2.0	8	3.0±0.4	52/32	30/25	26/3
Control group (n=78)	58/20	45.2±6.0	24.0±1.8	5	2.9±0.5	46/30	28/22	24/4
t/χ^2	0.176	0.552	0.771	0.531	0.121	0.032	0.022	0.201
P	0.675	0.402	0.264	0.466	0.663	0.858	0.881	0.650

Table 2. Comparison of surgery-related indicators between the two groups

Group	Case (n)	Operation time (min)	Intraoperative blood loss (ml)	Length of hospital stay (d)
Experimental group	84	33.5±10.5	9.8±1.7	2.5±0.41
Control group	78	68.1±12.3	33.0±5.6	6.0±1.4
t	-	7.889	15.660	3.229
P	-	0.001	< 0.001	0.012

Results

Comparison of baseline data between the two groups

The results of this study showed no statistical significances in gender, age, body mass index (BMI), complications, and diameter, location and grade of the nodule between the two groups (all $P < 0.05$), as shown in **Table 1**.

Comparison of relevant intraoperative and postoperative data between the two groups

The results of this study showed that the operation time, intraoperative blood loss and hospital stay in the experimental group were significantly less than those in the control group (all $P < 0.05$, **Table 2**).

Comparison of treatment effectiveness and prognosis between the two groups

Patients in both groups were successfully discharged. The neck incisions resulting from different surgical methods are shown in **Figure 2**. In addition, the clinical treatment effectiveness of patients in the experimental group was higher than that of patients in the control group, as shown in **Table 3** and **Figure 3**.

Comparison of thyroid function indicators between the two groups before and three months after operation

There was no statistical difference in preoperative serum levels of TSH, FT4, and FT3 between the two groups. However, three months post-treatment, the levels of FT3 and FT4 in both groups decreased, while the level of TSH increased. Notably, compared with the control group, the experimental group exhibited significantly higher levels of FT3 and FT4, and lower level of TSH (all $P < 0.05$), as shown in **Figure 4**.

Comparison of postoperative pain scores between the two groups

The results of this study showed that the postoperative VAS score of the experimental group was significantly lower than that of the control group ($P < 0.05$, **Figure 5**).

Comparison of postoperative cosmetic scores between the two groups of patients

The results showed that the cosmetic score, including OSAS, PSAS, and VSS scores, of the experimental group were higher than those of the control group at six months and one year after surgery (all $P < 0.05$), as shown in **Figure 6**.

Comparison of surgical complications between the two groups

The results showed that there was no statistical difference in the incidence of complications between the two groups, as shown in **Table 4**.

Discussion

When the size of the thyroid gland exceeds the normal range, it can lead to a benign condition

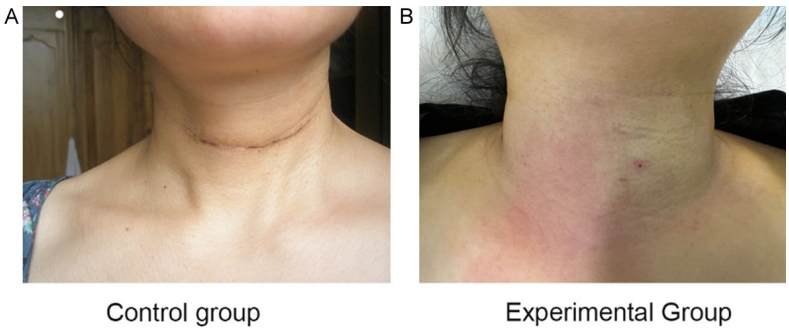

Figure 2. Neck incisions of different surgical methods. A: Traditional surgical incision; B: UGMVA incision.

Table 3. Comparison of clinical treatment effectiveness between the two groups

Group	Cure	Effective	Improvement	Invalid	Total Effective Rate
Experimental group (n=84)	48	24	8	4	80/84
Control group (n=78)	34	26	7	11	67/78
X^2			4.200		
P			0.040		

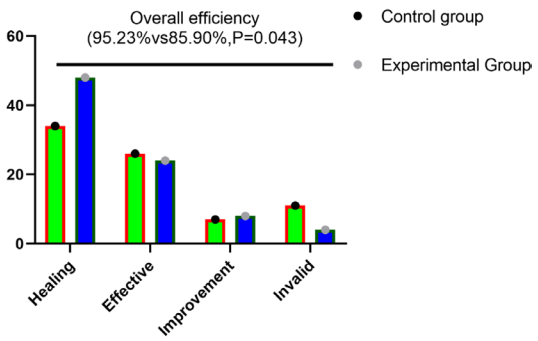

Figure 3. Comparison of treatment effectiveness between the two groups.

known as thyroid goiter. Various factors can cause thyroid goiters, including inadequate iodine intake, genetic factors, autoimmune diseases, and side effects of certain medications [13, 14]. Clinically, patients may present with no symptoms, while some may experience discomfort in the neck, difficulty swallowing, and shortness of breath. To reduce the potential manifestations of hyperthyroidism caused by excessive thyroid hormone production, patients often prefer the removal of thyroid goiter. However, traditional surgical excision has been associated with thyroid damage, leading to hypothyroidism. Besides, surgical incision scars are linked to psychological burden in female patients, affecting their quality of life [15].

Recently, UGMVA for thyroid nodules has been gradually applied in clinical practice due to its minimal trauma and aesthetic advantages. It has also achieved good clinical outcome while reducing damage to the thyroid functionally. In this study, despite certain thyroid function impairments in both groups after surgical treatment (TSH levels significantly increased, while FT4 and FT3 levels decreased), patients in the ablation group exhibited better thyroid function than those in the conventional surgery group. Possible mechanisms for these observations are as follows: Microwave ablation is a minimally invasive treatment method that uses microwave technology to target thyroid nodules. The process involves biologically active molecules within the nodules, such as negatively charged proteins, nucleic acids, and colloidal particles. These molecules interact with trace particles, generating high-frequency vibrations under the magnetic field. This vibration produces significant heat, raising the temperature of thyroid tissue and cells. The resulting heat destroys the targeted thyroid tissue while preserving overall thyroid function as much as possible. Similar research findings have been reported in previous studies [16-18]. Additionally, the results of this study showed that patients in the experimental group had significantly shorter operation duration and intraoperative blood loss compared to those in the control group. This suggests a lower degree of surgical stress in the experimental group, reducing the extent of inflammatory response in the body, which also contributes to the protection of thyroid function, consistent with previous research reports [19-21].

With the development of technology and social progress, the definition of beauty is constantly

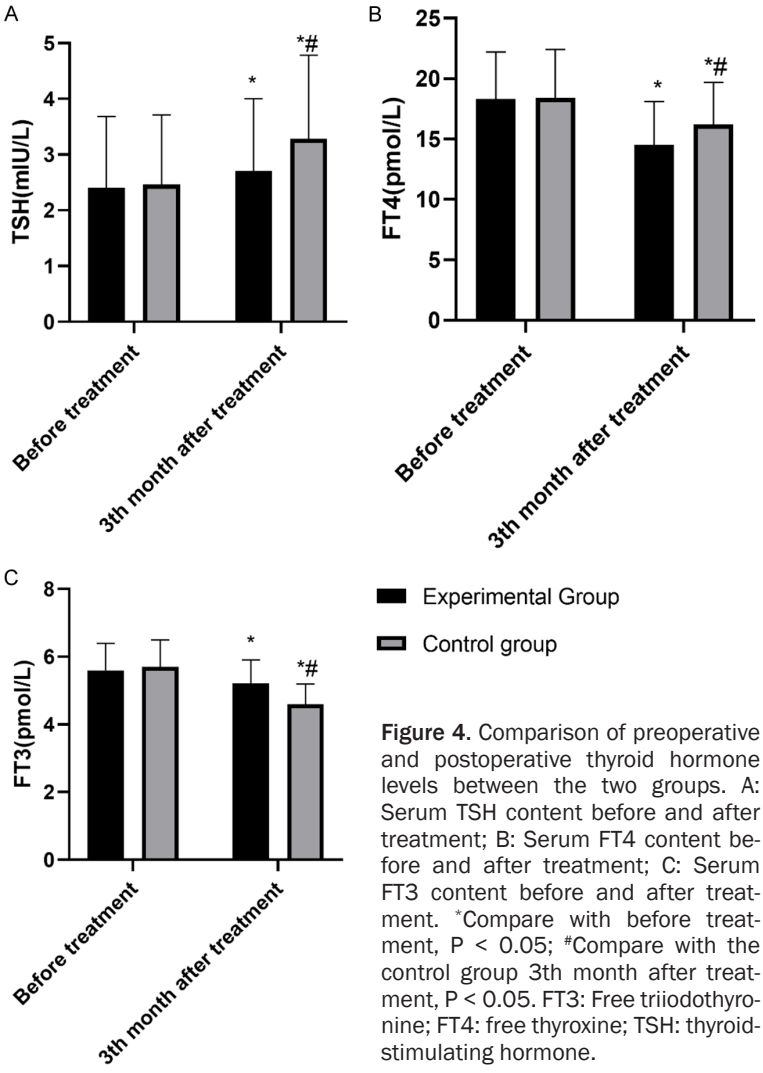

Figure 4. Comparison of preoperative and postoperative thyroid hormone levels between the two groups. A: Serum TSH content before and after treatment; B: Serum FT4 content before and after treatment; C: Serum FT3 content before and after treatment. *Compare with before treatment, $P < 0.05$; #Compare with the control group 3th month after treatment, $P < 0.05$. FT3: Free triiodothyronine; FT4: free thyroxine; TSH: thyroid-stimulating hormone.

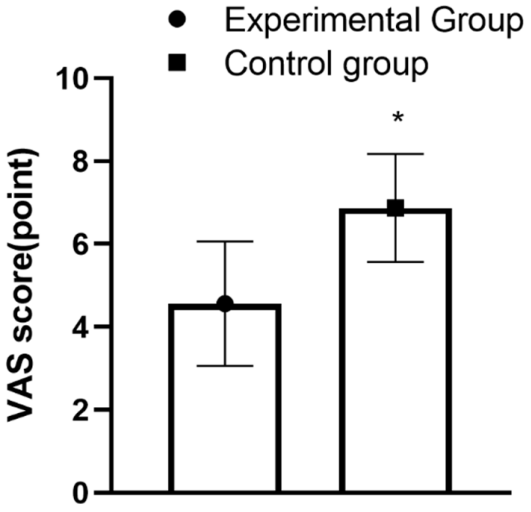

Figure 5. Comparison of pain scores between the two groups after treatment. *Compare with the experimental group, $P < 0.05$. VAS: Visual Analog Scale.

evolving, leading to the emergence of various cosmetic techniques and methods. The results of this study showed that the OSAS, PSAS and VSS scores of the ablation group were better than those of the control group, confirming that minimally invasive procedures can meet the patients' requirements for incisional aesthetics. Incisional cosmetics, as a method of surgically improving people's appearance, is increasingly being favored, gradually becoming a major component of healthcare service demands. The incision cosmetic score is a quantitative method used to assess the effectiveness of aesthetic surgery. It involves not only the degree of improvement in appearance after surgery, but also includes several aspects such as safety during the procedure, comfort during the recovery period, and durability of the surgical results. The degree of improvement in appearance is undoubtedly the most visual and valued aspect of incisional cosmetic scoring. People often visualize the change in appearance by comparing pre- and post-surgery photos.

The ablation procedure requires only a puncture needle, eliminating the need for additional incisions and thereby meeting patients' cosmetic preference, which is in full agreement with the findings of previous studies [22, 23]. At the same time, postoperative pain scores in the experimental group were lower than those in the control group, further confirming that minimally invasive incisions can reduce postoperative pain, enhance patients' comfort, and reduce discomfort in the neck. The results of this study also showed a trend of less neck discomfort in the experimental group compared to the control group, although there was no statistical difference, which may be related to the smaller sample size. Additionally, there were no

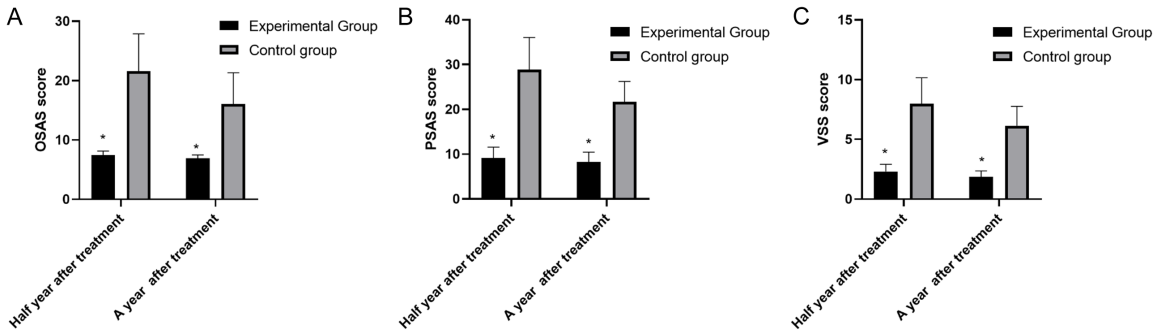

Figure 6. Comparison of cosmetic scores between the two groups of patients six months and one year after treatment. A: Cosmetic OSAS score; B: Cosmetic PSAS score; C: Cosmetic VSS score. *Compare with the control group, $P < 0.05$. OSAS: Observer Scar Assessment Scale; PSAS: Patient Scar Assessment Scale; VSS: Vancouver Scar Scale.

Table 4. Comparison of complications between the two groups

Group	Neck discomfort	Thyroid function impairment	Nerve injury	Incision infection	Total
Experimental group (n=84)	1	3	2	0	6
Control group (n=78)	5	2	1	1	9
χ^2			0.930		
P			0.335		

significant statistical differences in other complications, further reinforcing the conclusion that minimally invasive ablation procedures are highly safe [24, 25].

In summary, ultrasound-guided microwave ablation therapy for nodular goiters can expedite surgical procedures, protect patients' thyroid function, reduce postoperative pain, and enhance patients' aesthetic satisfaction, all while maintaining a high level of safety, making it worthy of clinical recommendation. However, this study is a single-center study with a limited number of subjects, and further large-scale, multicenter studies are needed to validate the clinical efficacy of ultrasound-guided minimally invasive ablation therapy for nodular goiters. Additionally, the inclusion of more objective serum indicators to evaluate the ablation effect would strengthen the conclusions of this study.

Disclosure of conflict of interest

None.

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