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Efficacy and Safety of Robot-Assisted Thyroidectomies: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: During the past few decades, robot-assisted surgeries in advanced medical fields have become very significant with respect to safety and efficacy as compared to conventional therapies. Various types of advanced robotic thyroidectomies are successfully performed worldwide. This systematic review and meta-analysis set out to assess the safety and efficacy of different robotic thyroidectomies compared with conventional procedures.

Methods: Data were collected by searching different databases from 2010 to 2024, and after screening, two randomized controlled trials and 11 observational studies were selected for review. A total of 2,123 patients were involved across all studies, and data were collected according to outcomes of interest. Risk-of-bias assessment was performed using the Cochrane tool and the Newcastle-Ottawa Scale. Subgroup analyses were also conducted among different robotic approaches.

Results: The primary outcomes of operation time and blood loss showed significant differences between all robotic thyroidectomy (RT) and conventional thyroidectomy (CT) groups, while other outcomes—length of hospital stay and pain parameters—showed no significant difference between RT and CT procedures.

Conclusion: Robot-assisted procedures are a comparable alternative to conventional therapies, as there is no significant difference between their outcomes with respect to safety and efficacy, along with satisfactory results regarding cosmetic scarring.

Keywords: Robotic Thyroidectomy; Conventional Thyroidectomy; Bilateral Axillo-Breast Approach; Transaxillary; Transoral; Facelift Approach.

INTRODUCTION

One of the most common endocrine surgeries practiced globally is the surgical excision of the thyroid gland, known as thyroidectomy [1], which is widely performed in the treatment of benign thyroid syndromes, thyroid cancers, and other thyroid-related disorders. Conventionally, open surgery frequently results in a noticeable neck scar, which may compromise quality of life, particularly for young patients and those concerned about their appearance. In recent years, advances in surgical techniques have led to the development of minimally invasive approaches, including robotic-assisted thyroidectomy (RAT), which offers improved cosmetic and functional outcomes.

Using robotic devices such as the da Vinci Surgical System, healthcare professionals can carry out robotic-assisted thyroidectomy through remote incisions, without prominent neck scarring [2]. This technique provides several potential advantages over conventional approaches, including higher accuracy through the use of robotic arms, greater proficiency, and improved perspective through three-dimensional imaging. By reducing recovery time and visible scarring, the ability to conduct the surgical procedure through small, remote incisions has significantly improved patient satisfaction [1, 3].

With the objective of preventing visible scarring and maximizing surgical safety and precision, there are four different robotic thyroidectomy approaches. Transaxillary robotic thyroidectomy (TART), the most prevalent robotic thyroidectomy methodology, works most effectively for patients with small to moderately large thyroid nodules, as it involves an incision in the axilla, enabling access to the thyroid gland without a noticeable scar on the neck [4]. Similarly, the retroauricular or facelift approach, sometimes referred to as the “face-lift” or “post-auricular” approach, is an appealing aesthetic procedure most appropriate for patients who value appearance; it requires an incision behind the ear, concealed within the hairline [5]. Through the oral cavity, the thyroid gland is accessible during transoral robotic thyroidectomy (TORT), which leaves no obvious external scar. Collectively, these robotic methods increase the safety, precision, and aesthetics of thyroid surgery. The bilateral axillo-breast approach (BABA) uses incisions in both the breast region and the axillae to provide a wide surgical field, which is advantageous when managing larger thyroid nodules or performing total thyroidectomy while maintaining excellent cosmetic outcomes [6, 7]. Each technique has distinct benefits, and selection depends on patient anatomy, thyroid disease characteristics, and surgeon expertise.

Despite the favourable results from robotic-assisted thyroidectomy, concerns remain regarding its affordability, safety, and reliability. It is necessary to address concerns about long-term outcomes, oncological safety, and the risk of complications. Furthermore, debate continues over the widespread implementation of robotic procedures due to their greater cost and longer learning curve. Thus, by examining its clinical outcomes, comparing it with traditional techniques, and investigating its position within modern thyroid surgery, this paper aims to evaluate the effectiveness and safety of robotic-assisted thyroidectomy. By addressing these factors, we hope to provide valuable insights into the potential of this innovative technique to transform thyroid surgery practice.

METHODS

Search Strategy

Randomized controlled trials (RCTs) and observational studies were searched using databases including PubMed, Cochrane Library, and Google Scholar. The search keywords were *“robotics”, “thyroidectomy”, “bilateral axillo-breast approach”, “transaxillary”, “transoral”* and *“facelifting”*. Additional inclusion criteria comprised studies published in English from 2010–2024, focusing on populations with clear reporting of the outcomes of interest.

Inclusion and Exclusion Criteria

Using the inclusion and exclusion criteria, one author reviewed all article titles and abstracts to filter out unrelated research. The inclusion criteria were as follows: (1) studies written in English; (2) comparative studies among BABA, TO, TA, FL, and CT; and (3) studies reporting at least one outcome of interest.

Where two studies were published by the same researcher or organization, the more recent or superior publication was selected. Studies were excluded if they were (1) case reports, reviews, editorials, or expert opinions; (2) not original articles; or (3) preclinical studies.

Data Extraction

Two authors independently extracted the following parameters from each study: (1) study characteristics (first author, year of publication, country, and number of patients); (2) study population characteristics (sex, mean age, and mean tumour size); (3) surgical primary and secondary outcomes (operative time, hospital stay, blood loss, pain score, and infection); (4) results as mean and standard deviation for the above outcomes; and (5) intervention and comparison group data.

Quality Assessment

Risk-of-bias assessment was conducted independently on all included studies (n = 13) using the Cochrane risk-of-bias tool for randomized controlled trials and the Newcastle-Ottawa Scale for observational studies. Using these tools, we evaluated bias domains including blinding of participants and personnel, randomization process, allocation concealment, incomplete outcome data, selective reporting, and other sources of bias. The final risk-of-bias evaluation provided a strong basis for determining the validity of this study.

Statistical Analysis

The meta-analysis was performed using RevMan software, version 5.4 (Cochrane Collaboration, Oxford, UK). For continuous variables, weighted mean differences (WMDs) and odds ratios (ORs) were calculated and reported with 95% confidence intervals (CIs). Results were aggregated and analyzed using a random-effects model when statistical heterogeneity existed (χ^2 test $p \leq 0.1$) and a fixed-effects model where the χ^2 test $p > 0.1$. Heterogeneity between studies was evaluated using the χ^2 and I^2 tests; heterogeneity was considered present if $I^2 > 50\%$ and the χ^2 test $p \leq 0.1$.

RESULTS

A total of 139 publications were identified after the initial database search. Among these, 25 duplicates were removed. After screening all titles, abstracts, and full texts as necessary, 13 studies were included in this meta-analysis (**Fig. 1**). Comparing all robotic thyroidectomies with conventional thyroidectomy, two articles related to the facelift technique, five to the transaxillary approach, six compared BABA with conventional thyroidectomy, and one study addressed transoral thyroidectomy.

Outcomes

Robot-assisted and conventional thyroidectomy showed no significant differences across most primary and secondary outcomes (**Table 2**). No single approach demonstrated clear superiority over the others, though all are equally practical approaches in the treatment of thyroid tumours or cancers. The pooled effect for operation time was MD = 45.02 (95% CI: 41.67, 48.37; $p < 0.00001$), favouring CT, with high heterogeneity ($I^2 = 99\%$); the pooled effect for blood loss was MD = –0.60 (95% CI: –1.32, 0.12; $p < 0.00001$), with significant heterogeneity ($I^2 = 96\%$) (Fig. 4, Fig. 5, respectively). Six studies reported data on length of hospital stay, with a non-significant pooled effect of MD = 0.03 (95% CI: –0.11, 0.17; $p = 0.65$) and moderate heterogeneity ($I^2 = 49\%$) (Fig. 6). Similarly, three studies reported pain data, with a pooled effect of MD = 0.98 (95% CI: 0.73, 1.23; $p < 0.00001$) and the highest heterogeneity among all outcomes ($I^2 = 99\%$) (Fig. 7).

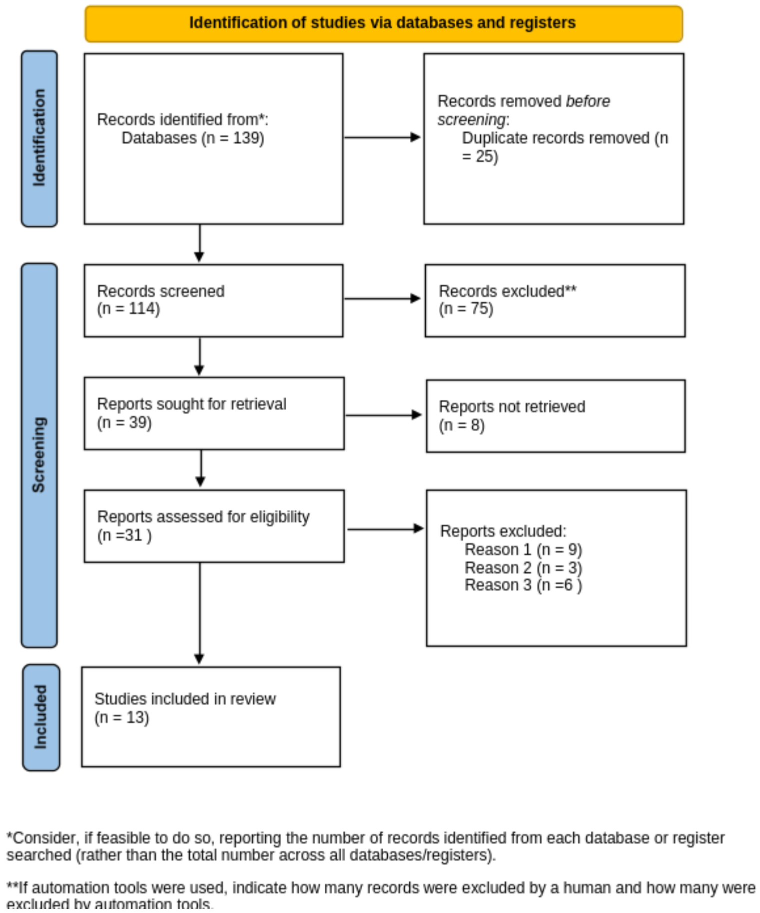

Fig. 1. PRISMA flow diagram for study selection.

Subgroup Analysis

In subgroup analysis, we compared all robotic thyroidectomies with one another to analyze the safety and efficacy of the more potent robotic procedures. For operation time, a significant difference was present among the BABA, TA, and FL robotic approaches, with pooled data of MD = 44.87 (95% CI: 41.46, 48.28; $p < 0.00001$) and high heterogeneity ($I^2 = 96.9\%$) (Fig. 8). Subgroup analysis for total blood loss among the surgeries (BABA, TA, FL) also showed significant differences, MD = –0.62 (95% CI: –1.34, 0.10; $p < 0.00001$), with high heterogeneity ($I^2 = 98.7\%$) (Fig. 9). For length of hospitalization, pooled data for BABA and TA showed no significant difference, MD = 0.03 (95% CI: –0.11, 0.17; p = 0.99), with 0% heterogeneity (Fig. 10). For pain, the BABA and TO approaches were compared and showed a significant difference, MD = 0.85 (95% CI: 0.67, 1.03; p = 0.04), with moderate heterogeneity ($I^2 = 76.4\%$) (Fig. 11).

Risk of Bias Assessment

After completing risk-of-bias assessment using the Cochrane tool and the Newcastle-Ottawa Scale, the two RCTs showed some concerns regarding bias, whereas all observational studies exhibited a low risk of bias upon evaluation (Fig. 2, Fig. 3; **Table 1**).

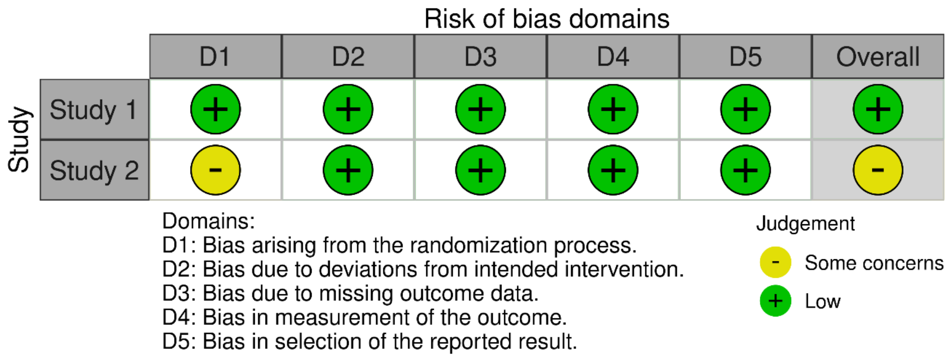

Fig. 2. Risk-of-bias traffic-light plot (Cochrane RoB 2 tool, randomized controlled trials).

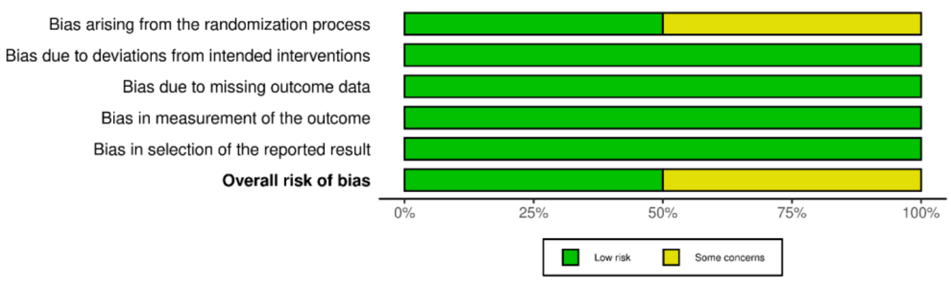

Fig. 3. Risk-of-bias summary plot (Cochrane RoB 2 tool, randomized controlled trials).

Table 1. Risk-of-bias assessment of observational studies by the Newcastle-Ottawa Scale.

Study	Selection	Comparability	Outcome
Yong Hee et al., 2015	★★★★	★	★★★
Tsung-Jung Liang et al., 2021	★★★★	★★	★★★
Hyungju Kwon et al., 2016	★★★★	★	★★★
Wan Wook Kim MD et al., 2018	★★★★	★★	★★★
J. Lee, MD et al., 2011	★★★★	★★	★★★
Doh Young Lee et al., 2015	★★★★	★★	★★★
Kyung Tae MD et al., 2019	★★★★	★★	★★★
Dong Won Lee et al., 2019	★★★★	★	★★★
Gabriele Materazzi et al., 2014	★★★★	★★	★★★

★ indicates one star awarded under Newcastle-Ottawa Scale domains for selection, comparability, and outcome assessment for cohort studies.

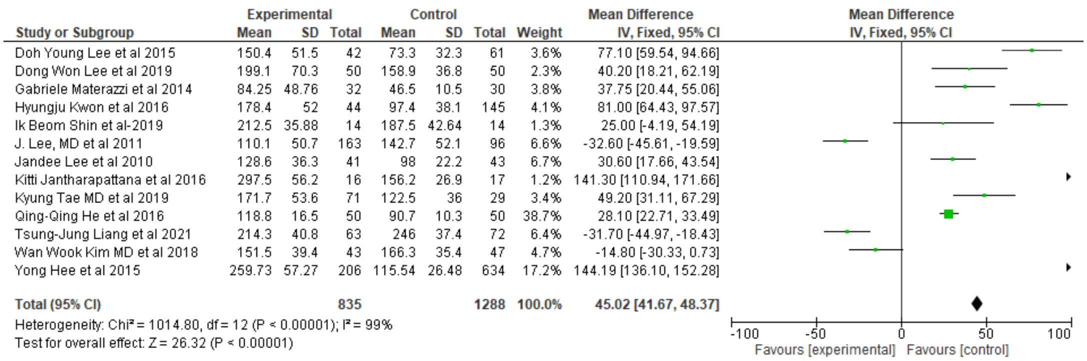

Fig. 4. Forest plot for comparison of robotic and conventional technique for operation time.

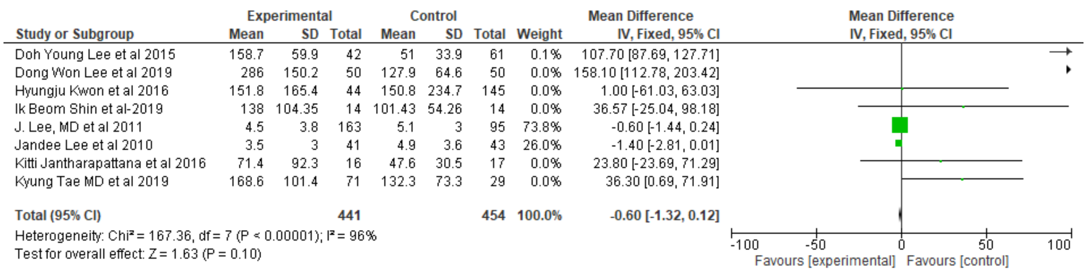

Fig. 5. Forest plot for comparison of robotic and conventional technique for blood loss.

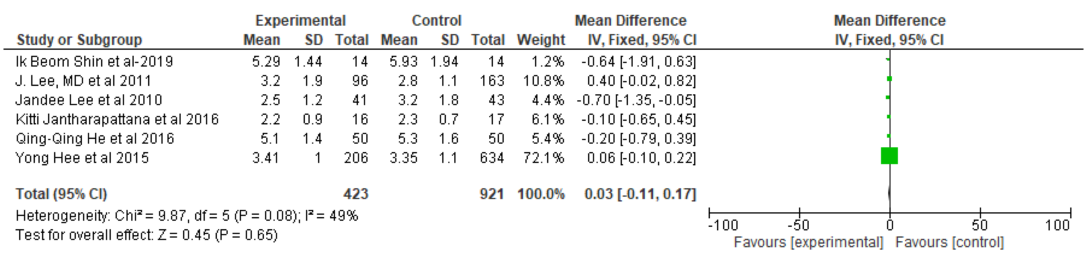

Fig. 6. Forest plot for comparison of robotic and conventional technique for length of stay.

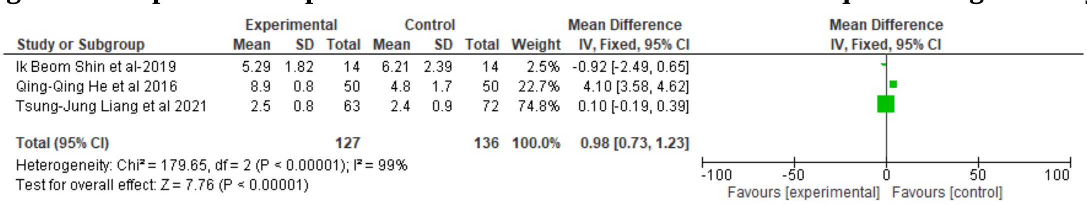

Fig. 7. Forest plot for comparison of robotic and conventional technique for pain.

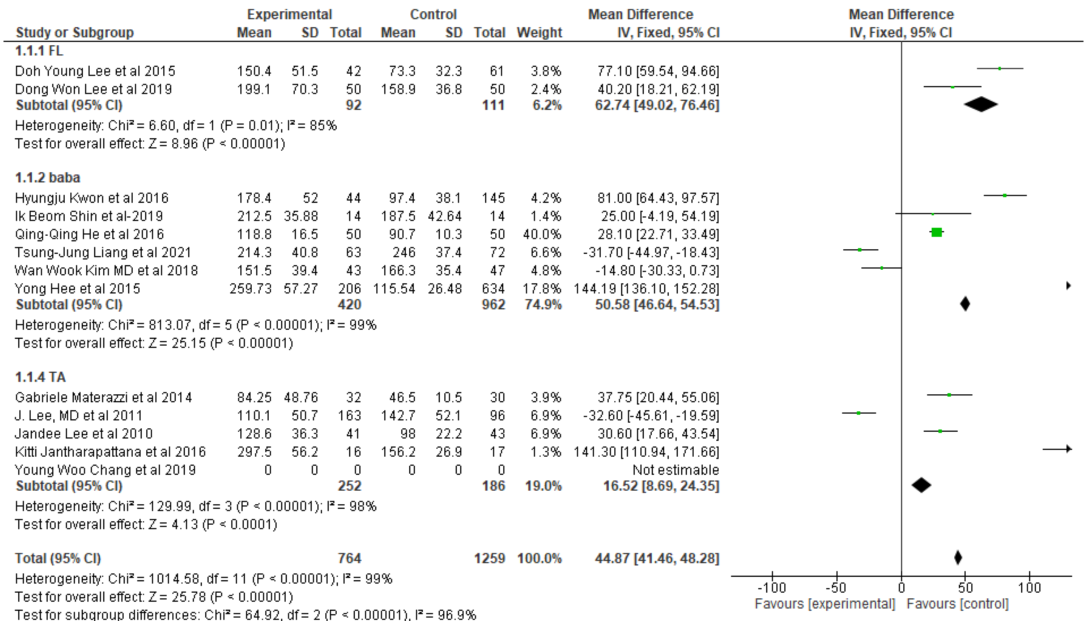

Fig. 8. Forest plot of subgroup analysis for operation time.

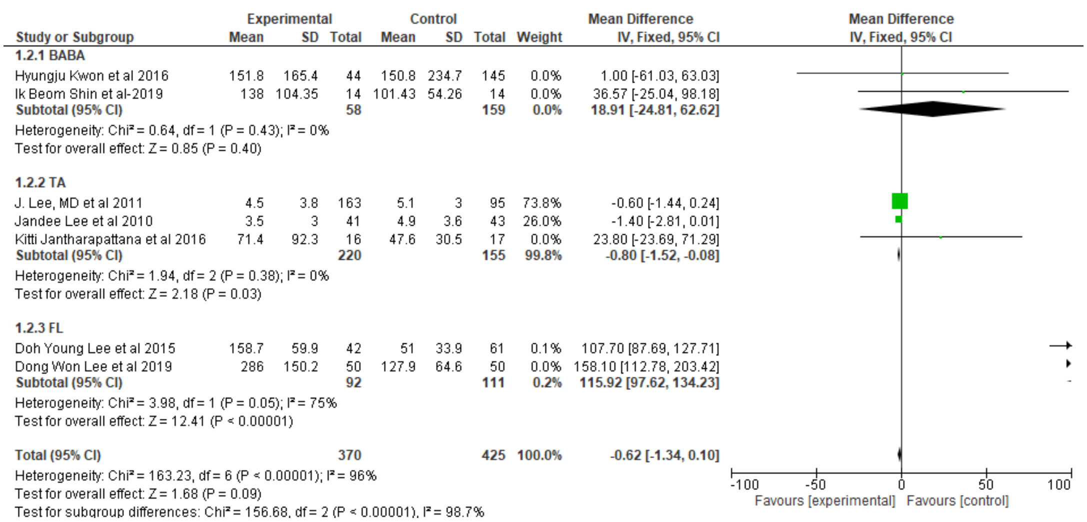

Fig. 9. Forest plot of subgroup analysis for blood loss.

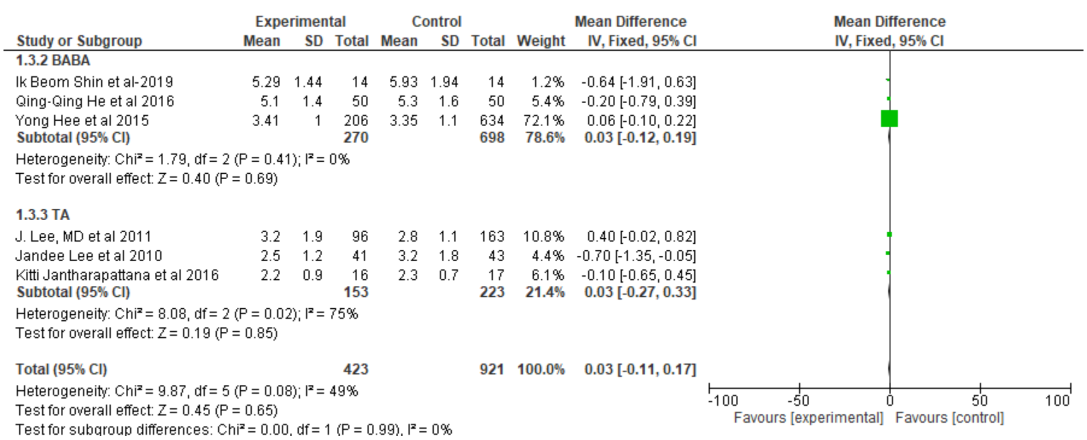

Fig. 10. Forest plot of subgroup analysis for length of hospital stay.

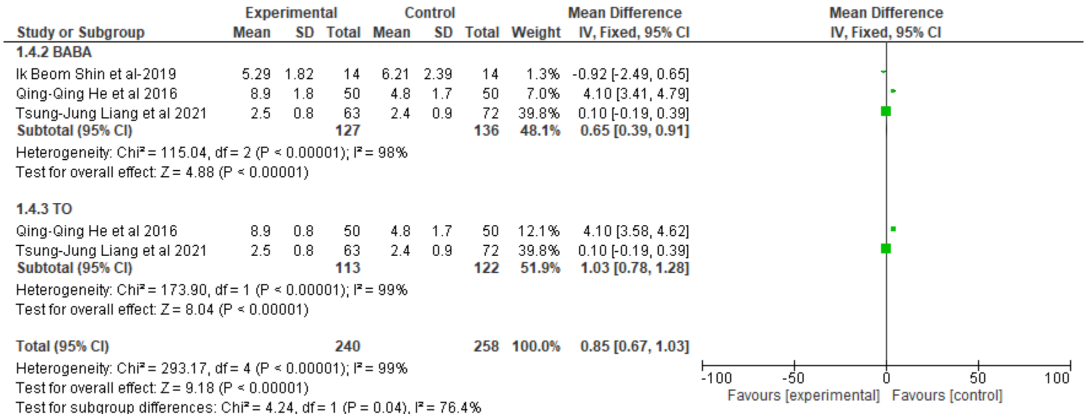

Fig. 11. Forest plot of subgroup analysis for pain.

Table 2. Results for outcomes.

Study	Outcome	Control (M±SD)	n	Intervention 1 (M±SD)	n	Intervention 2 (M±SD)	n
Ik Beom Shin et al., 2020 [8]	Operation time	187.50±42.64	14	212.50±35.88	14		
	Blood loss	101.43±54.26	14	138.00±104.35	14		
	Length of stay	5.93±1.94	14	5.29±1.44	14		
	Pain	6.21±2.39	14	5.29±1.82 (post-op 2h)	14		
Qing-Qing He et al., 2016 [9]	Operation time	90.7 ± 10.3	50	118.8 ± 16.5	50		
	Blood loss	<20	50	<20	50		
	Length of stay	5.3 ± 1.6	50	5.1 ± 1.4	50		
	Pain	4.8 ± 1.7	50	8.9 ± 0.8	50		
Yong Hee et al., 2015 [10]	Operation time	115.54± 26.48	634	259.73 ±57.27	206		
	Blood loss		634		206		
	Length of stay	3.35 ± 1.10	634	3.41± 1.00	206		
	Pain		634		206		
Tsung-Jung Liang et al., 2021 [11]	Operation time			BABA 214.3 ± 40.8	63	246.0 ± 37.4	72
	Blood loss			BABA 28.8 ± 55.8	63	24.8 ± 32.0	72
	Length of stay				63		72
	Pain			BABA 2.5 ± 0.8	63	2.4 ± 0.9	72
Hyungju Kwon et al., 2016 [12]	Operation time	97.4 ± 38.1	145	178.4 ± 52.0	44		
	Blood loss	150.8 ± 234.7	145	151.8 ± 165.4	44		

Study	Outcome	Control (M±SD)	n	Intervention 1 (M±SD)	n	Intervention 2 (M±SD)	n
	Length of stay	3.3 ± 0.7	145	3.4 ± 0.7	44		
	Pain		145		44		
Wan Wook Kim MD et al., 2018 [13]	Operation time			151.5 ± 39.4	43	166.3 ± 35.4	47
	Blood loss				43		47
	Length of stay				43		47
	Pain			4.1 ± 0.1	43	3.1 ± 0.2	47
Doh Young Lee et al., 2016 [14]	Operation time	74.3±32.3	61	150.4±51.5	42		
	Blood loss	51.0±33.9	61	158.7±59.9	42		
	Length of stay		61		42		
	Pain		61		42		
Kitti Jantharapattana et al., 2017 [15]	Operation time	156.2 ± 26.9	17	297.5 ± 56.2	16		
	Blood loss	47.6 ± 30.5	17	71.4 ± 92.3	16		
	Length of stay	2.3 ± 0.7	17	2.2 ± 0.9	16		
	Pain		17		16		
Gabriele Materazzi et al., 2014 [16]	Operation time	46.5 ± 10.5	30	84.25 ± 48.76	32		
	Blood loss		30		32		
	Length of stay	1.15 (1–3)	30	1.85 (1–4)	32		
	Pain		30		32		
Dong Won Lee et al., 2019 [17]	Operation time	158.9±36.8	50	199.1±70.3	50		
	Blood loss	127.9±64.6	50	286.0±150.2	50		
	Length of stay		50		50		
	Pain		50		50		
Kyung Tae MD et al., 2019 [18]	Operation time	122.5 ± 36.0	29	171.7 ± 53.6	71		
	Blood loss	132.3 ± 73.3	29	168.6 ± 101.4	71		
	Length of stay		29		71		
	Pain		29		71		
Jandee Lee et al., 2010 [19]	Operation time	98.0 ± 22.2	43	128.6 ± 36.3	41		
	Blood loss	4.9 ± 3.6	43	3.5 ± 3.0	41		
	Length of stay	3.2 ± 1.8	43	2.5 ± 1.2	41		
	Pain	5 (11.6%)	43	5 (12.2%)	41		

Study	Outcome	Control (M±SD)	n	Intervention 1 (M±SD)	n	Intervention 2 (M±SD)	n
J. Lee, MD et al., 2011 [20]	Operation time	142.7 ± 52.1	96	110.1 ± 50.7	163		
	Blood loss	5.1 ± 3.0	96	4.5 ± 3.8	163		
	Length of stay	3.2 ± 1.9	96	2.8 ± 1.1	163		
	Pain		96		163		

M±SD: mean ± standard deviation; n: number of participants; BABA: bilateral axillo-breast approach.

Table 3. Results of data extraction from selected studies.

Study	Study Design	Country	Enrollment Criteria	Exclusion Criteria	N	Blinding	Age (Mean/Median)	Intervention	Comparison	Primary Outcome	Secondary Outcome	Results
Ik Beom Shin et al-2020 [8]	Prospective RCT	Korea	Age 19–69 years	History of head-and-neck surgery, history of radiotherapy or scheduled for radiotherapy, scheduled for lateral neck lymph node dissection, pregnant	28	Double blind	19–69 years	BABA RoT with CO_2 insufflation; gasless BABA RoT using a suture-based flap elevation method	Conventional BABA RoT with CO_2 insufflation vs gasless BABA RoT with new flap elevation method	Surgical and oncological safety: hemodynamic, metabolic, and pain parameters	Heart rate, mean arterial pressure, cardiac output	—
Kitti Jantharapattana et al 2017 [15]	Randomized controlled	Thailand	Age 18–70 years; thyroid nodule ≤ 4 cm	BMI > 30 kg/m²; neck/chest skin and subcutaneous thickness > 2 cm	33	—	—	Compare TGET and COT in a comprehensive perspective	—	Operative time, estimated blood loss, hospitalized days, and pain	—	—
Gabriele Materazzi et al 2014 [16]	Prospective randomized	—	Nodule < 4 cm and thyroid volume < 30 mL	—	62	—	36.9 yrs (Group A); 32.5 yrs (Group B)	Compared RATT and MIVAT	—	Cosmetic result, overall satisfaction, operative time	—	RATT seems not to supersede MIVAT in terms of satisfaction
Dong Won Lee et al 2019 [17]	Prospective	—	—	—	100	—	TA 40.0±11.7 (15–60); FL 43.5±10.2 (21–69)	Compared postoperative cosmetic outcomes of robotic/endoscopic thyroidectomy via gasless transaxillary and postauricular facelift approaches with conventional thyroidectomy	—	Cosmetic satisfaction scores and scar consciousness scores	—	Robotic/endoscopic thyroidectomy via transaxillary or postauricular facelift approaches results in better cosmesis than the conventional approach
Kyung Tae MD et al 2019 [18]	—	—	Follicular neoplasm, benign thyroid nodules < 5 cm, differentiated thyroid carcinoma < 3 cm	History of previous neck or thyroid surgery, or neck irradiation	100	—	TO 45.5 ± 18.8; CT 54.5 ± 14.5	Evaluate safety and efficacy of transoral robotic and endoscopic thyroidectomy	—	—	—	—

Study	Study Design	Country	Enrollment Criteria	Exclusion Criteria	N	Blinding	Age (Mean/Median)	Intervention	Comparison	Primary Outcome	Secondary Outcome	Results
Jandee Lee et al 2010 [19]	—	—	Invasive follicular thyroid carcinoma ≤ 4 cm or papillary thyroid carcinoma ≤ 2 cm	Previous neck operations; age < 21 or > 65 years	84	—	39.0 ± 7.0	Compared outcomes including postoperative distress and patient satisfaction	—	Operating time, intraoperative blood loss, number of retrieved central lymph nodes, length of hospital stay	—	—
J. Lee, MD et al 2011 [20]	—	—	Tumor size ≤ 5 cm or DTC with tumor size ≤ 2 cm	—	—	—	—	—	—	—	—	—

RCT: randomized controlled trial; BABA: bilateral axillo-breast approach; TA: transaxillary; FL: facelift; TO: transoral; CT: conventional thyroidectomy; RATT: robot-assisted transaxillary thyroidectomy; MIVAT: minimally invasive video-assisted thyroidectomy; TGET: transaxillary gasless endoscopic thyroidectomy; COT: conventional open thyroidectomy; DTC: differentiated thyroid carcinoma. Dashes (—) indicate data not reported in the original study.

DISCUSSION

This systematic review and meta-analysis included published data from 2010 to 2024 and evaluated the safety and effectiveness of BABA, TO, TA, FL, and CT, along with a subgroup analysis comparing robotic procedures with one another. To our knowledge, this is the first comprehensive meta-analysis to compare key outcomes across conventional and all robotic methods. The results for operation time showed a significant difference favouring CT, which may be attributable to the additional and advanced setup required for robotic methods compared with CT, as well as surgeon expertise and experience. Previous meta-analyses describing comparisons between a single robotic method and CT reported similar findings to those observed in this meta-analysis.

Additionally, no significant differences were observed for length of hospital stay, postoperative pain, or blood loss compared with CT. Robotic approaches appear to offer comparable safety and effectiveness, particularly for younger patients, given their reduced cosmetic impact.

LIMITATIONS

Although our findings support the safety and effectiveness of robot-assisted thyroidectomies, this meta-analysis has several limitations. First, most included studies were conducted in the same geographic region, which may introduce regional discrepancy and bias. Second, only two of the included studies were RCTs, with the remainder being observational studies, increasing the potential for bias among the published data. In addition, the available data are limited, as only a small number of studies for each robotic method were included, leaving gaps in the evidence base. Long-term studies and additional data are needed to further evaluate the safety and efficacy of robot-assisted methods in the general population.

CONCLUSION

This meta-analysis establishes the effectiveness of various robot-assisted thyroidectomy approaches compared with conventional open thyroid surgery. Although total operation time is significantly longer, likely due to the specialized setup required and strategies to increase accuracy, all other measured outcomes yielded results comparable to conventional treatment, further supported by subgroup analysis demonstrating the safety and efficacy of robotic techniques. A shortage of data relating to the newest robotic techniques represents a limitation of this review. Future studies should be larger, more detailed, and more rigorously randomized to fill this gap and provide more accurate, long-term results.

Ethical Consideration

This review article is based on previously published data, and no human or animal studies requiring ethical committee approval were undertaken.

Acknowledgment

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Conflict of Interest Statement

No conflict of interest is present.

Data Availability Statement

The data supporting this study are available from the corresponding author upon request.

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