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Adolescents and Adults Undergoing Temperature-Controlled Surgical Instruments vs Electrocautery in Tonsillectomy
A Systematic Review and Meta-analysis of Randomized Clinical Trials

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IMPORTANCE Several temperature-controlled surgical instruments (TCSIs) have been used in tonsillectomy. However, to our knowledge, a meta-analysis of the differences between modern TCSIs and electrocautery (EC) has not been conducted.

OBJECTIVE To compare TCSIs with EC with regard to the intraoperative and postoperative parameters of tonsillectomy.

DATA SOURCES PubMed (MEDLINE), Embase, and the Cochrane Library were searched independently by 2 authors for relevant articles.

STUDY SELECTION A literature search identified randomized clinical trials comparing the outcomes of TCSIs vs EC. The search keywords were *harmonic scalpel*, *ultracision*, *PlasmaBlade*, *coblation*, *radiofrequency ablation*, and *tonsillectomy*. Studies of adult and adolescent patients were included.

DATA EXTRACTION AND SYNTHESIS Data from each study were extracted. A random-effects model was used in the pooled analysis.

MAIN OUTCOMES AND MEASURES Four outcomes were analyzed: postoperative pain level on days 1, 2, 7, and 14 after surgery; postoperative bleeding; operative time; and intraoperative blood loss.

RESULTS This meta-analysis included 11 studies with a total of 629 unique patients. (Mean ages ranged from 16 to 55 years.) The studies were further categorized by the methods of comparison. Five articles used between-participant comparisons, and 6 used within-participant comparisons (of the left vs right sides of the participant's body). The pooled results of the studies with between-participant measures showed that postoperative pain scores were lower in the TCSI group on the first day (standardized mean differences [SMD], −0.41 [95% CI, −0.77 to −0.06]) and seventh day (SMD, −0.76 [95% CI, −1.47 to −0.04]). The pooled results of the studies with within-participant measures showed that the postoperative pain scores were lower in the TCSI group on the first day (SMD, −0.37 [95% CI, −0.63 to −0.12]) and second day (SMD, −0.60 [95% CI, −1.10 to −0.10]). The pooled analysis of overall bleeding, major bleeding, minor bleeding, primary bleeding, and secondary bleeding in both the types of studies with between-participant measures and those with within-participant measures showed no significant differences between the TCSI and EC groups. Intraoperative blood loss and operative time were not significantly different between the groups.

CONCLUSIONS AND RELEVANCE Compared with EC, TCSIs were associated with significantly reduced pain on the first day after tonsillectomy, per this meta-analysis. The rates of overall bleeding, primary bleeding, secondary bleeding, major bleeding, and minor bleeding between TCSIs and EC were comparable. Intraoperative blood loss and operative time also showed no significant intergroup differences. Surgeons may consider using these modern instruments according to personal experiences, preferences, and cost-effectiveness criteria.

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Supplemental content

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Tonsillectomy is a commonly performed operation for the treatment of tonsil-associated diseases, mostly recurrent tonsillitis or adenotonsillar hypertrophy, which results in sleep-disordered breathing.[1] Tonsillectomy is a surgical procedure during which the entire tonsil, along with the capsule, is removed, leaving no remaining lymphatic tissue in the tonsillar fossa. Several surgical devices have been used in tonsillectomy; however, there is no consensus on the optimal instrumentation. The conventional technique of tonsillectomy relies on cold-knife dissection with knot tying for hemostasis. Electrocautery (EC), which may involve monopolar or bipolar instruments, is also used to decrease the operative time and intraoperative bleeding.[2] However, thermal injury caused by high temperatures (400°C-600°C) may increase postoperative pain and other complications.[3,4] With recent advances in instrument technology, several temperature-controlled surgical instruments (TCSIs) have been introduced in tonsillectomy procedures to reduce the thermal effects of EC. The Harmonic Scalpel (Ethicon Endo-Surgery Inc) uses ultrasonographic vibration of a blade at 55 kHz to achieve cutting with minimal thermal damage. The temperature of the surrounding tissue can reach approximately 40°C to 70°C, per the reported literature.[5] The pulsed-electron avalanche knife PlasmaBlade device (Medtronic Inc) uses radiofrequency energy to induce electrical plasma formation along the edge of the surgical blade. The operating temperature of the PlasmaBlade ranges from 40°C to 100°C.[6] The Coblation device (Arthrocare Inc) uses bipolar radiofrequency ablation by passing radiofrequency energy through a conductive medium to produce a plasma field for surgery. The temperature of tissue disintegration is reported at approximately 60°C.[7] The purpose of this study was to compare TCSIs with EC techniques on intraoperative and postoperative parameters for patients undergoing tonsillectomy who are older than 16 years.

Key Points

Question What are the differences between temperature-controlled surgical instruments and electrocautery on the outcomes of postoperative pain, postoperative bleeding, intraoperative blood loss, and operative time for tonsillectomy in adults and adolescents?

Findings In this systematic review and meta-analysis of 11 studies including 629 patients, temperature-controlled surgical instruments were found to significantly reduce pain on the first day after tonsillectomy compared with electrocautery techniques. There were no significant differences in the risk of overall bleeding, primary bleeding, secondary bleeding, major bleeding, or minor bleeding between the 2 types of surgical instruments, and the volume of intraoperative blood loss and operative time also showed no significant intergroup differences.

Meaning Temperature-controlled surgical instruments used in tonsillectomy for adults and adolescents may help reduce pain in the early postoperative period.

Methods

Literature Search

This study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[8] Two of the authors (Y.-C.L. and C.-M.L.) searched PubMed, Embase, and the Cochrane Library independently and extensively for articles of interest published before June 2019. The keywords used in the search process included *harmonic scalpel*, *ultracision*, *PlasmaBlade*, *coblation*, *radiofrequency ablation*, and *tonsillectomy*. Moreover, these 2 authors reviewed the reference lists of the included studies to identify additional articles.

Study Selection and Data Extraction

The inclusion criteria were trials including patients older than 16 years, randomized clinical trials, articles published in the English language, and studies comparing the outcomes between a TCSI (harmonic scalpel, PlasmaBlade, or coblation) and a hot technique (monopolar or bipolar EC). The exclusion criteria were based primarily on the absence of one of the inclusion criteria. Studies including pediatric participants, studies evaluating partial tonsillectomy or tonsillotomy, retrospective studies, nonrandomized studies, articles not published in English, duplicate studies, case reports, abstracts, letters to the editor, and articles with publication of the full text pending were excluded from the meta-analysis. Data were independently extracted from eligible articles by the 2 researchers (Y.-C.L. and C.-M.L.), and data discrepancies were resolved by discussion.

Outcomes

The main outcomes of this study included posttonsillectomy pain severity within 14 days after surgery, posttonsillectomy bleeding, intraoperative blood loss, and operative time. Postoperative pain severity was extracted from a visual analog scale (VAS) (score range, 0-10, with 0 indicating no pain and 10 indicating the worst possible pain). When necessary, means and measures of dispersion were approximated from figures in the included articles using WebPlotDigitizer version 2.5.0 for Windows (Ankit Rohatgi).[9]

Two authors (Y.-C.L. and C.-M.L.) independently assessed the methodologic quality of the included studies using a Cochrane risk of bias tool (RoB 1.0).[10] The tool includes the domains of random-sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, selective reporting, and other biases. We classified items as having low, high, or unclear risk of bias, relying only on the information presented in the included studies. Disagreements were discussed until consensus was achieved between the 2 authors mentioned.

Data Analysis

The results were analyzed using Comprehensive Meta-Analysis software, version 3 (Biostat). Standardized mean differences (SMDs) were calculated to compare postoperative pain VAS score, the volume of intraoperative blood loss, and the total operating time between the TCSI and EC groups. Odds ratios were calculated to compare the bleeding risk between the TCSI and EC groups. The overall effect

was pooled using a random-effects model. Statistical heterogeneity among studies was measured using the I^2 statistic, which calculated the proportion of overall variation attributable to between-study heterogeneity. A result of I^2 statistics exceeding 50% indicates moderate heterogeneity, and an I^2 statistic exceeding 75% indicates high heterogeneity.[11] Potential publication bias was assessed using a funnel plot and the Egger intercept test.[11] Any 2-sided P value less than .05 was considered statistically significant.

Results

Study Selection

The initial literature search yielded a total of 1131 articles. Studies that were duplicated, noninterventional studies, studies focusing on tonsillotomy (partial tonsillectomy) procedures, or non-English language articles were excluded. The remaining 57 potentially eligible studies were retrieved for a careful review of the full text. Among them, 45 articles were excluded for a lack of pain assessment or a lack of TCSI or EC use in the study. One oral presentation was also excluded. As a result, 11 articles[12-22] were included in this review. A flow diagram describing the process involved in study identification and inclusion and exclusion is shown in **Figure 1**. The eTable in the Supplement summarizes the literature search process and the keywords used.

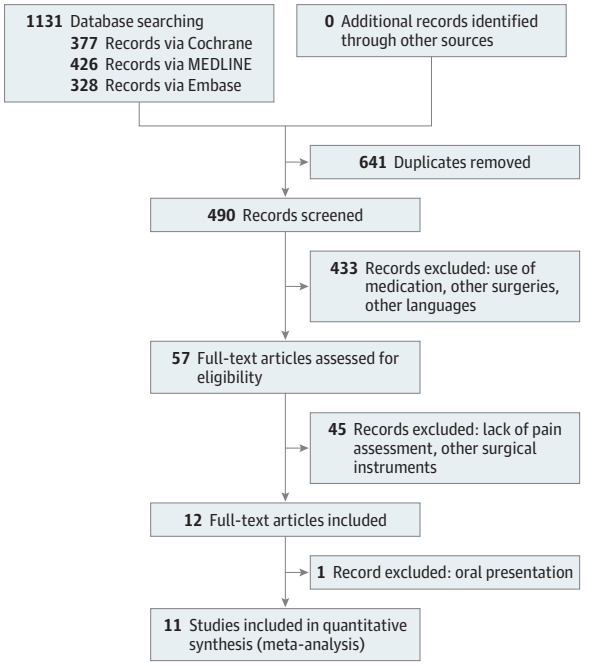
Demographics

The **Table** lists the basic demographics of the patients from the 11 included studies.[12-22] The study designs were all prospective randomized clinical trials with a level of evidence of Ib in all of them. The risk of bias assessment for each study is described in eFigure 1 and eFigure 2 in the Supplement. The primary risks of bias were attributable to the blinding of the study investigators.

Surgical Outcomes

The 11 studies enrolled in this review can be further categorized by the method of comparison. Five of the 11 articles[12-16] used between-participant comparisons, and 6 articles[17-22] used within-participant comparisons (the left side vs the right side of the participant's body). Meta-analyses of the between-participant studies and the within-participant studies were performed separately to introducing avoid unnecessary bias. Information concerning operative time,[13-16,19-22] intraoperative bleeding,[14,15,19-22] postoperative bleeding,[12-16,18,19] and postoperative pain[13-22] was reported by most of the enrolled studies. Meta-analyses for these parameters were therefore feasible, and the results are demonstrated in **Figures 2**, **3**, and **4**. Postoperative bleeding was further classified into primary bleeding (within 24 hours after surgery),[13] secondary bleeding (24 hours or more after surgery),[12-16,18,19] minor bleeding (not requiring hemostasis in the operating room),[13-15,18,19] and major bleeding (requiring hemostasis in the operating room).[12,13,16,19]

Figure 1. Flow Diagram of the Literature Search



Postoperative pain

All the included trials evaluated postoperative pain by VAS after tonsillectomy. The data were compared on days 1, 2, 7, and 14 after surgery for both the studies with between-participant measures and those with within-participant measures. The pooled results of between-participant comparison studies[12-16] showed that the VAS scores were lower in the TCSI group on the first postoperative day (SMD, −0.41 [95% CI, −0.77 to −0.06]) and seventh postoperative day (SMD, −0.76 [95% CI, −1.47 to −0.04]). On the other hand, the pooled results of the within-participant comparison studies[17-22] showed that the VAS scores were lower in the TCSI group on the first postoperative day (SMD, −0.37 [95% CI, −0.63 to −0.12]) and second postoperative day (SMD, −0.60 [95% CI, −1.10 to −0.10) (Figure 2). There was no significant difference in pain at day 14 in either the studies with between-participant measures or those with within-participant measures.

Postoperative Bleeding, Operative Time, and Blood Loss

In the present study, the incidence rates of overall bleeding were 3.2% (15 of 472 participants)[12-16] and 3.8% (6 of 157 participants)[18,19] for the between-participant studies and within-participant studies, respectively. The pooled analysis of overall bleeding, major bleeding, minor bleeding primary bleeding, and secondary bleeding in both the between-participant and within-participant studies showed no significant differences between the TCSI and EC groups (Figure 3). The pooled analysis of blood loss and operative time in both the between-participant and within-participant studies showed no significant differences between the TCSI and EC groups (Figure 4).

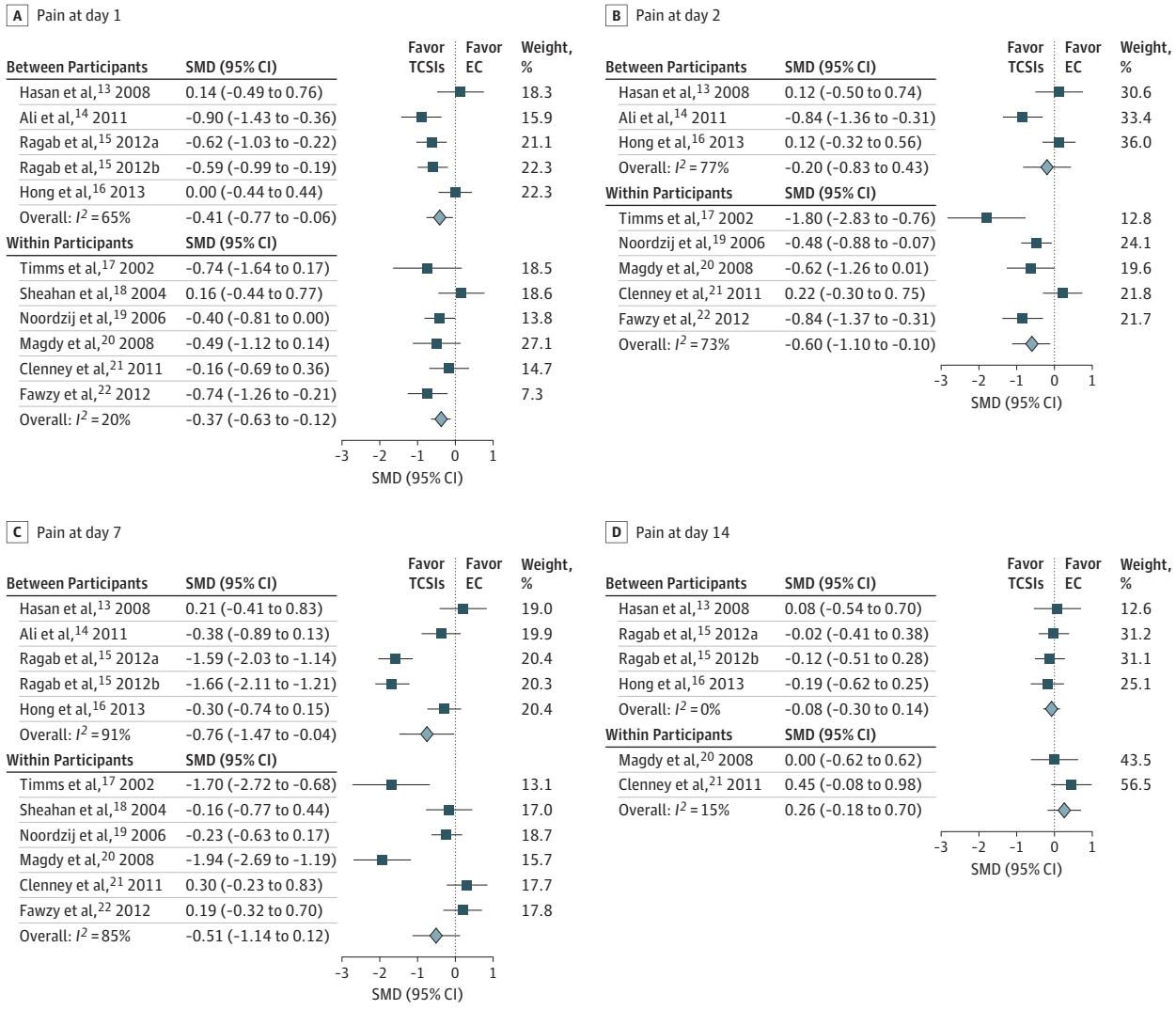
Table. Characteristics of the Included Studies

Source	Country	Temperature-Controlled Surgical Instruments	Electrocautery	Participants			Bleeding Events, No./Total No.		Indications
				Total No.	Mean (SD) Age, y	Sex, No. Male/No. Female	Cold Instruments	Hot Instruments	
Studies With Between-Participant Measures									
Tan et al,[12] 2006	Singapore	Harmonic scalpel	Monopolar	67	26.0 (7.9)	51/16	2/29 (both major and secondary)	0/38	CT/RT
Hasan et al,[13] 2008	Finland	Coblation	Bipolar	40	Range, 18-55	16/24	1/20 (major and secondary)	4/20 (3 major and 1 minor; 1 primary and 3 secondary)	CT/RT
Ali et al,[14] 2011	Pakistan	Harmonic scalpel	Monopolar	60	28.1 (7.4)	33/27	1/30 (minor and secondary)	3/30 (all minor and secondary)	CT/RT or obstructive sleep apnea
Ragab,[15] 2012	Egypt	Harmonic scalpel, coblation	Bipolar	300	29.0 (10.0)	173/127	1/75 (minor and secondary)	2/37 (both minor and secondary)	CT/RT
Hong et al,[16] 2013	Korea	Coblation	Monopolar	80	30.2	31/49	0/40	1/40 (minor and secondary)	CT/RT
Studies With Within-Participant Measures									
Timms et al,[17] 2002	UK	Coblation	Bipolar	10	25.3	3/7	NA	NA	CT/RT
Sheahan et al,[18] 2004	UK	Harmonic scalpel	Bipolar	21	Range, 16-31	5/16	1/21 (minor and secondary)	1/21 (minor and secondary)	NA[a]
Noordzij et al,[19] 2006	US	Coblation	Monopolar	48	22	10/38	1/48 (minor and secondary)	3/48 (2 major and 1 minor; all secondary)	CT/RT
Magdy et al,[20] 2008	Egypt	Coblation	Monopolar	20	22.9 (4.8)	11/9	NA	NA	CT/RT
Clenney et al,[21] 2011	US	PlasmaBlade	Monopolar	28	25.3	14/14	NA	NA	CT/RT
Fawzy et al,[22] 2012	Egypt	Coblation	Bipolar	30	27.0 (9.0)	21/9	NA	NA	NA[a]

Abbreviations: CT/RT, chronic tonsillitis or recurrent tonsillitis; NA, not available; UK, United Kingdom; US, United States.

[a] Patients underwent elective tonsillectomy.

Figure 2. Forest Plot of Pain After Tonsillectomy



EC indicates electrocautery; SMD, standardized mean differences; TCSIs, temperature-controlled surgical instruments.

Publication Bias

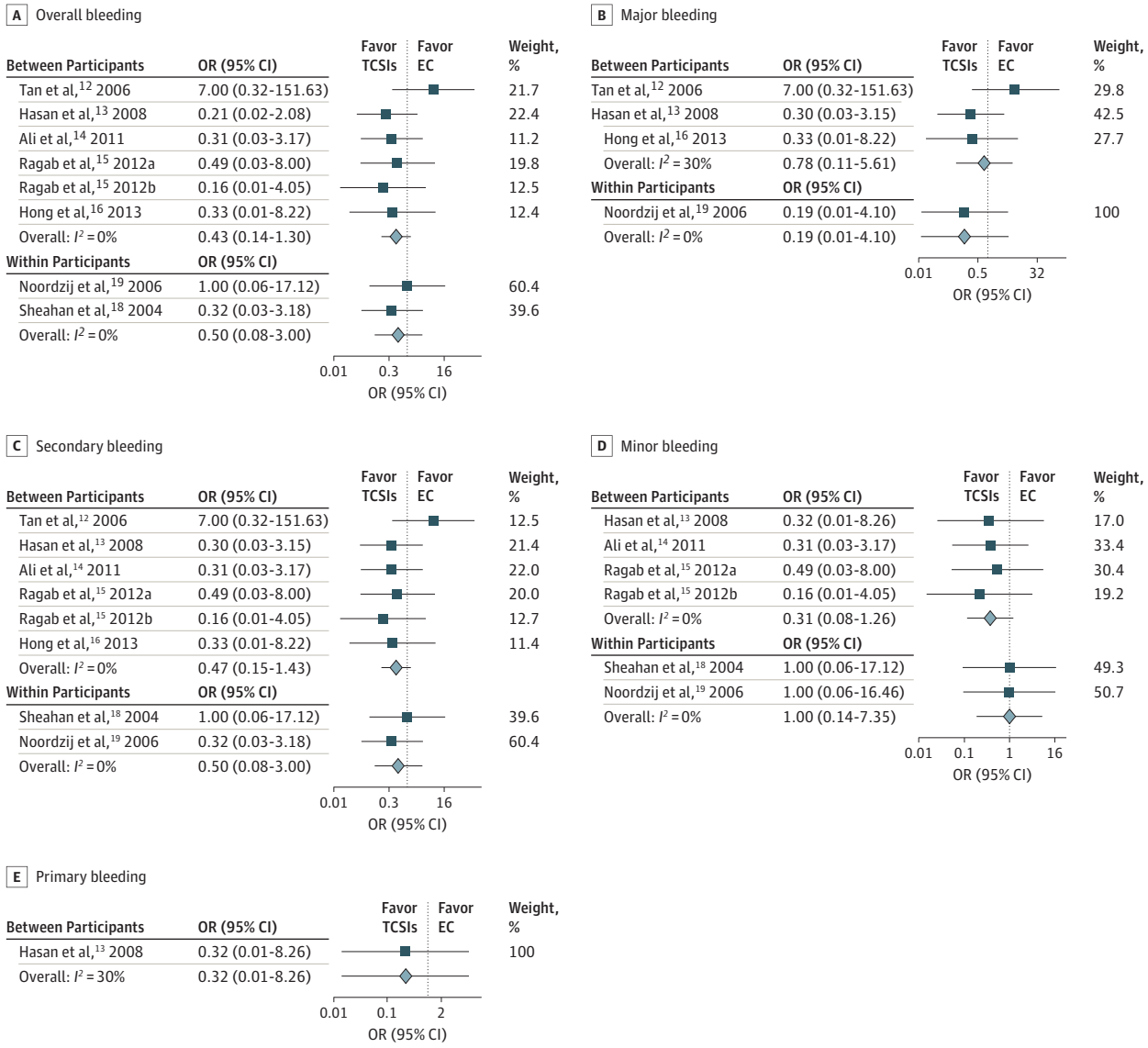
Funnel plots are presented in eFigure 3 and eFigure 4 in the Supplement. The plots of different parameters are generally symmetrical, suggesting no obvious publication bias. The results of the Egger intercept test also indicated no apparent publication bias.

Discussion

To our knowledge, the present study is the first meta-analysis to evaluate the differences between subcapsular tonsillectomy performed with TCSIs vs EC instruments. In addition, studies with between-participant measures and within-participant measures were both included and analyzed separately to determine the differences between these 2 types of surgical devices. For the between-participant studies, a meta-analysis showed significant pain reduction in the TCSI group on days 1 and 7 but not days 2 or 14 after surgery. For the studies with within-participant measures, a meta-analysis showed significant pain reduction in the TCSI group on days 1 and 2 but not on days 7 or 14 after surgery. The overall postoperative hemorrhage risks of the procedures with different instruments were not significantly different in the between-participant studies or the within-participant studies. Further analysis showed similar results in the risk of primary bleeding, secondary bleeding, major bleeding, and minor bleeding. The differences in intraoperative blood loss and operative time were not significant between groups with different surgical devices in either the between-participant or within-participant studies.

Tonsillectomy is one of the most commonly performed surgeries of otorhinolaryngologists. However, tonsillectomy is also associated with considerable postoperative pain and discomfort. Traditionally, tonsillectomy is performed using cold instruments (ie, a knife or scissors) or hot instruments (ie, ones

Figure 3. Forest Plot of Bleeding Incidence After Tonsillectomy

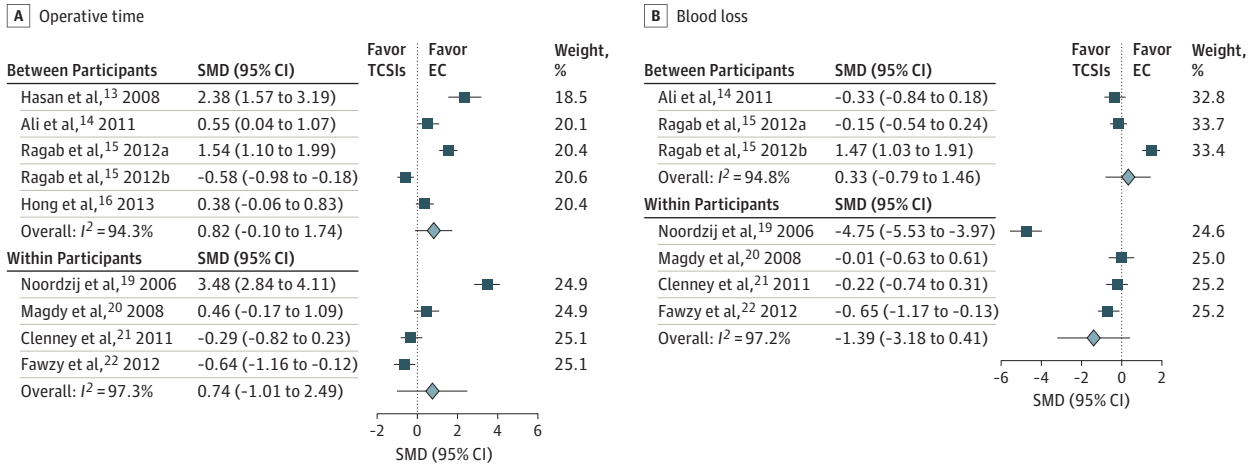


EC indicates electrocautery; OR, odds ratio; TCSIs, temperature-controlled surgical instruments.

for monopolar or bipolar electrosurgery). Although cold instruments seemed to provide a less painful recovery, hot techniques are still preferred by many surgeons for faster dissection and less intraoperative bleeding.[23] With the advancement of surgical devices, several instruments were introduced as a means of bridging the gap between cold and hot techniques. These devices, including the harmonic scalpel, PlasmaBlade, and coblation, provide adequate hemostasis during dissection while inducing less thermal injury to the involved tissue.[24] Compared with the high temperature produced by EC (400°C-600°C),[4] these TCSIs generally reach less than 100°C during surgery.

Postoperative pain is most intense in the recovery period following tonsillectomy.[25] Despite improvements in anesthesia and medication use, posttonsillectomy pain continues to be the main concern for patients, their families, and even physicians.[26] Postoperative pain not only influences the length of hospital stay but also the ability of patients to return to normal activity.[27] However, the pain experienced following tonsillectomy was not similar among different age groups. Children younger than 10 years seemed to have less pain and recover more quickly than older patients did.[25] The present meta-analysis, therefore, only enrolled studies of adolescents and adults to avoid potential bias associated with age differences. For studies with between-participant measures, our results showed that there was a significant difference in pain on postoperative days 1 and 7 but not on days 2 or 14. A possible explanation is that there were relatively fewer data available on postoperative day 2 than postoperative days 1 and 7. However, for the study that lacked reported data on day 2 in

Figure 4. Forest Plot of Operative Time and Intraoperative Blood Loss During Tonsillectomy



EC indicates electrocautery; SMD, standardized mean differences; TCSIs, temperature-controlled surgical instruments.

comparison with days 1 and 7, a lesser degree of pain in the TCSI group than in the EC group was highly possible, according to the figure provided in the article.[15] For within-participant studies, on the other hand, significantly less pain was observed in the TCSI group on postoperative day 1 and 2 but not on days 7 and 14. Nevertheless, the result on day 7 still favors the TCSI group (a SMD >0.5), although the difference was not significant. Based on these results, we think that the use of TCSIs is significantly associated with a lesser degree of pain on the first day after surgery.

Bleeding after tonsillectomy may lead to reoperation, blood transfusion, and even death. The prevention of bleeding after tonsillectomy is therefore one critical step in achieving a successful surgical outcome. In general, postoperative bleeding can be classified as primary and secondary as well as minor and major by the duration and severity of bleeding, respectively. This meta-analysis shows that the risk of overall bleeding, primary bleeding, secondary bleeding, major bleeding, and minor bleeding did not differ significantly between the TCSI group and EC group. These results were found in both the studies with between-participant and within-participant measures. In this study, the incidences of overall bleeding were 3.2% and 3.8% for the studies with between-participant measures and within-participant measures, respectively, which are compatible with results of previous studies.[28] Many researchers have attempted to study whether posttonsillectomy bleeding is associated with the types of surgical instrument used; however, the results are inconsistent. Several authors have suggested that other factors, such as the surgeon's experience, may be more critical to the risk of bleeding.[29] Our results support that TCSIs did not increase or decrease the risk of bleeding after tonsillectomy compared with EC instruments. Given the comparatively low incidence of postoperative bleeding, however, our meta-analysis was likely to have been underpowered to detect clinically meaningful differences between different groups.

Intraoperative bleeding and operative time are 2 factors that may affect each other. Many surgeons prefer a surgical instrument that can reduce intraoperative bleeding and operative time to minimize the difficulty of the tonsillectomy procedure. In previous studies, tonsillectomy with EC had less intraoperative bleeding and operative time than tonsillectomy with cold instruments.[2] Our results suggested that the use of TCSIs did not increase blood loss or operative time during tonsillectomy compared with EC. The lower thermal effect of these instruments, therefore, did not seem to cause more surgical difficulty than that caused by the high thermal effect of EC.

Limitations

This study had several limitations. First, we only analyzed the VAS scores of postoperative pain on days 1, 2, 7, and 14; we were not able to evaluate VAS scores at other points because of insufficient data. Second, parameters such as the amount of analgesic medication consumed, time to normal diet, and time to daily activity were not reported by most studies, making a pooled analysis difficult. Indications for tonsillectomy in each study may be another confounding factor. However, 8 of the 11 studies[12,13,15-17,19-21] in the present analysis enrolled only patients with chronic or recurrent tonsillitis, and no additional procedures, such as pharyngoplasty or palatoplasty, were mentioned in the remaining 3 articles.[14,18,22] One study[14] enrolled patients with recurrent tonsillitis, obstructive sleep apnea, history of quinsy, or those with suspected malignant conditions. Two studies[18,22] did not specify the indications. The analysis of funnel plots and Egger tests demonstrated no evidence of publication bias. However, these results should be interpreted with caution, because the small number of studies meant that the possibility of publication bias could not be excluded. Despite these limitations, our meta-analysis still provides evidence for the use of different instruments for tonsillectomy in patients older than 16 years.

Conclusions

Compared with EC, TCSIs can significantly reduce pain on the first day after tonsillectomy. However, it is unclear whether the observed differences at the early point are clinically meaningful. In addition, the findings were not conclusive for day 2, day 7, and later. We found similar rates of overall bleeding, primary bleeding, secondary bleeding, major bleeding, and minor bleeding between procedures using these 2 types of surgical instruments. The intraoperative blood loss and operative time also showed no significant intergroup differences. Surgeons may consider using these modern instruments according to personal experiences, preferences, and cost-effectiveness criteria.

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Concept and design: All authors.
Acquisition, analysis, or interpretation of data: Lee, Luo.
Drafting of the manuscript: Lee, Lin, Luo.
Critical revision of the manuscript for important intellectual content: Lee, Hsin, Fang, Tsai, Luo.
Statistical analysis: Lee, Luo.
Administrative, technical, or material support: Lee, Hsin, Lin, Luo.
Supervision: Lee, Hsin, Fang, Tsai.

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