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Postoperative Outcomes of Intracapsular Tonsillectomy With Coblation: A Systematic Review and Meta-Analysis

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Abstract

Objective. Following tonsillectomy, postoperative pain and hemorrhage from the tonsillar bed are causes of significant morbidity. Intracapsular tonsillectomy with Coblation is suggested to minimize such morbidity while remaining efficacious in long-term outcomes.
This systematic review and meta-analysis assessed short-term morbidity and long-term outcomes from intracapsular tonsillectomy with Coblation, focusing primarily on post-tonsillectomy hemorrhage.

Data Sources. Medline, Embase, and the Cochrane Library.

Review Methods. Guided by PRISMA guidelines, studies on intracapsular tonsillectomy with Coblation published between December 2002 and July 2022 evaluating frequency of posttonsillectomy hemorrhage were screened. Studies without primary data were excluded. Meta-analysis was conducted using the random-effect model. The primary outcome was the proportion of patients who experienced posttonsillectomy hemorrhage. The secondary outcomes were posttonsillectomy pain, the proportion requiring revision tonsillectomy, and severity of sleep-disordered breathing measured by polysomnography outcomes.

Results. From 14 studies there were 9821 patients. The proportion of total posttonsillectomy hemorrhage was 1.0% (95% confidence interval [CI] 0.5%-1.6%, n = 9821). The proportion experiencing primary hemorrhage, secondary hemorrhage, and those requiring further tonsil surgery were 0.1% (95% CI 0.0%-0.1%; study n = 7), 0.8% (95% CI 0.2%-1.4%; study n = 7), and 1.4% (95% CI 0.6%-2.2%; study n = 6), respectively. Mean reduction in apnea-hypopnea index was −16.0 events per hour (95% CI −8.8 to −23.3, study n = 3) and mean increase in oxygen nadir was 5.9% (95% CI 2.6%-9.1%, study n = 3).

Conclusion. Intracapsular tonsillectomy with Coblation has been demonstrated to have a low rate of posttonsillectomy hemorrhage. Data regarding long-term tonsil regrowth and need for reoperation were encouraging of the efficacy of this technique.

Keywords

palatine tonsil, postoperative hemorrhage, postoperative period, tonsillectomy

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Tonsillectomy is one of the most common pediatric surgical procedures with over 500,000 performed each year in the United States.[1] The American Academy of Otolaryngology–Head and Neck Surgery recommends tonsillectomy with or without adenoidectomy as a first-line treatment for children with obstructive sleep apnea (OSA) and sleep-disordered breathing (SDB).[2] Other common indications include recurrent acute tonsillitis, chronic tonsillitis, and recurrent peritonsillar abscess.[2-4]

Posttonsillectomy hemorrhage (PTH) is a potentially serious complication in the postoperative period. PTH can be described as primary (within 24 hours of surgery) or secondary (after 24 hours) with a peak incidence at post-operative days 7 to 10.[5] PTH can range from minor, with spontaneous resolution, to life-threatening indicating acute surgical intervention.[6] The reported prevalence of PTH is varied with primary PTH rates reported between 0.2% and 2%, and secondary PTH rates reported between 3% and 21.8%.[5,7-10] The pathophysiology of secondary PTH is not fully understood and current theories attribute it to sloughing of eschar, tonsil bed infection, or trauma secondary to solid food ingestion.[11] Another common cause for seeking medical

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advice is postoperative pain, which can remain a common complaint for up to 2 weeks postoperatively.[12]

Traditional tonsillectomy methods involve extracapsular tonsillectomy (ECT).[13-15] Intracapsular tonsillectomy (ICT) was popularized by Koltai and colleagues.[16] Preservation of the capsule and sparing of the underlying muscle was theorized to decrease the risk of PTH as the intracapsular vessels are half the caliber of the extra-capsular vessels.[17-19] Furthermore, as palatine tonsils are devoid of neural tissue, the intracapsular approach is theorized to generate less pain. Coblation ("cold ablation") involves passing radiofrequency energy through a conductive medium, usually saline, thereby producing a plasma field. The charged ions break molecular bonds to allow controlled tissue disintegration at a lower temperature than traditional "hot techniques." This decreases the amount of thermal damage to surrounding structures, which further contributes to relatively less pain.[13,20] The long-term efficacy of this technique has been questioned as ICT does not remove all tonsillar tissue leaving a potential for hyperplasia of the remnant and symptom recurrence.

A Cochrane review assessing Coblation for the extracapsular approach was published in 2017.[20] The primary aim of this systematic review was to examine the rate of PTH following the intracapsular approach with Coblation from available retrospective, prospective and randomized controlled studies. The secondary aims of this systematic review were to evaluate postoperative pain, alleviation of symptoms of SDB and recurrent tonsillitis, and the need for further surgical revision.

Methods

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[21] The protocol of this study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) in 2022 (CRD42022312098). An electronic search of Medline, EMBASE, and Cochrane library was conducted using the keywords "tonsil*," "tonsillectomy," "adenotonsil*," "intracapsular," "Subtotal," "partial," "coblation," "radiofrequency ablation," "ionized field ablation," and "cold ablation." Original human studies in the English language, published between December 2002 to July 2022 were searched. Studies were eligible for inclusion if they included primary data and reported the proportion of PTH in adults and/or children undergoing ICT with Coblation for any indication other than suspected malignancy. All duplicates in the searches were removed after cross-matching their titles, abstracts, authors, and year of publication.

Titles and abstracts were screened in a 2-step progress by 2 authors independently (HL and OA). Full texts of the remaining studies were retrieved and reviewed independently by the same 2 authors. Where assessment of the primary outcome was unclear, further clarification was sought from the corresponding author. Any study that did not meet the inclusion criteria, including lack of original data, was excluded from the study. In a secondary search, the reference lists of included studies from the primary search were manually screened and reviewed using the same process.

Data were extracted using a standardized form. Extracted variables included number of patients in the study who underwent ICT with Coblation, number of patients with PTH (overall, primary, secondary, requiring return to theater), number of patients with recurrent tonsillitis, number of patients requiring revision tonsil surgery, pain measurements as defined in the included studies, OSA-18 and T14 scores for SBD, polysomnography apnea-hypopnea index (AHI) and mean oxygen nadir.

Risk of bias was assessed using a modification of The Risk of Bias in Non-randomized Studies of Interventions 2016 (ROBINS-I).[22] Studies were evaluated on domains of bias: confounding, selection, classification, deviation from intervention, missing data, measurement, and selective reporting. An assessment of risk of bias (low, moderate, serious, critical, or no information) was attributed to each outcome extracted from each study.

Outcomes used in categorical analysis included the proportion of patients experiencing PTH (overall, primary, secondary, and requiring return to theater) and those requiring revision surgery. Numerical analysis included the difference in AHI and oxygen nadir before and after ICT with Coblation. For each variable, the values and correspondent standard errors were calculated. Random-effect meta-analysis was used to generate pooled estimates, with a fixed continuity correction of 0.5 applied where the study outcome was 0.0%. Heterogeneity across studies was assessed using the I^2 statistic. All analyses were conducted with Stata 17.0.

Results

The primary search yielded a total of 141 studies (**Figure 1**). Fifty-one duplicates were removed. Of the remaining 90 studies, 36 were excluded as the titles were concluded to be irrelevant and a further screen of abstracts excluded 21 studies. Of the remaining 33 studies, all full texts were screened and assessed for eligibility. This yielded 11 eligible studies. The reference lists of all 11 studies were manually searched in a secondary search with 3 further eligible studies identified. These were added to the primary search studies to yield 14 studies.

Fourteen studies (9821 patients)[23-36] met the inclusion criteria and were included in the analysis (**Figure 1**). The proportion of males ranged from 43.3% to 61.5%. There were 8 retrospective cohort studies, 3 prospective studies, and 3 randomized controlled trials. Where there was more than 1 study arm, data from the ICT with Coblation arm was collected (**Table 1**). Three studies[23,25,34] included

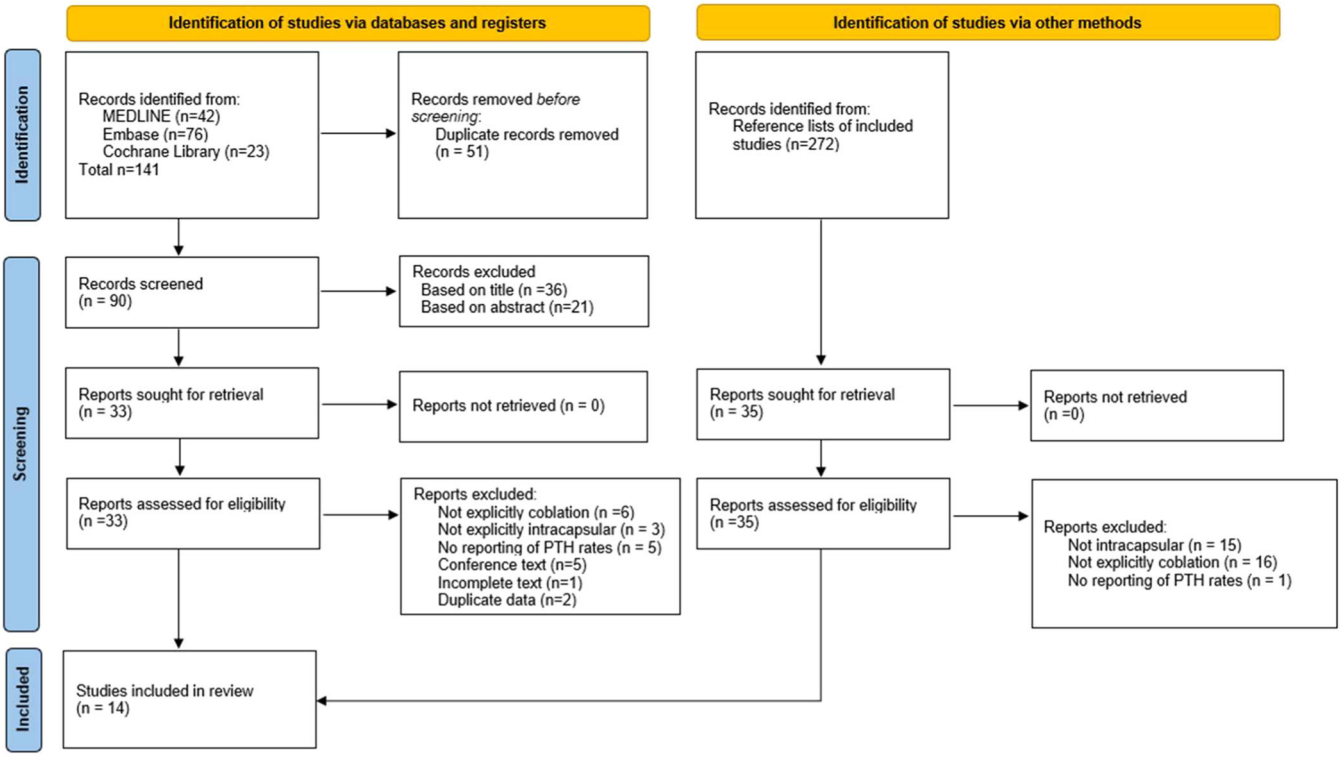

Figure 1. Flow diagram of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)[21] with 14 studies included in the systematic review.

adult patients. Two studies by Borgström et al reported original data from the same study cohort and were thereafter treated as the 1 study.[29,30] Bias was evaluated with the modified ROBINS-I tool with 9 studies with an overall moderate risk of bias and 5 studies with an overall serious risk of bias (**Figure 2**).

Posttonsillectomy Haemorrhage

Fourteen studies with 9821 patients were included in the Meta-analysis of total PTH rates (**Figure 3**). The pooled proportion of total PTH was 1.0% (95% confidence interval [CI] 0.5%-1.6%.), with high heterogeneity across studies (I^2: 80.8%).

Seven studies made a distinction between primary and secondary PTH.[27-33,36] Among the 8065 patients included in the meta-analysis of primary PTH, the pooled proportion of primary PTH was 0.1% (95% CI 0.0%-0.1%) (**Figure 4**). Heterogeneity for the forest plot for primary PTH was low across studies (I^2: 0.0%). A total of 7878 patients were included in the meta-analysis of secondary PTH, with the pooled proportion of secondary PTH of 0.8% (95% CI 0.2%-1.4%) (**Figure 5**). Heterogeneity for the forest plot for secondary PTH was high across studies (I^2: 77.2%).

A total of 8490 patients across 10 studies[23,24,26,27,29-33,35,36] were included in a meta-analysis of the proportion of patients requiring return to theatre for arrest of posttonsillectomy bleeding. The pooled proportion of patients needing a return to theatre for arrest of posttonsillectomy bleed was 0.1% (95% CI 0.0%-0.2%), with low heterogeneity across studies (I^2: 0.0%).

Pain

A total of 10 studies, all on pediatric patients,[23,24,27-33,35,36] reported pain outcomes in the postoperative period. Pain assessment varied significantly across studies and as such the reported findings could not be analyzed in meta-analysis.

Pain Scales and Days Until Pain-Free

Borgström et al used the Faces Pain Scale Revised (FPS-R) and Visual Analogue Scale (VAS) to assess pain.[29,30] FPS-R was used to estimate the first day of no pain according to the pediatric patient. This occurred at a median of 5 days postoperatively. VAS was used to assess when caregivers estimated their child to be pain-free and occurred at a median of 6 days posttonsillectomy. Chan et al assessed pain with the Wong-Baker FACES scale to estimate when children were pain-free with a median of 6.5 days postoperatively.[24] Both of these studies commented on a postoperative analgesic regime (see days on analgesics below). Duarte et al used a postoperative questionnaire which reported pain as mild, moderate, or severe and of the 25 who had ICT with Coblation who responded, 9 described mild pain, 11 moderate, and 5 severe.[27] There was no description regarding the timing

Table 1. Overview of Studies Included in Systematic Review

Study	Study design	Study groups	Patients (n)	Age (mean (range); years)	Male (n [%])	Indication				Risk of Bias for PTH
						Recurrent Tonsillitis (n)	SDB/ OSA (n)	Recurrent tonsillitis and SDB/OSA (n)	Other (n)	
Lee et al[23]	Retrospective	Single arm Coblation ICT	528	5; (1-62)	246 (46.6)	360	127	39	2	Serious
Chan et al[24]	RCT	Coblation ICT vs Monopolar ECT	27	6.4; (3 -12)	16 (59.3)	0	27	0	0	Moderate
Divi et al[25]	Retrospective	Coblation ICT vs Coblation ECT vs Non-coblation ECT not otherwise specified	303	-	-	-	-	-	-	Serious
Duarte et al[27]	Retrospective	Coblation ICT vs Coblation ECT	157	6.7; (2-18)	68 (43.3)	13	133	10	1	Moderate
Sunnergren et al[28]	Retrospective	Coblation ICT vs Monopolar ICT	677	7.2; (-)	359 (53.0)	0	677	0	0	Moderate
Zhang et al[26]	Prospective	Single arm Coblation ICT	82	4.8; (2.4 -11)	44 (53.7)	0	82	0	0	Serious
Borgström et al[29,30]	RCT	Coblation ICT vs cold steel ECT	39	3.75; (2-6)	24 (61.5)	0	39	0	0	Moderate
Attard et al[31]	Retrospective	Coblation ICT vs Coblation ECT	330	4.3; (-)	172 (52.1)	0	330	0	0	Moderate
Varadharajan et al[32]	Prospective	Single arm Coblation ICT	80	7.2; (2-16)	-	38	0	42	0	Moderate
Amin et al[33]	Prospective	Single arm Coblation ICT	1257	5.1; (0.9-18)	-	62	727	466	2	Moderate
Mukerji et al[35]	Retrospective	Coblation ICT vs Coblation or Electrocautery ECT	467	6.23; (-)	250 (53.5)	57	410	0	0	Moderate
Naidoo et al[34]	Retrospective	Coblation ICT vs Colbation ECT	351	7; (0.8-74.3)	186 (53.0)	124	143	75	9	Serious
Powell et al[36]	Retrospective	Single arm Coblation ICT	5525	4[a]; (0-16)	3309 (59.9)	563	4626	-	336	Moderate

[a]Median age.

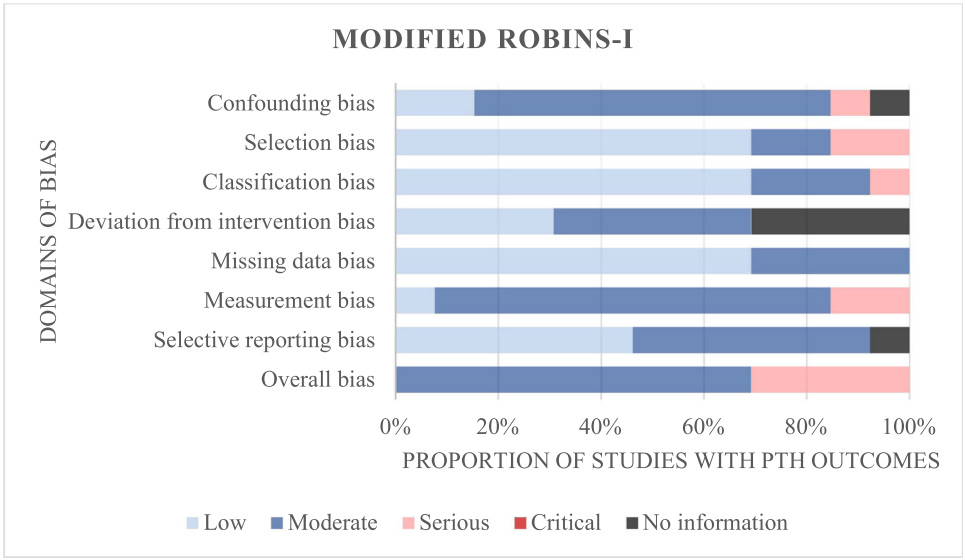

Figure 2. Modified ROBINS-I risk of bias assessment for the variable of posttonsillectomy hemorrhage.

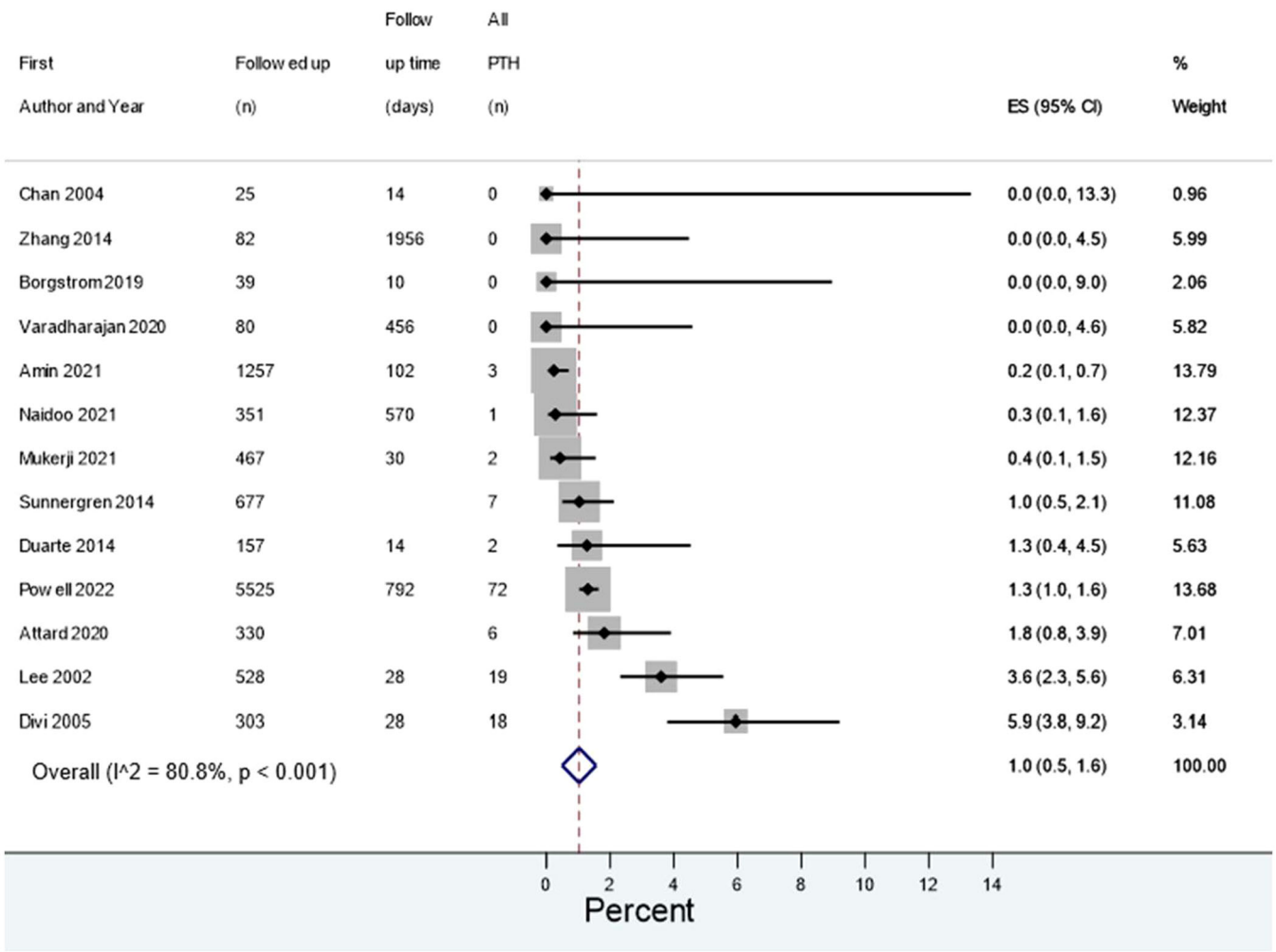

Figure 3. Forest plot of the total rate of posttonsillectomy hemorrhage; $I^2 = 80.8\%$, $P < .001$. CI, confidence interval; ES, effect size; PTH, posttonsillectomy hemorrhage.

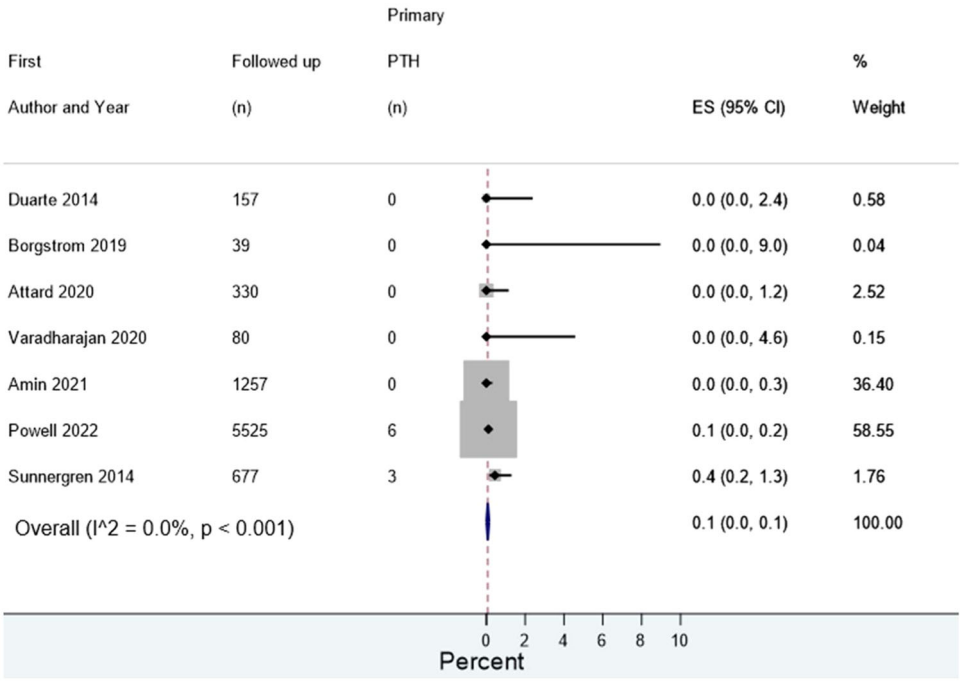

Figure 4. Forest plot of proportion of primary posttonsillectomy hemorrhage; $I^2 = 0.0\%$, $P < .001$. CI, confidence interval; ES, effect size; PTH, posttonsillectomy hemorrhage.

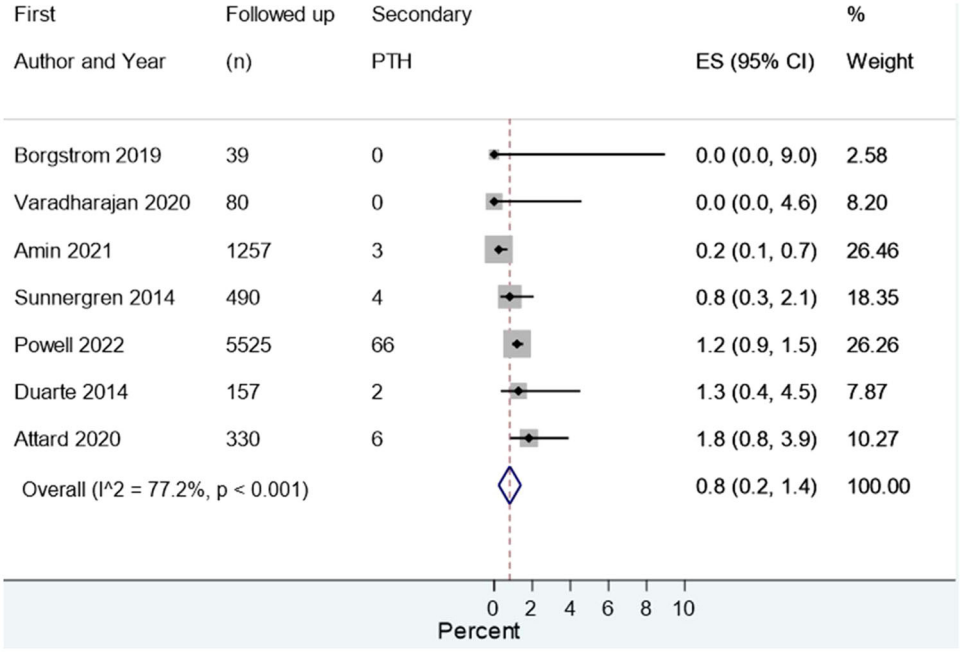

Figure 5. Forest of proportion of secondary posttonsillectomy hemorrhage; $I^2 = 77.2\%$, $P < .001$. CI, confidence interval; ES, effect size; PTH, posttonsillectomy hemorrhage.

of this survey relative to the date of surgery or any postoperative guidance.

Days on Analgesics

Four studies reported estimates of how many days children took analgesics.[24,28-30,33] Borgström et al reported a median of 7 days.[29,30] Postoperative guidance was for regular nonsteroidal anti-inflammatories and acetaminophen for the first 3 days and a decreased dose of acetaminophen from day 4 onwards. The recommendation was for pain relief to be taken as needed from day 3 until pain free. Sunnergren et al reported a mean number of 4.7 days of patients taking analgesia.[28] No

postoperative analgesia guidance was described. Amin et al reported a mean of 6 days on analgesia and described postoperative instructions of regular acetaminophen and ibuprofen for a week.[33] Chan et al reported a median of 6.4 days of patients taking analgesia.[24] This study reported that patients were discharged with acetaminophen with codeine elixir but did not provide further details regarding the postoperative instructions.

Two further studies, which did not report days of analgesia used, described postoperative instructions regarding analgesia. Varadharajan et al described a regular weight base dosage of oral acetaminophen and ibuprofen for 7 days and continued use as needed.[32] A maximum duration of total analgesia was not described. Attard et al described a prescription of oral acetaminophen and ibuprofen as needed without further clarification of duration or frequency.[31]

Days Until Return to Normal Diet

Four studies reported estimates of when children returned to a normal diet as observed by their caregivers.[24,27,29,30,33] This was reported as a median of 6 days by Borgström et al,[29,30] a mean of 5.4 days by Duarte et al[27] a median of zero days by Amin et al[33] and a median of 4.4 days by Chan et al.[24] The time of follow up ranged from 10 days to 14.5 weeks. Of these studies, only Borgström et al provided detail of their postoperative diet instruction where patients were advised that there were no postoperative restrictions to diet.[29,30]

Days Until Return to Normal Activity

Three studies reported caregiver estimates of how many days until children resumed preoperative activity levels.[24,31,33] This was reported as medians of 5 days by Attard et al,[31] 7 days by Amin et al,[33] and 4.1 days by Chan et al.[24] In the initial 100 cases in the study by Amin et al, caregivers were advised that the children would require 2 weeks off school/nursery but this was subsequently relaxed as excellent recovery was reported.[33] Limitations to activity were not described in the other 2 studies.

Other Measures of Pain

Varadharajan et al[32] reported no readmissions for pain while Lee et al[23] reported 1 readmission (1/528) for dehydration secondary to pain and Powell et al[36] reported 18 readmissions for pain (18/5815). Mukerji et al[35] reported a lower percentage of patients required postoperative narcotics in the ICT with Coblation group when compared to extracapsular technique (2.8% vs 35%, $P < .0001$).

Regrowth

Zhang et al reported the proportion of tonsillar regrowth (which was not further defined) of 6.1% (5/82) in a mean follow-up period of 64.3 months.[26] Chan et al reported the proportion of patients with residual tonsil tissue at 3 and 12 months after surgery.[24] The proportion of patients with residual tonsil tissue at 3 and 12 months were 66.7% (14/21) and 72.7% (16/22), respectively. However, the volume of residual tonsil tissue was generally small and "seemed to be of no clinical consequence." The proportion of patients with residual tonsil tissue of greater than 10% were 9.5% (2/21) and 4.5% (1/22), respectively at 3 and 12 months postoperatively.[24]

Recurrent Tonsillitis Symptom Alleviation

Three studies assessed postoperative recurrent tonsillitis with a range of follow-up time between 30 and 1419 days.[28,32,33] Sunnergren et al asked the question "Did your child receive antibiotics because of infection?" on a 30-day questionnaire as part of the Swedish National Tonsil Registry and reported 5.2% (25/485) received antibiotics for tonsillitis following ICT with Coblation.[28] Varadharajan et al assessed symptom improvement by comparing the mean score of the infectious domain of the T14 questionnaire[37] before and after surgery, reporting a change from 22.1 to 1.5 over a median follow-up period of 15.2 months in 80 patients.[32] Amin et al evaluated symptoms by comparing the median score of the infectious domain of the T14 questionnaire.[33] A change in median infection score from 13 to 0 was reported for 1257 patients with a median implied follow-up period of 1419 days.

Sleep-Disordered Breathing/Obstructive Sleep Apnea Symptom Alleviation

Postoperative obstructive symptoms were evaluated in 7 studies with differing methods of assessment.[24,26,28-30,32,33,35] Three studies used OSA-18[38] and T14[37] symptom assessment tools. Borgström et al reported a reduction in median total OSA-18 symptom score from 66 to 31 in 36 patients 1 year after surgery.[29,30] Varadharajan et al and Amin et al both reported a reduction in the scores of the obstructive domain of the T14 questionnaire.[32,33] Varadharajan et al reported a mean reduction from 10.6 to 1.5 in 80 patients with a mean follow-up period of 13 months.[32] Amin et al reported a mean reduction from 17 to 0 in 1257 patients over a median follow-up of 1419 days (46.7 months).[33] In a randomized controlled trial comparing 27 children with ICT with Coblation to 28 children with ECT, Chan et al found no significant difference at 1-year postoperative follow-up in the extent of symptom elevation between the 2 groups.[24] This led the authors to conclude that ICT with Coblation was efficacious in treatment of children with obstructive tonsillar hypertrophy. Sunnergren et al reviewed the National Tonsil Register in Sweden from 2009 to 2012, and among patients who had ICT with Coblation (n = 374), 74.1% reported their symptoms were gone at 6 months follow-up, with further 21.4% reporting

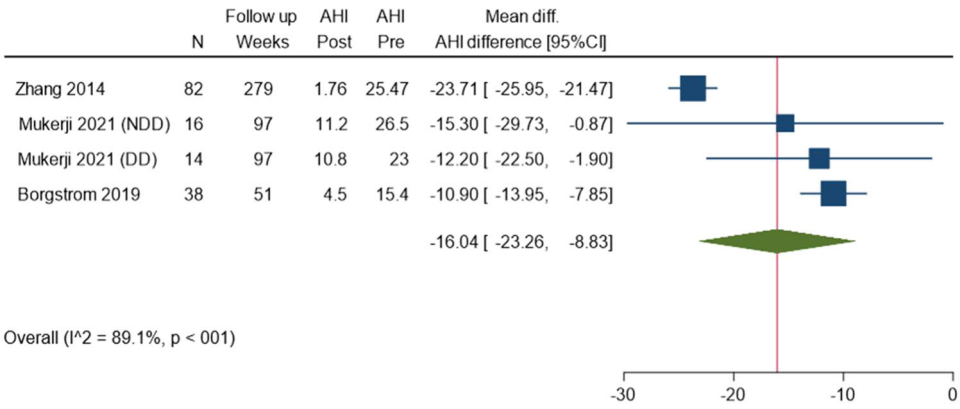

Figure 6. Forest plot of difference in mean Apnea-Hypopnea Index (AHI) with associated mean follow-up time in weeks; $I^2 = 89.1\%$, $P < .001$. CI, confidence Interval.

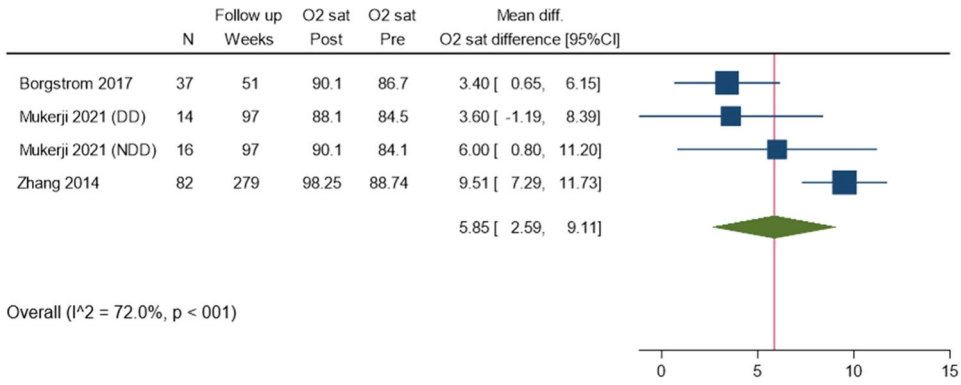

Figure 7. Forest plot of difference in mean oxygen saturation with associated mean follow-up time in weeks; $I^2 = 72.0\%$, $P < .001$. CI, confidence interval.

their symptoms were almost gone.[28] No patient reported worsening of their symptoms.

Polysomnography data were presented in 3 studies with follow-up between 51 and 279 weeks for a total of 150 patients.[26,29,30,35] Polysomnography data were pooled into a meta-analysis with a mean improvement in AHI of 16.0 events per hour (95% CI −8.8 to −23.3), with high heterogeneity across studies (I^2: 89.1%) (**Figure 6**). Meta-analysis also demonstrated an increase in mean oxygen saturation of 5.9% (95% CI 2.6%-9.1%) with high heterogeneity across studies (I^2: 72.0%) (**Figure 7**).

Further Revision

Six studies with a total of 7720 patients reported data on the proportion of patients who underwent revision tonsillectomy surgery following ICT with Coblation.[26,29,30,33-36] The pooled proportion of patients requiring further surgery was 1.4% (95% CI 0.6%-2.2%) as demonstrated in **Figure 8**. Heterogeneity was high across studies (I^2: 80.2). Zhang et al reported 2 patients undergoing revision due to symptoms of SDB.[26] Borgstrom et al reported 5 revisions in a mean period of 14 months after initial surgery for recurrence of OSA evaluated by symptoms, tonsillar re-growth, and AHI studies.[29,30] Amin et al reported 33 patients undergoing revision surgery.[33] Of these, 28 revisions in 27 patients were performed for recurrent obstructive symptoms in a median interval of 27.2 months from initial surgery and 6 patients had revisions for recurrent tonsillitis/sore throat at a median interval of 24.7 months from initial surgery. Naidoo et al reported 1 patient had revision for development of peritonsillar abscess.[34] Mukerji et al reported 5 revision tonsillectomies for recurrence of SDB symptoms.[35] Finally, Powell et al reported a total of 64 revision tonsillectomies but the indications were not clarified in the study.[36]

Discussion

This systematic review and meta-analysis found a low rate of total PTH of 1.0% and a revision tonsillectomy rate of 1.4% among patients who underwent ICT with Coblation. With the combination of intracapsular approach and the Coblation device, this review could not demonstrate whether the low rate of PTH could be attributed to the intracapsular technique or the Coblation device.

This systematic review did not examine ICT using other devices. However, the ICT technique has consistently been reported to have a lower rate of PTH compared to ECT techniques.[39-41] In a systematic review,

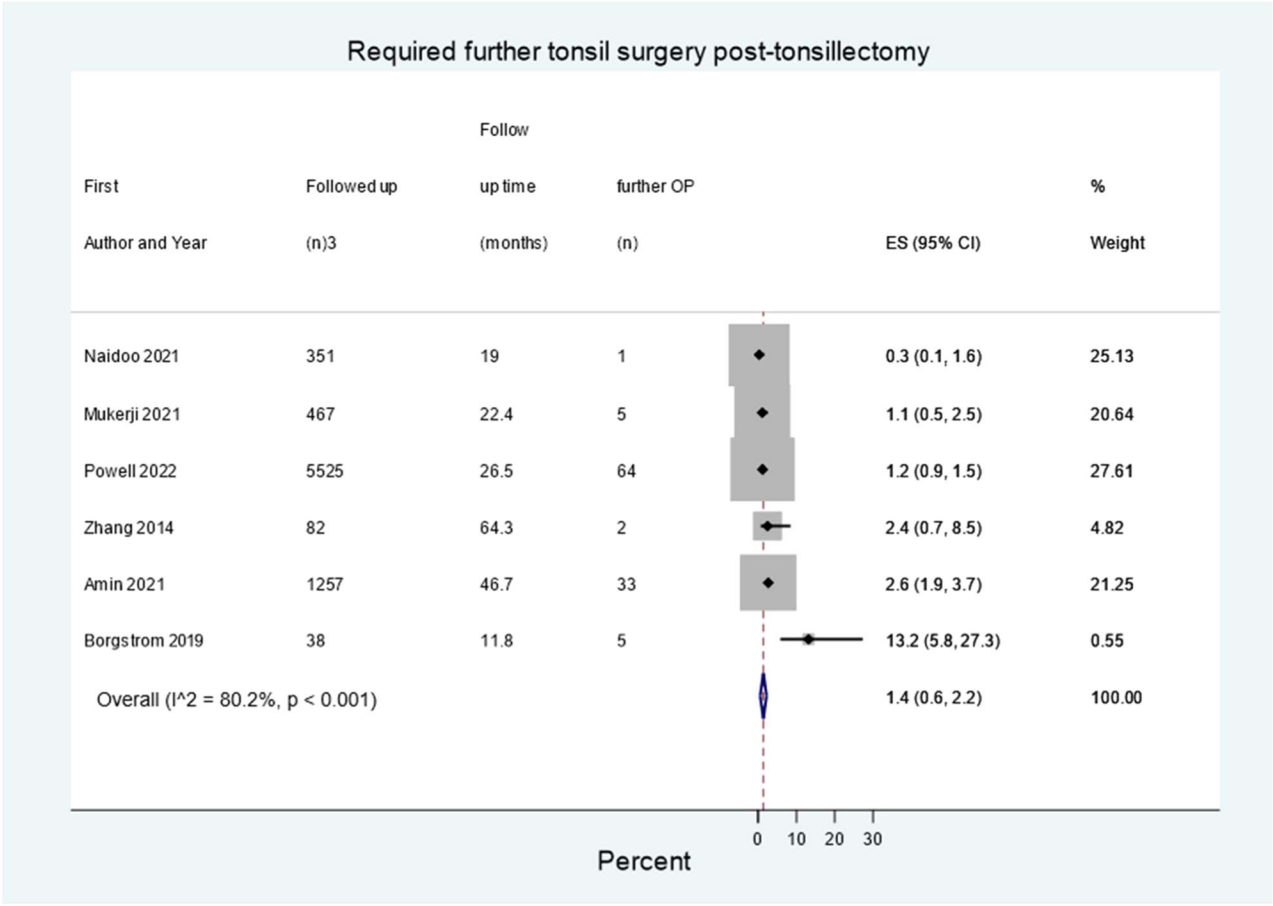

Figure 8. Forest plot of proportion of patients undergoing further surgical revision following intracapsular tonsillectomy with Coblation; $I^2 = 80.2\%$, $P < .001$. CI, confidence interval; ES, estimated size.

Daskalakis et al compared the rate of PTH in patients who underwent ICT with those who underwent ECT with Coblation.[42] In total 3 studies, including 209 patients who had ICT with Coblation and 311 patients who had ECT with Coblation, were analyzed. Two patients (1.0%) in the ICT with Coblation group experienced PTH as opposed to 16 patients (5.1%) in the ECT with Coblation group, albeit no meta-analysis was carried out.[42] When the Coblation device is used for ECT, it appears that the rate of PTH is comparable to other ECT techniques. A 2011 systematic review of 24 studies looking at ECT with Coblation reported rates of overall, primary, and secondary PTH as 4.1%, 0.9%, and 3.6% respectively.[43] Similarly when comparing across ICT devices, a 2017 meta-analysis by Kim et al found no difference in PTH between ICT with microdebrider and ICT with Coblation groups.[41] This leads to a postulation that the technique of ICT rather than the device contributes to a lower rate of PTH. This conclusion is supported by anatomical studies of the tonsil, such that any ICT surgery would lead to reduced bleeding regardless of the device used. Assuming postoperative PTH outcomes are shown to be similar in the ICT group regardless of the device used, other factors such as cost, and availability of equipment may dictate the appropriate device used. In a retrospective study comparing adenoidectomy techniques, Sjogren et al found that while the cost of use of microdebrider or Coblation device for adenoidectomy were similar ($833 and $797, respectively), the need for revision surgery was higher among patients in the microdebrider group (9.7% vs 5.3%, $P = .0336$).[44]

Our study has suggested that ICT with Coblation is favorable with respect to pain outcomes. This conclusion is similar to previous meta-analyses comparing Coblation with other techniques.[20,45,46] While the heterogeneity of the data does not allow a strong conclusion that ICT with Coblation is less painful, pooling qualitative data from individual studies would suggest this.

Our study confirms significant improvement in SDB symptoms post-ICT with Coblation with the outcome comparable to ECT techniques. Assessment of symptom alleviation for SDB varied between studies therefore quantitative analysis was conducted on available polysomnography data. The mean improvement in AHI was 16.0 (95% CI −8.8 to 23.3) events per hour as shown in **Figure 4**. Comparatively, a 2009 meta-analysis of 1079 patients undergoing ECT and adenoidectomy for SDB reported mean improvement in AHI of 12.4 events per

hour.[47] While there are no studies with direct comparison of AHI between ICT with Coblation and ECT with Coblation, a 2018 Meta-analysis comparing ICT with microdebrider to conventional ECT techniques demonstrated no significant difference in postoperative AHI scores between the 2 techniques.[48] This would support the postulation that the ICT with Coblation is comparable in efficacy in symptom alleviation for SDB.

ICT for recurrent tonsillitis has been criticized for concerns that remaining lymphoid tissue can still become infected and undergo hypertrophy. In a systematic review of 1312 pediatric patients, Walton et al found no significant difference in the rate of pharyngitis between the ICT and the ECT groups.[39] The paucity of data on recurrent tonsillitis rates following ICT with Coblation does not allow this aspect to be fully addressed despite encouraging findings from the included studies.

The pooled rate of revision surgery was 1.4% in this systematic review. The rate of revision surgery following ICT varies between 0.8% and 11.9% in the literature.[49] Odhagen et al examined the rate of revision tonsillectomy surgery among 27,535 pediatric patients (aged 1-12 years) and reported a revision rate of 3.9% among those who underwent ICT and 0.6% among those who underwent ECT.[50] The rate of revision surgery was shown to be inversely related to the age at which primary surgery was performed.[50] Variation in the rates between studies could be attributed to the age at the primary operation, duration of follow-up, and how close to the tonsillar capsule the ICT with Coblation is taken. Subtypes of ICT have been recognized with "intra-capsular complete tonsillectomy" referring to removal of all tonsil tissue without breaching the tonsillar capsule, "intra-capsular partial tonsillectomy" where most, but not all, of tonsillar tissue is removed, and finally "tonsillotomy" where the exophytic or crypts of the tonsils are removed.[5] This subclassification is not consistently utilized therefore subgroup analysis was not possible.

Considering limitations of this study, the variation in reporting and the lack of standardization contributed to high heterogeneity in almost all the meta-analyses in this study. This systematic review and meta-analysis sought to have a broad scope to capture the current practice of ICT. All but 3 studies were observational studies and of the included randomized-controlled trials the number of participants were small. When evaluating these studies with a modified ROBINS-I criteria, most studies had a moderate risk of bias.

In meta-analysis of secondary PTH, the heterogeneity across studies was high. This potentially reflects clinical diversity such as variation in how secondary PTH is captured in these studies. Methodological diversity between studies (eg, retrospective vs prospective studies, or observational vs interventional studies) may have also contributed to heterogeneity. Primary PTH or PTH requiring surgical intervention would be a more objective measure of PTH and this is reflected in low heterogeneity seen in both meta-analyses of primary PTH and return to theatre. However, this is 1 extreme, relatively uncommon, and not an accurate representation of the typical clinical presentation.

Due to significant heterogeneity in the measurements of pain, we were unable to make strong conclusions regarding the pain outcomes of ICT with Coblation. Furthermore, there was considerable variation in post-operative instruction which is not unexpected given differences in surgeon preference. The extent that post-operative guidance played in parental/patient expectations and experience of pain, activity levels, dietary intake, and other aspects of recovery is difficult to evaluate. Postoperative analgesic guidance was not consistently reported. We could not draw meaningful conclusions on how significantly subjective reports of pain were confounded by patients' analgesic regimes. We were similarly unable to evaluate the effect of post-operative guidance on return to activity or normal diet.

There was a variable length of follow-up therefore patients who underwent further revision surgery outside of the "follow-up" time frame will not have been captured. Therefore, the revision rate in this study may be an underestimate of the true revision rate. Similarly, the timing at which revision surgery took place relative to the time of the initial surgery, and the age at which revision surgery was undertaken, was not consistently reported. This lack of standardized follow-up period limits the conclusions which can be drawn regarding the effect of age on the rates of revision surgery following ICT with Coblation. However, the same limitations could also apply to the rate of revision in studies with ECT. This systematic review only examined ICT with Coblation, however, other methods of ICT are available and a large, randomized control trial may be required to compare the efficacy of different ICT devices. Finally, cost-analysis, not reviewed in this study, is likely to play an important role in decision making at an institutional level where resources and financial restraints are common.

Conclusion

ICT with Coblation is an effective technique for tonsillectomy. There is a low rate of PTH and there appears to be a favorable postoperative pain outcome. This will need to be balanced against what appears to be a slightly higher rate of revision surgery compared to ECT and should form part of the informed consent discussion.

Author Contributions

Huiying Lin, study conception and design, study selection and evaluation, data extraction, writing of manuscript; **Behzad Hajarizadeh**, study conception and design, data analysis and interpretation, writing of manuscript; **Andrew James Wood**, study conception and design, writing of manuscript, study supervision. **Kumanan Selvarajah**, study conception and design, writing of manuscript. **Omid Ahmadi**, study design, study selection and evaluation, writing of manuscript, study

supervision. All authors discussed results and reviewed the final manuscript.

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