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Very-Low Energy Monopolar Reduces Post-Tonsillectomy Hemorrhage Versus Standard Energy Techniques

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Objectives/Hypothesis: To compare rates of post-tonsillectomy hemorrhage (PTH) between a very-low energy transfer monopolar technique (VLET) and standard energy techniques.

Study Design: Retrospective controlled cohort study.

Methods: All tonsillectomies performed by practice physicians during the period January 1, 2010 to August 31, 2019 were identified. Three groups were created based on surgeon technique utilization: the study group (VLET) and two control groups (exclusive standard energy monopolar [Standard]; exclusive "hot" technique without exclusive monopolar use [Mixed "Hot"]). Each group's PTH occurrences requiring surgical intervention (PTHRSI) were identified and rates compared.

Results: During the study period 11,348 tonsillectomies were performed (4,427 Standard, 1,374 VLET, 5,547 Mixed "Hot"), and 167 (1.47%) PTHRSI events identified (14 primary (<24 hours), 153 secondary (>24 hours), 12 repeat (>1PTHRSI/patient). Compared to the Standard group secondary and total PTHRSI rates (1.47%, 1.60%), the Mixed "Hot" group experienced similar rates (1.57%, $P = .54$; 1.68%, $P = .64$), but the VLET group experienced significantly lower rates (0.15%, $P = .0026$, adjusted odds ratio [OR] 0.114 [0.028–0.469]; 0.22%, $P = .0016$, adjusted OR 0.155 [0.048–0.494]). Age was a significant risk factor for both secondary and total PTHRSI ($P = .0025$, $P = .0024$, adjusted OR 1.02/year [1.01–1.03]). No significant difference in rate of primary PTHRSI was seen collectively or in any age group. The <12VLET Group experienced 0 episodes of secondary PTHRSI and a total PTHRSI rate of 0.09% in 1060 tonsillectomies.

Conclusions: Standard energy techniques had an adjusted odds ratio over 8-fold higher for secondary PTHRSI and over 6-fold higher for total PTHRSI compared to the minimized energy transfer VLET technique.

Key Words: Tonsillectomy, hemorrhage, electrocautery, diathermy, monopolar, energy.

Level of Evidence: 3

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INTRODUCTION

Tonsillectomy is one of the most frequently performed surgical operations.[1] It is a low-risk procedure with few complications. Postoperative pain is a significant concern, but hemorrhage is the most feared complication due to its association with fatality, especially in pediatric patients with insufficient vascular reserve.[2] Post-tonsillectomy hemorrhage (PTH) remains the number one complication causing mortality and malpractice settlements, apart from the increased cost of necessary treatment.[3]

Additionally, for every episode of operative bleeding, there is a reported 7%–12% chance of repeat bleeding requiring additional operative treatment.[4,5] Each of these surgical procedures carries additional risk of anesthetic complications related to airway control issues for emergent intubation in a bleeding individual with a full stomach.

Tonsillectomy consists of two phases, the dissection phase of removing the tonsil, and the hemostasis phase where bleeding caused during the dissection phase is controlled. PTH is categorized as primary when occurring within the first 24 hours after surgery, and secondary when occurring anytime thereafter.[1,6] It is generally accepted that primary PTH is due to inadequate hemostasis and secondary PTH is related to tissue trauma incurred during dissection and hemostasis.[1,7,8] A wide body of literature reports the lowest secondary bleeding rates are associated with purely cold (no diathermy) techniques.[8–16] These are considered the "gold standard."[17] Unfortunately purely cold techniques lead to higher intraoperative blood loss[6,17] and rates of primary PTH,[11,12,18,19] which is difficult to rationalize especially for a young child.[4,6,10,14,20] In contradistinction, techniques utilizing diathermy (hot) components for either dissection or hemostasis have been shown to result in higher rates of secondary PTH.[8–11,16,19]

A recent American survey reported monopolar cautery is currently the most popular technique utilized for tonsillectomy.[21] Very few studies examining bleeding complications related to electrosurgical tonsillectomy state the power settings used to perform the dissection or hemostasis[6,7,22] compared to studies that do not.[2,4,8,11–13,15–17,19,20,23,24] Given the association of electrosurgical techniques with secondary

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hemorrhage, this seems a critical factor to ignore. According to the first law of thermodynamics, higher electrical energy delivered to the tissue can only be dissipated as heat which means more and deeper tissue damage in the tonsillar fossa.

With the goal of finding a technique with minimized intraoperative blood loss and postoperative primary bleeding rates typically associated with electrosurgical dissection, very low postoperative secondary bleeding rates typically associated with cold knife dissection, and the highest surgical success rates normally achieved only with complete extracapsular tonsillectomy,[25,26] the author developed the very low energy needle-point monopolar electro-dissection technique described herein.

The objective of this study is to investigate if utilizing a minimized energy transfer monopolar tonsillectomy technique results in a lower rate of PTH compared to typical higher energy techniques.

MATERIALS AND METHODS

Patients

Institutional review board (IRB) exemption was granted from the University of Louisville IRB (#19.1033). The practice Greenway electronic health record billing system was queried for patients who underwent tonsillectomy with or without other procedures during the study period January 1, 2010 through August 31, 2019 and 11,348 patients identified. Age in years to one decimal place, sex, and indication for surgery for each patient was recorded. We divided the cohort of patients into three treatment groups, a study (VLET) and two controls (Standard and Mixed "Hot"), based on technique energy utilization. For each group, bleeding control codes (42960, 42961, 42962) were queried through September 31, 2019 and 186 PTH occurrences identified. Those records were reviewed in detail by a two-surgeon study team to confirm an operative report related to control of PTH. Nineteen events were found to have nonoperative control and 167 hemorrhages required surgical intervention in the operating room (PTHRSI). Hemorrhages having control performed within the 24 hours postoperatively were considered primary hemorrhages (1PTHRSI), and those having control beyond 24 hours postoperatively were considered secondary hemorrhages (2PTHRSI). Repeat episodes in the same patient were considered repeat hemorrhages (>1PTHRSI).

Interventions

All tonsillectomies performed by the practice's surgeons (19) during the study period were performed utilizing "hot" techniques (laser, coblation, monopolar, plasma knife, or a combination). Each surgeon's procedures were performed at multiple facilities with multiple models of electrosurgical generators. Every surgeon was residency trained. Practice patterns regarding ibuprofen usage were collected for each surgeon and their patients assigned into three categories: ibuprofen avoidance, possible ibuprofen, and scheduled ibuprofen.

VLET Group

The VLET group consists of the patients operated by the author (near the middle of the experience level) utilizing solely the very low energy transfer needle-point monopolar technique. Every patient underwent tonsillectomy with the same intent: to perform an as complete as possible extracapsular dissection minimizing the electrical and mechanical tissue trauma to the remaining tissue bed. Dissection was completed using a bovie pen with a guarded teflon needle tip (Covidien EDGE Insulated Needle Electrode Model 1465) trying to stay in the plane directly extracapsular with the energy aimed at the tonsillar specimen whenever possible. Power settings were 0-1 W pure cut, 8 W fulgurate coagulation. Hemostasis was achieved using the suction monopolar cautery with power settings of 0-1 W pure cut, 25 W fulgurate coagulation. Short bursts of precise "spot welding" were used to minimize the transfer of electrical energy to the least amount possible yet achieve hemostasis. The procedures were performed at 13 facilities with multiple different electrosurgical generators. No routine blood tests were obtained preoperatively. Intravenous decadron was routinely used by the

TABLE I.
Tonsillectomy Group Demographics.

	Total	Mixed "Hot"[†]	Standard[‡]	VLET[§]	*P* Value[*]
Surgeons	19	10	8	1	
Mean Age	12.21	12.56	12.36	10.28	<0.0001
SD	11.59	12.01	11.56	9.63	
Female (%)	6296 (55.48%)	3124 (56.32%)	2451 (55.36%)	721 (52.47%)	0.0364
Male (%)	5052 (44.52%)	2423 (43.68%)	1976 (44.64%)	653 (47.53%)	
Obstruction[‖] (%)	6214 (54.76%)	3113 (56.12%)	2317 (52.34)	784 (57.06%)	<0.0001
Infection[¶] (%)	4826 (42.53%)	2343 (42.24%)	1933 (43.66%)	550 (40.03%)	
Both[#] (%)	101 (0.89%)	17 (0.31%)	47 (1.06%)	37 (2.69%)	
Neither[††] (%)	207 (1.82%)	74 (1.33%)	130 (2.94%)	3 (0.22%)	
Total	11,348	5547	4427	1374	

[*] *P*-values calculated by analysis of variance for mean age and chi-squared for sex between the three groups.
[†] Tonsillectomies performed by 10 surgeons utilizing more than one "hot" technique (incl. monopolar, coblation, laser, plasma knife).
[‡] Tonsillectomies performed by eight surgeons solely utilizing standard energy monopolar diathermy.
[§] Tonsillectomies performed by one surgeon solely utilizing very low energy transfer needle-point monopolar technique.
[‖] Indication related to obstruction/enlargement.
[¶] Indication related to infection.
[#] Indication related to both obstruction/enlargement and infection.
[††] Indication related to neither obstruction/enlargement nor infection.

TABLE II.
Ibuprofen Utilization Among Groups based on Surgeon Practice Pattern.

	VLET[†]	Standard[‡]	Mixed "Hot"[§]
Ibuprofen recommended[‖]	394 (28.68%)		438 (7.90%)
Ibuprofen possibly recommended[¶]		499 (11.27%)	2079 (37.48%)
Ibuprofen avoided[#]	980 (71.32%)	2907 (88.73%)	3030 (54.62%)
Total	1374	4427	5547

[†]Tonsillectomy performed by one surgeon solely utilizing very low energy transfer needle-point monopolar technique.
[‡]Tonsillectomy performed by eight surgeons solely using standard energy monopolar diathermy.
[§]Tonsillectomy performed by 10 surgeons not solely using monopolar diathermy (incl. monopolar, coblation, laser, plasma knife).
[‖]Patients recommended scheduled postoperative ibuprofen.
[¶]Patients recommended avoiding postoperative ibuprofen or scheduled ibuprofen due to change in surgeon practice pattern.
[#]Patients recommended scheduled post-operative ibuprofen.

TABLE III.
Group Post-Tonsillectomy Hemorrhage Requiring Surgical Intervention Results.

Technique	Tonsillectomies	PTHRSI[†]	1PTHRSI[‡]	2PTHRSI[§]	>1PTHRSI[¶]
All	11,348	167 (1.47%)	14 (0.12%)	153 (1.35%)	11 (7.05%)
Mixed "Hot"[#]	5547	93 (1.68%)	6 (0.10%)	87 (1.57%)	4 (4.49%)
Standard[††]	4427	71 (1.60%)	6 (0.14%)	65 (1.47%)	7 (10.94%)
VLET[‡‡]	1374	3 (0.22%)	1 (0.07%)	2 (0.15%)	0 (0.00%)

[†]Post-tonsillectomy hemorrhage requiring surgical intervention.
[‡]Primary post-tonsillectomy hemorrhage requiring surgical intervention.
[§]Secondary post-tonsillectomy hemorrhage requiring surgical intervention.
[¶]Repeat post-tonsillectomy hemorrhage requiring surgical intervention.
[#]Tonsillectomy performed by 10 surgeons not solely utilizing monopolar diathermy (incl. monopolar, coblation, laser, plasma knife).
[††]Tonsillectomy performed by eight surgeons solely utilizing standard energy monopolar diathermy.
[‡‡]Tonsillectomy performed by one surgeon solely utilizing very low energy transfer needle-point monopolar technique.

TABLE IV.
Analysis of Risk Factors for per Patient PTHRSI[†].

	Total PTHRSI		Secondary PTHRSI	
Risk Factor	Odds Ratio [95% CI]	*P* Value[*]	Odds Ratio [95% CI]	*P* Value
Sex				
Male	1.0		1.0	
Female	0.89 [0.65–1.22]	0.47	0.97 [0.69–1.36]	0.85
Age (per year)	1.018 [1.006–1.030]	0.0024	1.017 [1.006–1.029]	0.0025
Group				
Standard[‡]	1.0		1.0	
Mixed "Hot"[§]	1.08 [0.78–1.50]	0.64	1.11 [0.79–1.56]	0.54
VLET[‖]	0.155 [0.048–0.494]	0.0016	0.114 [0.028–0.469]	0.0026
Indication				
Neither[¶]	1.0			
Obstruction[#]	1.83 [0.42–7.95]	0.42		
Infection[††]	3.23 [0.76–13.73]	0.11		
Both[‡‡]	2.49 [0.22–28.86]	0.47		

[*]*P*-values calculated by multivariate logistic regression, repeat bleeding episodes excluded. Indication excluded from 2PTHRSI due to poor data fit.
[†]Post-tonsillectomy hemorrhage requiring surgical intervention.
[‡]Tonsillectomy performed by eight surgeons solely using standard energy monopolar diathermy.
[§]Tonsillectomy performed by 10 surgeons not solely using monopolar diathermy (incl. monopolar, coblation, laser, plasma knife).
[‖]Tonsillectomy performed by one surgeon solely utilizing very low energy transfer needle-point monopolar technique.
[¶]Indication related to neither obstruction/enlargement nor infection.
[#]Indication related to obstruction/enlargement.
[††]Indication related to infection.
[‡‡]Indication related to both obstruction/enlargement and infection.

TABLE V.
VLET[†]/Standard[‡] Groups PTHRSI[§] Comparison.

Collective	Tonsillectomies	PTHRSI	1PTHRSI[‖]	2PTHRSI[¶]	>1PTHRSI[#]
Standard	4427	71 (1.60%)	6 (0.14%)	65 (1.47%)	7 (10.94%)
VLET	1374	3 (0.22%)	1 (0.07%)	2 (0.15%)	0 (0.00%)
P-value*		<.00001	1	<.00001	1
<12 years old	Tonsillectomies	PTHRSI	1PTHRSI	2PTHRSI	>1PTHRSI
Standard	2957 (66.8%)	29 (0.98%)	3 (0.10%)	26 (0.88%)	1 (3.57%)
VLET	1060 (77.1%)	1 (0.09%)	1 (0.09%)	0 (0.00%)	0 (0.00%)
P-value		0.0026	1	0.0005	1
≥12 years old	Tonsillectomies	PTHRSI	1PTHRSI	2PTHRSI	>1PTHRSI
Standard	1470 (33.2%)	42 (2.86%)	3 (0.20%)	39 (2.65%)	6 (16.67%)
VLET	314 (22.9%)	2 (0.64%)	0 (0.00%)	2 (0.64%)	0 (0.00%)
P-value		0.0158	1	0.035	1

*P-values calculated using Fisher's exact test.
[†]Tonsillectomy performed by one surgeon solely utilizing very low energy transfer needle-point monopolar technique.
[‡]Tonsillectomy performed by eight surgeons solely using standard energy monopolar diathermy.
[§]Post-tonsillectomy hemorrhage requiring surgical intervention.
[‖]Primary post-tonsillectomy hemorrhage requiring surgical intervention.
[¶]Secondary post-tonsillectomy hemorrhage requiring surgical intervention.
[#]Repeat post-tonsillectomy hemorrhage requiring surgical intervention.

anesthetist at a dose of 0.5 mg/kg up to 10 mg. An injectate of either 0.20% ropivacaine or 0.25% bupivacaine was injected into the tonsillar fossa at the completion of the procedure. Perioperative antibiotics were not used unless indicated for another medical condition. A soft diet was recommended for 14 days and any activity within reason was allowed.

The Standard Group

The standard group consists of the patients undergoing tonsillectomy by the eight other surgeons in the practice solely utilizing monopolar dissection and hemostasis. Power settings included: pure or blend cut ranging from 0 W to 30 W in combination with spray cautery ranging from 12 W to 20 W.

The Mixed "Hot" Group

The Mixed "Hot" group consists of patients undergoing tonsillectomy by the 10 surgeons in the practice not solely utilizing monopolar dissection and hemostasis during the study period. Techniques included monopolar, coblation, CO_2 laser, the plasma knife, or a combination.

Subgrouping

The data from the purely monopolar groups (Standard and VLET) were divided into two subgroups by age (<12 years old and ≥12 years old).

Statistical Analysis

One-way analysis of variance was used to compare the mean ages among the three treatment groups. Association between the categorical variables treatment group and sex was examined by chi-squared test. Associations between treatment group and indication as well as indication and PTHRSI were examined by Fisher's exact test. In an attempt to correct for known associations with PTH, logistic regression in SAS was used to model binary response variables given the variables age, sex, indication, and treatment group. Odds ratios include 95% confidence intervals. For the purely monopolar treatment groups, the independence between treatment group and the categorical variables PTHRSI, 1PTHRSI, 2PTHRSI, and >1PTHRSI was examined using Fisher's exact test in R due to small cell counts. *P*-values of greater than .05 were considered not significant.

RESULTS

Characteristics of Patients

A total of 11,348 tonsillectomies were performed during the study period (5547 Other "Hot," 4427 Standard, 1347 VLET). The patients in the VLET group were on average 2.08–2.28 years younger ($P < .0001$) and 2.89%–3.85% higher percentage male ($P = .0364$) than the Standard and Mixed "Hot" groups, respectively. There was a significant difference in indication distribution among the three groups ($P < .0001$). Ibuprofen usage was higher in the VLET group (28.7%) than the maximum possible in the Standard group (11.27%) (Tables I and II).

Multivariate Analysis of PTHRSI Risk

With only 14 events, there were not enough occurrences of 1PTHRSI for multivariate analysis. Adding Indication to 2PTHRSI analysis resulted in lack of fit so it was excluded. There was no significant difference in the rate of PTHRSI or 2PTHRSI between the Mixed "Hot" group (1.68%, 1.57%) and the Standard group (1.60%, 1.47%; $P = .64, .54$). The VLET group, however, did have a significantly lower PTHRSI rate (0.22%, odds ratio [OR] 0.155 [0.048–0.494]; $P = .0016$) and 2PTHRSI rate (0.15%, OR 0.114 [0.028–0.469]; $P = .0026$). Gender did not have an effect on PTHRSI ($P = .47$) or 2PTHRSI ($P = .85$) rates. Increasing age was a significant risk factor for both PTHRSI ($P = .0024$) and 2PTHRSI ($P = .0025$), with a per year odds ratio of 1.02 [1.01–1.03] for each. In reference to neither infection nor obstruction,

indication did not have a significant effect on PTHRSI rate (infection $P = .11$, obstruction $P = .42$, both $P = .47$) (Tables III and IV).

Purely Monopolar Techniques (Standard and VLET Groups)

For 2PTHRSI, compared to the standard group, the VLET group experienced a significant decrease for those <12 years old (0.00% vs. 0.88%, $P = .0005$), for those ≥12 years old (0.64% vs. 2.65%, $P = .0347$) and collectively (0.15% vs. 1.47%, $P < .0001$). For 1PTHRSI there was no significant difference between the groups in any age subgroup or collectively (0.00%–0.09% vs. 0.10%–0.20%, $P = 1$) which was rare (0.2% or lower) regardless of technique. Secondary PTHRSI made up 92% of all PTHRSI in the Standard group and 67% in the VLET group. The reduction in 2PTHRSI while maintaining the same rate of 1PTHRSI led to a significant reduction in the rate of total PTHRSI for those <12 years old (0.09% vs. 0.98%, $P = .0026$), for those ≥12 years old (0.64% vs. 2.86%, $P = .0158$) and collectively (0.22% vs. 1.60%, $P < .0001$). The VLET group had no episodes of >1PTHRSI, while the standard group had a >1PTHRSI rate of 3.57% in the younger group, 16.67% in the older group, and 10.94% collectively. This lacked sufficient power (n = 64) to be statistically significant ($P = 1.0$ for all groups) (Table V).

The VLET technique was associated with zero episodes of 2PTHRSI in those <12 years old in 1060 tonsillectomies.

DISCUSSION

Tonsillectomy is considered to be a highly effective procedure for the current indications. Despite this, there remains some morbidity and inherent risks of the procedure. Pain and bleeding remain the top concerns[2,3,6,13,19,27,28] and the number one and two reasons cited for changing techniques.[28]

Postoperative hemorrhage will always be a concern and every effort should be made to reduce this complication as it is the number one cause of mortality.[3] The results of this study show a modification of the most popular technique utilized by otolaryngologists in America[21,28] reduces the odds ratio of PTHRSI by over six times, meaningfully lowering the rate to 0.22%, while maintaining the highest surgical success rates normally only achieved by extracapsular tonsillectomy.[25,26] The difference compared to the other groups was achieved by reducing the 2PTHRSI rate which made up the majority of PTHRSI. A key observation: utilizing the VLET technique in the population most vulnerable to the lethal side effects of hemorrhage, those less than 12 years old, resulted in zero episodes of 2PTHRSI in 1060 tonsillectomies. This same group benefits the most from decreased intraoperative blood loss related to using "hot" diathermy techniques in place of cold dissection.[6,10,14,20]

Fortunately, PTH is an uncommon complication, therefore it requires high power studies to demonstrate differences in outcomes.[29] A 2017 meta-analysis of 73 studies involving pediatric tonsillectomy found a total PTHRSI rate of 2.2%.[30] A 2013 meta-analysis found the average total PTHRSI rates to be close to 2% (0.91%–4.5%).[26] Their recommendation was to lower the diathermy current to the lowest level possible to minimize PTH. A 2011 large multi-center prospective trial found PTHRSI rates of 1.5% (0.7% 1PTHRSI and 0.8% 2PTHRSI).[8] They found techniques with the highest amounts of heat resulted in the highest rates of 2PTHRSI. The largest prospective tonsillectomy trial to date (n = 33,921), the National Prospective Tonsillectomy Audit, showed among the various techniques, the lowest 1PTHRSI rate (0.3%) was achieved with the addition of bipolar cautery hemostasis to cold steel dissection, which was associated with a 2PTHRSI rate of 0.4%.[31] The lowest 2PTHRSI rate (0.2%) was achieved with purely cold steel dissection and hemostasis but yielded a 1PTHRSI rate of 0.7%. Before the trial was complete, an interim report was published noting higher 2PTHRSI rates with "Hot" techniques and recommended a reduction in amount of energy used. After this guidance the 2PTHRSI rates decreased (0.6% to 0.4%) but the 1PTHRSI rate increased (0.4% to 0.5%). Several other studies have shown diathermy provides protection against 1PTHRSI,[8,10–12,19] but is a substantial risk factor for 2PTHRSI.[8–12,19] There appears to be a delicate balance to using as little as possible energy for dissection and hemostasis to minimize 2PTHRSI yet adequate energy for hemostasis to minimize 1PTHRSI which is a principle the VLET technique obeys. The lowest PTHRSI rate we have found reported in a large series for complete electrocautery tonsillectomy was a pediatric study by Gallagher utilizing "low-wattage electrocautery."[23] In their group of 1289 patients, the PTHRSI rate was 0.31%. The VLET group PTHRSI rate (0.22%) is slightly lower than this rate despite including older ages associated with a higher rate of PTH. Although the wattage settings were not described in their study, it is possible the VLET technique further reduced the tissue energy transfer and similarly reduced the PTHRSI rate. The PTHRSI rates in the Standard group (1.60%) and Mixed "Hot" group (1.68%) are in line with the international norms reported for hot techniques. The VLET group has a 1PTHRSI rate (0.07%) that compares favorably to the best 1PTHRSI rate achieved by the addition of bipolar hemostasis to cold dissection (0.3%) yet maintains a 2PTHRSI rate (0.15%) that compares favorably to the best 2PTHRSI rate in the purely cold group (0.2%).[31] Thus, it has neither the results expected from a cold nor hot technique alone yet preserves the benefits of both techniques.

Energy in Tonsillectomy

The ideal application of energy for tonsillectomy has to date remained elusive. A study examining tissue penetration of electrosurgical currents found joule heating, not heat conduction, to be primarily responsible for unintended thermal damages.[32] As energy delivered is the product of power setting selected and time of application, time is as important a factor as the power setting. Using low power settings with short pulse time was recommended. A critical component of the VLET technique is the precise application and short pulse times used for cauterization of bleeding vessels. This is essential during the hemostasis phase of the operation as during this time the energy is aimed at muscle tissue, which is subject to the highest rate of joule heating and

thermal damage making it susceptible to later tissue necrosis and exposure of vessels causing secondary hemorrhage. This theory is supported by Lowe showing the careful application of 6-8 W of bipolar energy hemostasis after cold steel tonsillectomy resulted in the same rate of secondary hemorrhage as purely cold tonsillectomy.[33] They determined there was a dose–response relationship to the power settings selected and complications. It was proposed that those who chose a lower power setting could have naturally used that power more judiciously. Reducing the amount of deep energy transmission could be accomplished with another technique. Intracapsular tonsillotomy preserves a rind of residual tonsil which provides a layer of protection from energy related necrosis to the underlying musculature. In a recent large meta-analysis tonsillotomy was associated with a PTHRSI rate of 0.2%. although it was also associated with a revision tonsillectomy rate of 1.37% which negates some benefits of avoiding re-operation for PTHRSI.[34] As the VLET 2PTHRSI rates are similar or better to the best results in a large series of energy-less, purely "cold" tonsillectomies, it appears that the VLET power setting and technique is sufficiently low enough to limit energy transfer.

Although not a part of this study, there may be potential benefits to the VLET technique other than reduced PTH rates. A study by Cardozo involved a novel device that measured time application of power (power-time product) and showed a positive correlation between postoperative pain measured at all four time points and energy usage, although the study was not of a sufficient power (n = 101) to show a difference in 2PTHRSI.[27] Their study supports the possibility that the lower energy transfer used in the VLET technique could result in less postoperative pain. Recently, a report by Carr demonstrated reducing the power settings for tonsillectomy resulted in a higher than linear reduction in plume particulate concentrations measured near the surgeon.[35] The lowest setting for their study was 12 W, so reducing the settings to 8 W, as used in our study, would likely further reduce the particulate concentrations and exposure to operating room personnel.

Unfortunately, studies that measure the time and power product are not common and therefore data on energy as a variable in the etiology of primary and secondary hemorrhage is not widely available. Despite this there are multiple studies that demonstrate lower rates of secondary hemorrhage with the minimization of diathermy which this study further supports.[8–12,14,22]

Study Limitations

Retrospective review. Because of the retrospective nature of this study, and the limitations of the database, it is possible PTHRSI episodes were not counted due to not being billed properly or having their hemorrhage controlled outside the practice. This inaccuracy should be similar between the three groups. Compared to minor bleeding, PTHRSI is felt to be the most accurate and meaningful method of tracking PTH as it creates a recognizable event.[5,8,10,12] A previous study has reported that 53% of PTH resolves spontaneously and this less clinically significant bleeding is likely to be missed by retrospective reviews.[4] Since 2011 the AAO guidelines have recommended the documentation of bleeding episodes and analyzing hemorrhage rates annually.[1,36] The PTHRSI rates for the Standard and Mixed "Hot" groups are in line with those previously reported in the literature indicating reasonable data validity.

NSAID use. Differences in NSAID use among the groups could affect bleeding rates. As ibuprofen is a non-prescription medication without record, we provided the surgeon practice patterns in an attempt to control for this. Based on these patterns, it is unlikely comparisons between the VLET and Standard groups were affected by ibuprofen usage.

Surgeon experience. There are studies suggesting that experience can be a PTH factor[8,10,24] and some suggesting the opposite.[9,13,19,23] This study only involved a group of fully trained, experienced surgeons in which the author was near the middle of the experience level.

It is certainly possible an unknown factor was not considered in the analysis which could have influenced PTH. Despite the shortcomings, the results of this study are consistent with relevant literature reporting decreased energy transfer leads to decreased tissue damage and lower secondary PTH rates.[8–12,14,19]

Future Directions

It has previously been advocated that the makers of electrocautery devices feature a display of total energy delivered[27,31] and we concur this would provide vital feedback to the surgeon. Data from such a device could yield the missing variable required to correlate the inconsistent rates of PTH and pain. Considering the low PTHRSI rates seen in this study, a very-large prospective trial would be the only way to achieve adequate power in a reasonable time period. This retrospective review in the least provides possible considerations to design such a study.

CONCLUSION

Standard energy "hot" techniques had an adjusted odds ratio over 6-fold higher for PTHRSI and over 8-fold higher for 2PTHRSI compared to the minimized energy transfer VLET technique. This difference appears due to a significant reduction in 2PTHRSI without increasing 1PTHRSI. To date, these are the lowest PTHRSI rates reported for diathermy extracapsular tonsillectomy in a large series. The VLET technique had a 2PTHRSI rate similar to those reported for purely cold tonsillectomy yet maintains a very low 1PTHRSI rate normally only achieved with diathermy tonsillectomy.

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Author Contributions

S.D.S.: Design, data mining, analysis, writing, editing, reviewing; D.V.W.: Co-investigator data mining, analysis, editing, reviewing; A.N.: statistical analysis; A.J.S.: statistical analysis.

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