The Effect of Energy Devices, Nerve Monitors, and Drains on Thyroidectomy Outcomes: An American College of Surgeons National Surgical Quality Improvement Project Database Analysis

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Abstract

The effect of energy devices, nerve monitors, and drains on thyroidectomy outcomes has been examined for each tool independently. Current literature supports the routine use of energy devices and nerve monitors and does not support the routine use of drains. The effect of these operative tools is interrelated and should be examined concurrently. The aim of this study was to describe the risk-adjusted effect of each of these tools on thyroidectomy outcomes. A retrospective analysis of 17 985 open thyroidectomy procedures was conducted using the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) 2016–2018 thyroidectomy targeted procedure database. All open thyroidectomies were included. The risk-adjusted effect of energy devices, nerve monitors, and drains on 30-day outcomes was calculated by multiple logistic regression. Energy devices were associated with a decreased risk of hematoma and decreased extended length of stay without increased risk of hypocalcemia or recurrent laryngeal nerve injury. Nerve monitors were associated with a decreased risk of overall morbidity, decreased recurrent laryngeal nerve injury, and decreased extended length of stay without an increased risk of adverse outcomes. Drains were associated with an increased risk of bleeding, reoperation, and extended length of stay without decreasing hematoma. Our results support the routine use of energy devices and nerve monitors for thyroidectomy and do not support the routine use of drains for thyroidectomy.

Keywords

thyroidectomy, outcomes, ACS-NSQIP, hematoma, recurrent laryngeal nerve injury, bleeding, energy device, nerve monitor, drain

Abbreviations and Acronyms

ACS-NSQIP = American College of Surgeons - National Surgical Quality Improvement Program
AIC = Akaike Information Criterion
ASA = American Society of Anesthesiologists
BMI = body mass index
CHF = congestive heart failure
COPD = chronic obstructive pulmonary disease
INR = international normalized ratio
LOS = length of stay
OR = odds ratio
RLN = recurrent laryngeal nerve
SSI = surgical site infection

Introduction

Thyroidectomy is a common procedure performed for a wide variety of indications by different types of specialists. Energy devices, nerve monitors, and drains are commonly, but not universally, used for thyroidectomy procedures.

The literature generally supports the routine use of energy devices. Energy devices have been shown to decrease postoperative hematoma, extended length of stay (LOS), and intraoperative blood loss compared to conventional hemostasis,[1,2] without increasing rates of recurrent laryngeal nerve (RLN) injury.[1,3,4] Despite lack of data supporting the routine use of nerve monitors,[5-8] the American Head and Neck Society has published a consensus statement supporting the routine use of nerve monitors during thyroidectomy.[9] The routine use of drains is not generally supported by the literature. Drains have not been found to decrease the rate of post-thyroidectomy bleeding and hematoma,[10-15] and have been associated with several other adverse outcomes.[11-15]

The effects of energy devices, nerve monitors, and drains have been studied independently. However, their effects are interrelated. For example, energy device use may decrease hematoma rate, which would decrease the need for a drain, but it may also increase the risk of RLN injury, which would increase the need for a nerve monitor. Examining the 3 methods discussed and their outcomes concurrently will provide a more comprehensive basis for decision-making during thyroidectomy. Our goal was to describe the risk-adjusted effect of each of these tools on thyroidectomy outcomes. We hypothesize that energy devices will be associated with decreased rates of hematoma and bleeding, nerve monitors will be associated with a decreased rate of RLN injury, and drains will be associated with an increased rate of hematoma.

Materials and Methods

Data Source

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a nationwide quality improvement initiative based on high-fidelity, professionally curated data. The ACS-NSQIP database contains over 150 data points regarding patient demographics, indications, preoperative comorbidities, laboratory values, and 30-day outcomes on a procedure level basis. The ACS-NSQIP targeted procedure – thyroidectomy database, first released in 2016, contains an additional set of thyroidectomy-specific data points, such as previous neck surgery, concurrent neck dissection, use of energy devices, use of intraoperative nerve monitoring, placement of a drain, postoperative hypocalcemia, postoperative RLN injury, and others. This study was exempt from Institutional Review Board approval as the data contained no patient identifying information.

Patient Selection

A total of 17 985 open thyroidectomies conducted from 2016 to 2018 were included. No further exclusion criteria were applied.

Patient Cohorts

Patients were split into overlapping cohorts based on operative tools used during the procedure. Tools analyzed were energy devices, nerve monitors, and drains. Use of an energy device was derived from the "THY_SCALPEL" variable in the targeted procedure database, which was defined as the use of Harmonic scalpel, LigaSure, or other vessel sealant device. This variable does not capture the use, or non-use, of monopolar energy devices. Use of a nerve monitor was derived from the "THY_ELECTRO" variable in the targeted procedure database, which was defined as the use of intraoperative electrophysiologic or electromyographic RLN monitoring. Use of a drain was derived from the "THY_DRAINUSE" variable in the targeted procedure database, which was defined as the use of any surgical drain.

Predictor Variables

Patient demographics/general health, thyroid-specific history/indications, operation details, operative tool use, comorbidities, and pre-operative labs were analyzed as predictor variables. Demographic and general health variables included persons aged ≥65 years, sex, obesity (body mass index [BMI] ≥30 kg/m^2), functional status (independent or not independent), race (White, Black, or Other), and American Society of Anesthesiologists (ASA) classification (ASA I-II, ASA III, or ASA IV-V). Thyroid-specific history/indications included history of neck surgery and neoplastic indication. Operation details included extent of resection (total/subtotal thyroidectomy, or hemithyroidectomy), neck dissection, concurrent sub-platysmal neck surgery, operation duration, and wound class (class I or not class I). Comorbidities included congestive heart failure (CHF), hypertension, smoking within the past 1 year, dyspnea within the past 30 days, chronic obstructive pulmonary disease (COPD), dialysis, weight loss >10% within the past 6 months, disseminated cancer, bleeding disorder, diabetes, and steroid or immunosuppressive therapy within the past 30 days. Laboratory values included hypoalbuminemia (albumin <3.5 g/dL), hyperbilirubinemia (bilirubin >1.2 mg/dL), elevated creatinine (creatinine >1.2 mg/dL [male] or 1.1 mg/dL [female]), anemia (hematocrit <30%), elevated international normalized ratio (INR >1.4), thrombocytopenia (platelet <100 000/μL), and leukocytosis (white blood cell >11 000/μL). All predictor variables were treated as categorical variables, the majority of which were binary except as indicated above. Several other pre-operative comorbidities are captured in the ACS-NSQIP database but were excluded from this analysis because of a low number of occurrences

Outcome Variables

All outcomes reported in the ACS-NSQIP database are 30-day outcomes. Outcomes analyzed were overall morbidity, hypocalcemia, neck hematoma, RLN injury, pulmonary morbidity, wound morbidity, bleeding requiring transfusion, readmission, reoperation, and length of hospital stay (LOS) greater than the median. Neck hematoma and RLN injury were defined as the noted presence of either, regardless of severity. Overall morbidity was defined as the presence of 1 or more major postoperative complications. Pulmonary morbidity was defined as 1 or more occurrences of postoperative pneumonia, ventilator requirement >48 hours post-operation, or reintubation. Wound morbidity was defined as 1 or more occurrences of superficial surgical site infection (SSI), deep SSI, organ space SSI, or wound dehiscence.

Statistical Analysis

Bivariate analysis of the distribution of predictor variables by operative tool use was conducted using Chi-square tests. Multivariate analysis of the effect of each tool on outcomes was conducted by multiple logistic regression using models constructed by forward/backward stepwise minimization of Akaike Information Criterion (AIC), starting with fully saturated models and setting the minimum model to include energy device use, nerve monitor use, and drain use as predictors regardless of impact on AIC. This resulted in a risk-adjusted odds ratio (OR) and corresponding 95% confidence interval (95% CI) of the specified outcome given the use of each tool. Statistical significance was assigned to *P* value <.05. Statistical analysis was performed using R version 3.5.1.

ACS-NSQIP Disclosure Statement

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS-NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Results

Patient Characteristics

Patient characteristics of energy device and no energy device groups are reported in Table 1. A total of 11 487 cases (63.9%) used energy devices. Patients in the energy device group had a higher rate of total/subtotal thyroidectomy (64.7% vs 59.3%;

P < .0001), operation time > median (52.4% vs 45.4%; *P* < .0001), and hypertension (40.4% vs 34.6%; *P* < .0001). Patients in the energy device group had a lower rate of history of neck surgery (9.1% vs 12.5%; *P* < .0001) and neck dissection (23.9% vs 35.0%; *P* < .0001). Patients in the energy device group had no difference in rate of concurrent neck surgery (11.9% vs 12.4%; *P* = .3714), bleeding disorder (1.1% vs 1.2%; *P* = .6585), elevated INR (0.44% vs 0.46%; *P* = .8161), and thrombocytopenia (0.39% vs 0.35%; *P* = .6510).

Patient characteristics of nerve monitor and no nerve monitor groups are reported in Table 2. A total of 11 352 cases (63.1%) used nerve monitors. Patients in the nerve monitor group had a higher rate of obesity (47.7% vs 42.6%; *P* < .0001), total thyroidectomy (64.1% vs 60.4%; *P*=.0027), neck dissection (29.5% vs 25.2%; *P* < .0001), and operative time > median (54.1% vs 42.7%; *P* < .0001). Patients in the nerve monitor group had a lower rate of concurrent neck surgery (11.5% vs 13.0%; *P* = .0038). Patients in the nerve monitor group had no difference in rate of history of neck surgery (10.4% vs 10.2%; *P*=v.8098), and neoplastic indication (61.7% vs 63.2%; *P* = .2246).

Patient characteristics of drain and no drain groups are reported in Table 3. In total, 5029 cases (28.0%) used drains. Patients in the drain group had a higher rate of obesity (51.8% vs 43.5%; *P* < .0001), total thyroidectomy (73.8% vs 58.5%; *P* < .0001), neck dissection (32.2% vs 26.3%; *P* <.0001), operation time > median (69.4% vs 42.3%; *P* < .0001), wound class II-IV (3.2% vs 2.1%; *P* < .0001), hypertension (43.1% vs 36.4%; *P* < .0001), smoking (16.9% vs 13.4%; *P* < .0001), preoperative dyspnea (9.9% vs 5.7%; *P* <.0001), COPD (3.4% vs 2.2%; *P* < .0001), and thrombocytopenia (0.58% vs 0.30%; *P* = .0069). Patients in the drain group had a lower rate of neoplastic indication (59.3% vs 63.4%; *P* = .0020). Patients in the drain group had no difference in rate of history of neck surgery (10.8% vs 10.1%; *P* = .1957), concurrent neck surgery (11.5% vs 12.3%; *P* = .2134), bleeding disorder (1.3% vs 1.0%; *P* = .0832), and elevated INR (0.52% vs 0.42%; *P* = .3166).

Operative Tool Usage

The distribution of operative tools used for thyroidectomy is depicted in Figure 1. The most used combination is energy devices and nerve monitors (33.3%). The next 3 most used combinations are energy devices only (13.9%), nerve monitors only (12.3%), and all 3 tools (12.1%). The three least commonly used combinations were energy devices and drains (4.5%), drains and nerve monitors (5.4%), and drains only (5.9%). None of the 3 tools were used in 12.5% of cases.

Outcomes

Results of our bivariate (unadjusted) outcomes analysis for energy devices are reported in Table 4. Patients in the energy device group had a lower rate of hematoma (1.6% vs 2.2%; *P* = .0112), pulmonary morbidity (0.60% vs 0.89%; *P* = .0267), wound morbidity (0.65% vs 0.92%; *P* = .0490), and LOS > median (10.2% vs 21.4%; *P* < .0001). Patients in the energy device group had no difference in rate of overall morbidity (15.1% vs 16.2%; *P* = .0586), any RLN injury (6.2% vs 5.8%; *P* = .3118), and bleeding requiring transfusion (0.20% vs 0.26%; *P* = .3200). Patients in the energy device group did not have a higher rate of any of the analyzed adverse outcomes.

Results of our bivariate (unadjusted) outcomes analysis for nerve monitors are reported in Table 5. Patients in the nerve monitor group had a lower rate of overall morbidity (14.9% vs 16.5%; *P* = .0096), RLN injury (5.6% vs 6.7%; *P* = .0056), pulmonary morbidity (0.60% vs 0.89%; *P* = .0274), and LOS > median (11.6% vs 18.8%; *P* < .0001). Patients in the nerve monitor group did not have a higher rate of any of the analyzed adverse outcomes.

Results of our bivariate (unadjusted) outcomes analysis for drains are reported in Table 6. Patients in the drain group had a higher rate of overall morbidity (18.9% vs 14.2%; *P* < .0001), hypocalcemia (8.9% vs 7.1%; *P* = .0001), any RLN injury (7.7% vs 5.4%; *P* < .0001), pulmonary morbidity (1.3% vs 0.46%; *P* < .0001), wound morbidity (0.99% vs 0.66%; *P* = .0216), bleeding requiring transfusion (0.50% vs 0.12%; *P* < .0001), readmission (3.3% vs 2.6%; *P* = .0096), reoperation (2.0% vs 1.2%; *P* < .0001), and LOS > median (29.6% vs 8.2%; *P* < .0001). Patients in the drain group had no difference in rate of hematoma (2.0% vs 1.8%; *P* = .3874). Patients in the drain group did not have a lower rate of any of the analyzed adverse outcomes.

Results of our multivariate (risk-adjusted) outcomes analysis for energy devices, nerve monitors, and drains are reported in Table 7. These results are graphically depicted in forest plots in Figures 2–4. Energy devices were found to be independently associated with a decreased risk of hematoma (OR, 0.72; 95% CI, 0.57-0.92; *P* = .0090), and LOS > median (OR, 0.62; 95% CI, 0.56-0.69; *P*<v.0001). Energy devices were not associated with an increased risk of any of the analyzed adverse outcomes, including hypocalcemia (OR, 0.98; 95% CI, 0.86-1.11; *P* = .7401) and RLN injury (OR, 1.11; 95% CI, 0.97-1.29; *P* = .1363). Nerve monitors were found to be independently associated with a decreased risk of overall morbidity (OR, 0.86; 95% CI, 0.79-0.94; *P* = .0011), RLN injury (OR, 0.75; 95% CI, 0.65-0.85; *P* < .0001), pulmonary morbidity (OR, 0.65; 95% CI, 0.44-0.98; *P* = .372), and LOS > median (OR, 0.71; 95% CI, 0.64-0.78; *P* < .0001). Nerve monitors were not associated with an increased risk of any of the analyzed adverse outcomes. Drains were found to be independently associated with an increased risk of overall morbidity (OR, 1.12; 95% CI, 1.02-1.23; *P* = .0136), any RLN injury (OR, 1.20, 95% CI, 1.05-1.38; *P* = .0084), pulmonary morbidity (OR, 1.80; 95% CI, 1.22-2.65; *P* = .0030), bleeding requiring transfusion (OR, 2.48; 95% CI, 1.21-5.20; *P* = .0138), reoperation (OR, 1.40; 95% CI, 1.07-1.81; *P* = .0117), and LOS > median (OR, 3.78; 95% CI, 3.42-4.19; *P* < .0001). Drains

Table 1. Patient Characteristics of No Energy Device and Energy Device Groups

Predictor Variable	All n (%)	No Energy Device n (%)	Energy Device n (%)	*P* value[a]
Total	17 985 (100.0)	6498 (36.1)	11 487 (63.9)	-
Demographics/general health				
Age ≥ 65 years	3974 (22.1)	1461 (22.5)	2513 (21.9)	.4091
Male	3988 (22.2)	1583 (24.4)	2405 (20.9)	<.0001*
Obese (BMI ≥ 30 kg/m^2)	8242 (45.8)	2621 (40.3)	5621 (48.9)	<.0001*
Functional status not independent	93 (0.5)	38 (0.6)	55 (0.5)	.3891
Race				
White	9914 (55.1)	2425 (37.3)	7489 (65.2)	<.0001*
Black	2597 (14.4)	592 (9.1)	2005 (17.5)	
Other	5474 (30.4)	3481 (53.6)	1993 (17.4)	
ASA Classification				
Class I-II	11 554 (64.2)	4290 (66.0)	7264 (63.2)	<.0001*
Class III	6052 (33.7)	2049 (31.5)	4003 (34.9)	
Class IV-V	379 (2.1)	159 (2.5)	220 (1.9)	
Thyroid-specific history/indications				
History of neck surgery	1854 (10.3)	810 (12.5)	1044 (9.1)	<.0001*
Neoplastic indication	11 195 (62.3)	4302 (66.2)	6893 (60.0)	<.0001*
Operation details				
Total or subtotal thyroidectomy	11 283 (62.7)	3854 (59.3)	7429 (64.7)	<.0001*
Neck dissection	5022 (27.9)	2276 (35.0)	2746 (23.9)	<.0001*
Concurrent neck surgery	2169 (12.1)	804 (12.4)	1365 (11.9)	.3714
Operation time > median (103 minutes)	8971 (49.9)	2953 (45.4)	6018 (52.4)	<.0001*
Wound class not 1-clean	428 (2.4)	167 (2.6)	261 (2.3)	.2275
Other tool use				
Nerve monitor used	11 352 (63.1)	3181 (49.0)	8171 (71.1)	<.0001*
Drain used	5029 (28.0)	2038 (31.4)	2991 (26.0)	<.0001*
Comorbidities				
CHF within 30 days	77 (0.4)	24 (0.4)	53 (0.5)	.3433
Hypertension requiring treatment	6889 (38.3)	2250 (34.6)	4639 (40.4)	<.0001*
Smoke cigarettes within 1 year	2587 (14.4)	872 (13.4)	1715 (14.9)	.0099*
Dyspnea within 30 days	1242 (6.9)	416 (6.4)	826 (7.2)	.0513
COPD	457 (2.5)	158 (2.4)	299 (2.6)	.4954
Dialysis	80 (0.4)	27 (0.4)	53 (0.5)	.6418
Weight loss > 10% in last 6 months	112 (0.6)	40 (0.6)	72 (0.6)	1.0
Disseminated cancer	179 (1.0)	77 (1.2)	102 (0.9)	.0622
Bleeding disorder	200 (1.1)	75 (1.2)	125 (1.1)	.6585
Diabetes	2419 (13.5)	785 (12.1)	1634 (14.2)	.0002*
Steroid or immunosuppression within 30 days	505 (2.8)	177 (2.7)	328 (2.9)	.6431
Preoperative labs				
Albumin < 3.5 g/dL	426 (2.4)	148 (2.3)	278 (2.4)	.5451
Bilirubin > 1.2 mg/dL	178 (1.0)	51 (0.8)	127 (1.1)	.0423*
Creatinine > 1.2 (M) or > 1.1 (F) mg/dL	974 (5.4)	298 (4.6)	676 (5.9)	.0003*
Hematocrit < 30%	187 (1.0)	64 (1.0)	123 (1.1)	.5431
INR > 1.4	80 (0.4)	30 (0.5)	50 (0.4)	.8161
Platelet < 100 000 /µL	68 (0.4)	23 (0.4)	45 (0.4)	.615
WBC > 11 000 /µL	678 (3.8)	232 (3.6)	446 (3.9)	.2987

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; M, male; F, female; INR, international normalized ratio; WBC, white blood cell count.

Table 2. Patient Characteristics of No Nerve Monitor and Nerve Monitor Groups				
Predictor Variable	**All n (%)**	**No Nerve Monitor n (%)**	**Nerve Monitor n (%)**	***P* value[a]**
Total	17 985 (100.0)	6633 (36.9)	11 352 (63.1)	-
Demographics/general health				
Age ≥ 65 years	3974 (22.1)	1500 (22.6)	2474 (21.8)	.2637
Male	3988 (22.2)	1552 (23.4)	2436 (21.5)	.0079*
Obese (BMI ≥ 30 kg/m^2)	8242 (45.8)	2824 (42.6)	5418 (47.7)	<.0001*
Functional status not independent	93 (0.5)	33 (0.5)	60 (0.5)	.8295
Race				
White	9914 (55.1)	3117 (47.0)	6797 (59.9)	<.0001*
Black	2597 (14.4)	656 (9.9)	1941 (17.1)	
Other	5474 (30.4)	2860 (43.1)	2614 (23.0)	
ASA Classification				
Class I-II	11 554 (64.2)	4322 (65.2)	7232 (63.7)	<.0001*
Class III	6052 (33.7)	2138 (32.2)	3914 (34.5)	
Class IV-V	379 (2.1)	173 (2.6)	206 (1.8)	
Thyroid-specific history/indications				
History of neck surgery	1854 (10.3)	679 (10.2)	1175 (10.4)	.8098
Neoplastic indication	11 195 (62.3)	4191 (63.2)	7004 (61.7)	.2246
Operation details				
Total or subtotal thyroidectomy	11 283 (62.7)	4007 (60.4)	7276 (64.1)	.0027*
Neck dissection	5022 (27.9)	1671 (25.2)	3351 (29.5)	<.0001*
Concurrent neck surgery	2169 (12.1)	865 (13.0)	1304 (11.5)	.0038*
Operation time > median (103 minutes)	8971 (49.9)	2832 (42.7)	6139 (54.1)	<.0001*
Wound class not 1-clean	428 (2.4)	140 (2.1)	288 (2.5)	.0714
Other tool use				
Nerve monitor used	11 487 (63.9)	3316 (50.0)	8171 (72.0)	<.0001*
Drain used	5029 (28.0)	1883 (28.4)	3146 (27.7)	.4132
Comorbidities				
CHF within 30 days	77 (0.4)	24 (0.4)	53 (0.5)	.3433
Hypertension requiring treatment	6889 (38.3)	2406 (36.3)	4483 (39.5)	.0007*
Smoke cigarettes within 1 year	2587 (14.4)	918 (13.8)	1669 (14.7)	.1424
Dyspnea within 30 days	1242 (6.9)	492 (7.4)	750 (6.6)	.0455*
COPD	457 (2.5)	150 (2.3)	307 (2.7)	.0656
Dialysis	80 (0.4)	33 (0.5)	47 (0.4)	.4884
Weight loss > 10% in last 6 months	112 (0.6)	29 (0.4)	83 (0.7)	.0186*
Disseminated cancer	179 (1.0)	67 (1.0)	112 (1.0)	.8769
Bleeding disorder	200 (1.1)	73 (1.1)	127 (1.1)	.8836
Diabetes	2419 (13.5)	881 (13.3)	1538 (13.6)	.643
Steroid or immunosuppression within 30 days	505 (2.8)	176 (2.7)	329 (2.9)	.3562
Preoperative labs				
Albumin < 3.5 g/dL	426 (2.4)	148 (2.2)	278 (2.5)	.366
Bilirubin > 1.2 mg/dL	178 (1.0)	61 (0.9)	117 (1.0)	.4378
Creatinine > 1.2 (M) or > 1.1 (F) mg/dL	974 (5.4)	355 (5.4)	619 (5.5)	.7905
Hematocrit < 30%	187 (1.0)	70 (1.1)	117 (1.0)	.8795
INR > 1.4	80 (0.4)	31 (0.5)	49 (0.4)	.8174
Platelet < 100 000 /µL	68 (0.4)	27 (0.4)	41 (0.4)	0615
WBC > 11 000 /µL	678 (3.8)	258 (3.9)	420 (3.7)	.5242

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; M, male; F, female; INR, international normalized ratio; WBC, white blood cell count.

Table 3. Patient Characteristics of No Drain and Drain Groups				
Predictor Variable	**All n (%)**	**No Drain n (%)**	**Drain n (%)**	***P* value[a]**
Total	17 985 (100.0)	12 956 (72.0)	5029 (28.0)	-
Demographics/general health				
Age ≥ 65 years	3974 (22.1)	2752 (21.2)	1222 (24.3)	<.0001*
Male	3988 (22.2)	2631 (20.3)	1357 (27.0)	<.0001*
Obese (BMI ≥ 30 kg/m^2)	8242 (45.8)	5637 (43.5)	2605 (51.8)	<.0001*
Functional status not independent	93 (0.5)	55 (0.4)	38 (0.8)	.0056*
Race				
White	9914 (55.1)	7102 (54.8)	2812 (55.9)	<.0001*
Black	2597 (14.4)	1786 (13.8)	811 (16.1)	
Other	5474 (30.4)	4068 (31.4)	1406 (28.0)	
ASA Classification				
Class I-II	11 554 (64.2)	8728 (67.4)	2826 (56.2)	<.0001*
Class III	6052 (33.7)	4007 (30.9)	2045 (40.7)	
Class IV-V	379 (2.1)	221 (1.7)	158 (3.1)	
Thyroid-specific history/indications				
History of neck surgery	1854 (10.3)	1311 (10.1)	543 (10.8)	.1957
Neoplastic indication	11 195 (62.3)	8212 (63.4)	2983 (59.3)	.002*
Operation details				
Total or subtotal thyroidectomy	11 283 (62.7)	7574 (58.5)	3709 (73.8)	<.0001*
Neck dissection	5022 (27.9)	3404 (26.3)	1618 (32.2)	<.0001*
Concurrent neck surgery	2169 (12.1)	1589 (12.3)	580 (11.5)	.2134
Operation time > median (103 minutes)	8971 (49.9)	5480 (42.3)	3491 (69.4)	<.0001*
Wound class not 1-clean	428 (2.4)	266 (2.1)	162 (3.2)	<.0001*
Other tool use				
Nerve monitor used	11 487 (63.9)	8496 (65.6)	2991 (59.5)	<.0001*
Drain used	11 352 (63.1)	8206 (63.3)	3146 (62.6)	.5582
Comorbidities				
CHF within 30 days	77 (0.4)	57 (0.4)	20 (0.4)	.6139
Hypertension requiring treatment	6889 (38.3)	4721 (36.4)	2168 (43.1)	<.0001*
Smoke cigarettes within 1 year	2587 (14.4)	1737 (13.4)	850 (16.9)	<.0001*
Dyspnea within 30 days	1242 (6.9)	742 (5.7)	500 (9.9)	<.0001*
COPD	457 (2.5)	288 (2.2)	169 (3.4)	<.0001*
Dialysis	80 (0.4)	60 (0.5)	20 (0.4)	.6165
Weight loss > 10% in last 6 months	112 (0.6)	68 (0.5)	44 (0.9)	.006*
Disseminated cancer	179 (1.0)	83 (0.6)	96 (1.9)	<.0001*
Bleeding disorder	200 (1.1)	133 (1.0)	67 (1.3)	.0832
Diabetes	2419 (13.5)	1614 (12.5)	805 (16.0)	<.0001*
Steroid or immunosuppression within 30 days	505 (2.8)	346 (2.7)	159 (3.2)	.0742
Preoperative labs				
Albumin < 3.5 g/dL	426 (2.4)	246 (1.9)	180 (3.6)	<.0001*
Bilirubin > 1.2 mg/dL	178 (1.0)	137 (1.1)	41 (0.8)	.1334
Creatinine > 1.2 (M) or > 1.1 (F) mg/dL	974 (5.4)	671 (5.2)	303 (6.0)	.0268*
Hematocrit < 30%	187 (1.0)	120 (0.9)	67 (1.3)	.0144*
INR > 1.4	80 (0.4)	54 (0.4)	26 (0.5)	.3166
Platelet < 100 000 /µL	68 (0.4)	39 (0.3)	29 (0.6)	.0069*
WBC > 11 000 /µL	678 (3.8)	463 (3.6)	215 (4.3)	.0325*

[a] Asterisk (*) represents statistical significance at P value <0.05. Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; M, male; F, female; INR, international normalized ratio; WBC, white blood cell count.

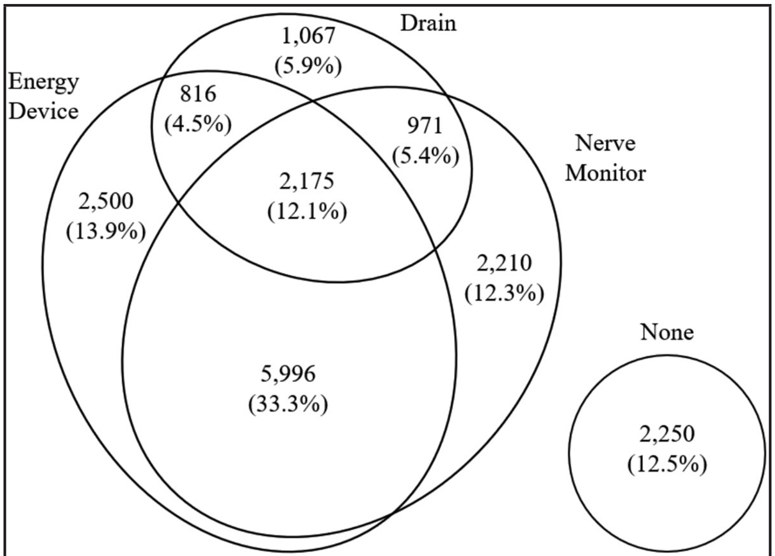

Figure 1. Euler Diagram of Tools Used for Thyroidectomy (N = 17 985)

Table 4. Bivariate (Unadjusted) Outcomes Analysis for Energy Devices

Outcome	All n (%)	No Energy Device n (%)	Energy Device n (%)	*P* value[a]
Total	17 985 (100.0)	6498 (36.1)	11 487 (63.9)	-
Overall morbidity	2791 (15.5)	1056 (16.3)	1735 (15.1)	.0586
Hypocalcemia	1365 (7.6)	524 (8.1)	841 (7.3)	.0807
Any hematoma	326 (1.8)	140 (2.2)	186 (1.6)	.0112*
Any RLN Injury	1084 (6.0)	376 (5.8)	708 (6.2)	.3118
Pulmonary morbidity (Pneumonia, Ventilator > 48 hours, Reintubation)	127 (0.7)	58 (0.9)	69 (0.6)	.0267*
Wound morbidity (Superficial SSI, Deep SSI, Organ Space SSI, Dehiscence)	135 (0.8)	60 (0.9)	75 (0.7)	.049*
Bleeding requiring transfusion	40 (0.2)	17 (0.3)	23 (0.2)	.32
Readmission	499 (2.8)	178 (2.7)	321 (2.8)	.8521
Reoperation	254 (1.4)	96 (1.5)	158 (1.4)	.6015
LOS > Median (1 day)	2556 (14.2)	1387 (21.4)	1169 (10.2)	<.0001*

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: RLN, recurrent laryngeal nerve; SSI, surgical site infection; LOS, length of stay.

Table 5. Bivariate (Unadjusted) Outcomes Analysis for Nerve Monitors

Outcome	All n (%)	No Nerve Monitor n (%)	Nerve Monitor n (%)	*P* value[a]
Total	17 985 (100.0)	6633 (36.9)	11 352 (63.1)	-
Overall morbidity	2791 (15.5)	1095 (16.5)	1696 (14.9)	.0096*
Hypocalcemia	1365 (7.6)	527 (8.0)	838 (7.4)	.1781
Any hematoma	326 (1.8)	125 (1.9)	201 (1.8)	.5658
Any RLN Injury	1084 (6.0)	444 (6.7)	640 (5.6)	.0056*
Pulmonary morbidity (Pneumonia, Ventilator > 48 hours, Reintubation)	127 (0.7)	59 (0.9)	68 (0.6)	.0274*
Wound morbidity (Superficial SSI, Deep SSI, Organ Space SSI, Dehiscence)	135 (0.8)	54 (0.8)	81 (0.7)	.4759
Bleeding requiring transfusion	40 (0.2)	18 (0.3)	22 (0.2)	.3272
Readmission	499 (2.8)	194 (2.9)	305 (2.7)	.3535
Reoperation	254 (1.4)	95 (1.4)	159 (1.4)	.8966
LOS > Median (1 day)	2556 (14.2)	1245 (18.8)	1311 (11.5)	<.0001*

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: RLN, recurrent laryngeal nerve; SSI, surgical site infection; LOS, length of stay.

Table 6. Bivariate (Unadjusted) Outcomes Analysis for Drains				
Outcome	**All n (%)**	**No Drain n (%)**	**Drain n (%)**	***P* value[a]**
Total	17 985 (100.0)	12 956 (72.0)	5029 (28.0)	-
Overall morbidity	2791 (15.5)	1842 (14.2)	949 (18.9)	<.0001*
Hypocalcemia	1365 (7.6)	919 (7.1)	446 (8.9)	.0001*
Any hematoma	326 (1.8)	228 (1.7)	98 (2.0)	.3874
Any RLN Injury	1084 (6.0)	698 (5.4)	386 (7.7)	<.0001*
Pulmonary morbidity (Pneumonia, Ventilator >48 hrs, Reintubation)	127 (0.7)	60 (0.5)	67 (1.3)	<.0001*
Wound morbidity (Superficial SSI, Deep SSI, Organ Space SSI, Dehiscence)	135 (0.8)	85 (0.7)	50 (1.0)	.0216*
Bleeding requiring transfusion	40 (0.2)	15 (0.1)	25 (0.5)	<.0001*
Readmission	499 (2.8)	333 (2.6)	166 (3.3)	.0096*
Reoperation	254 (1.4)	154 (1.2)	100 (2.0)	<.0001*
LOS > Median (1 day)	2556 (14.2)	1066 (8.2)	1490 (29.6)	<.0001*

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: RLN, recurrent laryngeal nerve; SSI, surgical site infection; LOS, length of stay.

Table 7. Multivariate Outcomes Analysis						
Outcome	**Energy Device**		**Nerve Monitor**		**Drain**	
	OR (95% CI)	***P* value[a]**	**OR (95% CI)**	***P* value[a]**	**OR (95% CI)**	***P* value[a]**
Overall Morbidity	0.99 (0.90-1.09)	.8294	0.86 (0.79-0.94)	.0011*	1.12 (1.02-1.23)	.0136*
Hypocalcemia	0.98 (0.86-1.11)	.7401	0.92 (0.82-1.05)	.2075	1.00 (0.88-1.14)	.9519
Any hematoma	0.72 (0.57-0.92)	.0090*	0.98 (0.77-1.24)	.8472	0.87 (0.67-1.12)	.2796
Any RLN Injury	1.11 (0.97-1.29)	.1363	0.75 (0.65-0.85)	<.0001*	1.20 (1.05-1.38)	.0084*
Pulmonary morbidity (Pneumonia, Ventilator >48 hrs, Reintubation)	0.75 (0.50-1.12)	.1516	0.65 (0.44-0.98)	.0372*	1.80 (1.22-2.65)	.0030*
Wound morbidity (Superficial SSI, Deep SSI, Organ Space SSI, Dehiscence)	1.06 (0.73-1.57)	.7521	1.04 (0.73-1.51)	.8206	1.30 (0.90-1.85)	.1599
Bleeding requiring transfusion	1.39 (0.66-2.99)	.3936	0.90 (0.43-1.92)	.7901	2.48 (1.21-5.20)	.0138*
Readmission	1.02 (0.84-1.24)	.8516	0.87 (0.72-1.05)	.1405	1.05 (0.86-1.28)	.6329
Reoperation	0.99 (0.75-1.32)	.9324	0.97 (0.74-1.27)	.8044	1.40 (1.07-1.81)	.0117*
LOS > Median (1 day)	0.62 (0.56-0.69)	<.0001*	0.71 (0.64-0.78)	<.0001*	3.78 (3.42-4.19)	<.0001*

[a] Asterisk (*) represents statistical significance at *P* value <.05. Abbreviations: CI, confidence interval; RLN, recurrent laryngeal nerve; SSI, surgical site infection; LOS, length of stay.

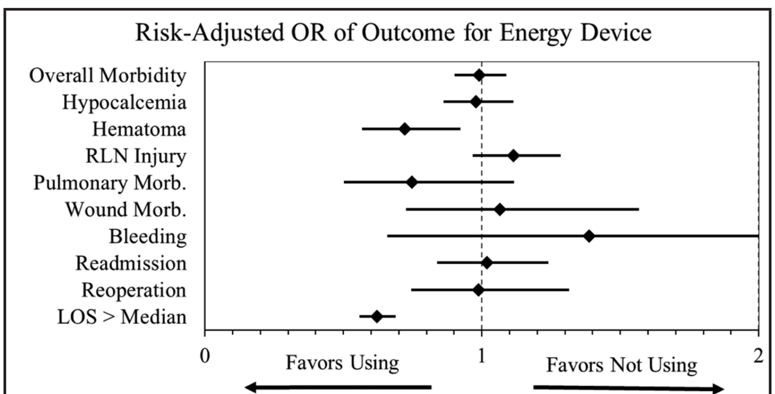

Figure 2. Forest plot of Odds Ratios for Energy Devices

Abbreviations: OR, odds ratio; RLN, recurrent laryngeal nerve; LOS, length of stay.

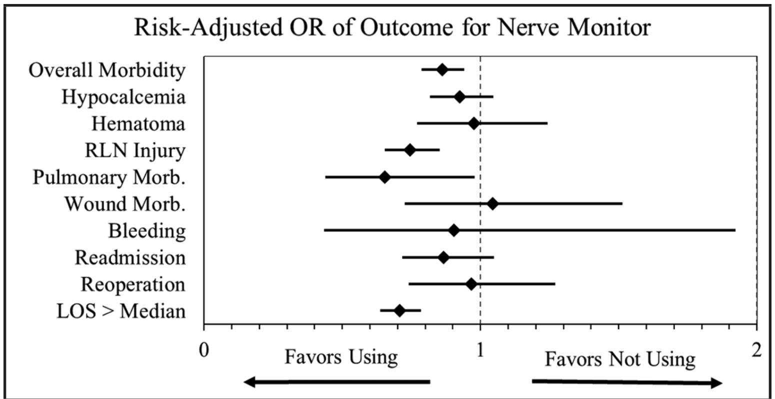

Figure 3. Forest plot of Odds Ratios for Nerve Monitors

Abbreviations: OR, odds ratio; RLN, recurrent laryngeal nerve; LOS, length of stay.

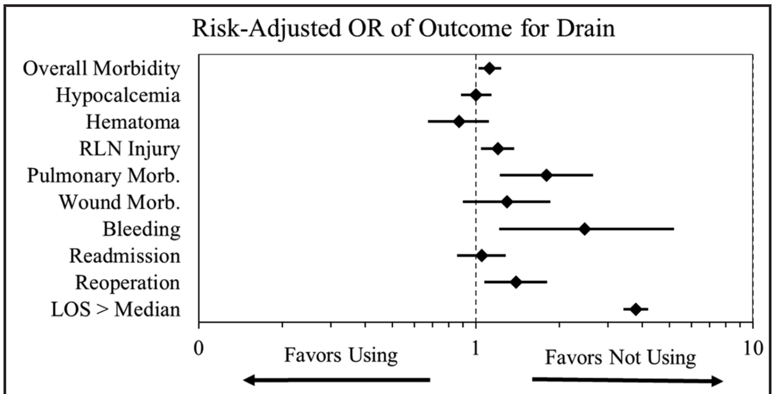

Figure 4. Forest plot of Odds Ratios for Drains

Abbreviations: OR, odds ratio; RLN, recurrent laryngeal nerve; LOS, length of stay.

were not associated with a decreased risk of any of the analyzed adverse outcomes, including hematoma (OR, 0.87; 95% CI, 0.67-1.12; *P*= .2796) and wound morbidity (OR, 1.30; 95% CI, 0.90-1.85; *P*=.1599).

Discussion

We have found that energy devices are associated with a decreased rate of hematoma and decreased LOS greater than the median without an increase in hypocalcemia, RLN injury, or any other adverse outcome. This is consistent with some studies that have shown a lower rate of both hematoma and extended LOS.[1] In fact, energy devices have been shown to have a lower volume of intraoperative blood loss when compared to conventional hemostasis,[2] and it has been estimated that the number needed to treat with an energy device to avoid 1 hematoma is 74.[1] However, others have found no significant difference in postoperative hematoma rate with energy devices compared to conventional hemostasis,[16] and Carlander et al found a higher rate of topical hemostatic agents used with energy devices.[4] Our results are also consistent with other studies finding no difference in RLN injury between energy devices and conventional hemostasis.[1,3,4] In fact, energy devices have been shown to be safe in a porcine model if used greater than 2 mm from the RLN.[17] We found no association between energy devices and hypocalcemia, which is in contrast to others who have found higher[4] and lower[2] rates of hypocalcemia. Although the literature has somewhat mixed results, our results support the routine use of energy devices for thyroidectomy.

We have found that nerve monitors are associated with a decreased rate of overall morbidity, RLN injury, pulmonary morbidity, and LOS greater than the median without an increase in any other adverse outcome. This is in contrast to many other studies on the subject. A large Cochrane review, published in 2019, found no difference in permanent RLN palsy, transient RLN palsy, transient hypoparathyroidism, and operative time between nerve monitor use and visual nerve identification.[5] Several studies have shown no reduction in risk of RLN injury with nerve monitors compared to direct visual identification of the RLN.[6,7] Surprisingly, Chung et al found that nerve monitor use was associated with an increased risk of RLN injury in partial thyroidectomy and lower rates of RLN injury in total thyroidectomy.[8] Nerve monitor use is associated with a learning curve of approximately 60–90 cases before rates of complication decline,[18] and hospital volume may also influence the effectiveness of nerve monitors as lower rates of RLN injury have been associated with hospitals where more than half of the cases used nerve monitors.[8] Nonetheless, the American Head and Neck Society has published a consensus statement that nerve monitoring can provide more information than sight alone during thyroidectomy.[9] They further state that in cases of loss of nerve monitor signal, the surgeon should consider staging the contralateral procedure to limit the risk of bilateral vocal cord paralysis.[9] Also, a Markov chain analysis by Al-Quarayshi et al found that nerve monitoring during thyroidectomy costs $46 427.97 per quality-adjusted life-year saved and is the preferred strategy in 85.8% of the population.[19] Our results, combined with the consensus statement of the American Head and Neck Society, support the routine use of nerve monitors for thyroidectomy.

We have found that drains are associated with an increased rate of overall morbidity, any RLN injury, pulmonary morbidity, bleeding requiring transfusion, reoperation, and LOS greater than the median without a decrease in hematoma or any other adverse outcome. This finding is consistent with many other studies on the subject. Some have found that drain use is associated with an increased rate of postoperative bleeding and hematoma,[10] and others have found that drain use is not associated with a decreased rate of postoperative hematoma.[11–15] Drain use is also associated with several other adverse outcomes such as unplanned intubation, extended LOS, hypoparathyroidism, transient RLN injury, postoperative pain, wound infection, and LOS.[11–15] Even Halstead, in 1913, in an article about thyroidectomy said, “Hemostasis is attended to with scrupulous care, and the wounds are closed without drainage.”[20] Our results, combined with much of the literature on the subject, do not support the routine use of drains for thyroidectomy.

This study has several limitations. First, its retrospective nature precludes conclusions of causality. Specifically, many factors go into a surgeon’s decision to use a drain. Many of those factors were captured by the ACS-NSQIP database and analyzed in our study, but there are many others that were not, including known and unknown factors. Another weakness concerns the completeness of data in the ACS-NSQIP database, particularly pre-operative lab values for thrombocytopenia and coagulopathy. Patients with incomplete values were assumed to be normal, but it is entirely possible that some of the patients with bleeding/hematoma complications had thrombocytopenia and/or coagulopathy, and their complications ended up being associated with drain use rather than their underlying, uncaptured, thrombocytopenia/coagulopathy. Finally, as is the case with any retrospective database analysis, many relevant data points are not captured in the database including, but not limited to, drain type and suction, anticoagulation/antiplatelet therapy, specific type of energy device and nerve monitor, topical hemostatic agent use, surgeon training, and surgeon and hospital volume.

We have found several associations between the surgical tools studied and thyroidectomy outcomes. Energy devices are associated with a decreased rate of hematoma and decreased LOS greater than the median without an increase in hypocalcemia or RLN injury. Nerve monitors are associated with a decreased rate of overall morbidity, decreased RLN injury, decreased pulmonary morbidity, and decreased LOS greater than the median. Drains are associated with an increased rate of overall morbidity, increased RLN injury, increased pulmonary morbidity, bleeding requiring transfusion, reoperation, and LOS greater than the median without a decrease in hematoma. Our results support the routine use of energy devices and nerve monitors and do not support the routine use of drains.

Conflict of Interest

None of the authors identify a conflict of interest.

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