Original Article

National perspective on hospital readmissions following adrenalectomy

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Background: Examining risk factors of readmission in adrenalectomy patients and estimated the cost burden of unplanned readmission on the United States' healthcare system.

Methods: According to the Nationwide Readmission Database, 20,494 patients underwent adrenalectomy between 2010–2014. Demographics, comorbidities, clinical data, length of stay (LOS), annual case volume, and discharge disposition of 30- and 90-day readmission cohorts were compared to the non-readmitted cohort.

Results: A total of 1,463 (7.9%) and 1,959 (12.7%) adrenalectomy patients were readmitted at 30 and 90 days after discharge, respectively. Prolonged initial hospital stays [odds ratio (OR) =1.93; 95% confidence interval (CI): 1.63–2.27] and postoperative complications (OR =4.91; 95% CI: 1.98–12.16) were associated with a higher risk of readmission. Complications were significantly more frequent in patients with a primary or secondary malignancy (OR =1.42; 95% CI: 1.23–1.64) and in patients undergoing a procedure at a low adrenalectomy volume hospital [hazard ratio (HR) =0.75; 95% CI: 0.62–0.91; P=0.003]. Readmission extended overall LOS by an average of 2.06 days, costing an additional $18,529.49 per admission.

Conclusions: Readmission adds significantly to the burden of disease after adrenalectomy. Understanding contributing factors may identify strategies to reduce readmissions and improve healthcare for patients.

Keywords: Adrenalectomy; readmission rate; complication rate; length of stay (LOS); healthcare cost

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Introduction

Adrenalectomy is an increasingly common procedure in general, urologic, and endocrine surgery. Due to advancements in diagnostic technology and minimally invasive surgical procedures, adrenalectomies have increased by 45% in the past 20 years (1-3). Currently, laparoscopic adrenalectomy is the standard operative approach, with reduced postoperative pain, shorter length of hospital stay, and minimal scarring (2). Despite the widespread practice of this minimally invasive technique and its low associated mortality rate, the complication rates of adrenalectomy procedures range upwards of 20%, and the mean hospital length of stay (LOS) is reported to range from 3 to 8 days (4,5). Reported intraoperative complications include vascular injury, pleural injury, and injury to gastrointestinal organs (6). Postoperative complications include wound infection, urinary tract infection, deep vein thrombosis, sepsis, myocardial infarction, stroke, and mortality (7). Severe complications can lead to hospital readmission, which is used as a metric of hospital quality of care (8).

Readmissions represent a significant burden to the health care system (9). High readmission rates correlate with decreased quality of care, decreased patient well-being, and increased hospital costs (10,11). Recent literature has focused on analyzing readmission data for specific surgical procedures, as readmission magnitude and risk factors for post-surgical procedures are not well defined (12). Post-adrenalectomy readmission rates range from 2–10% (9). Given the heterogeneity of disease etiology and increasing frequency of adrenalectomies, identifying clusters of patients at higher risk of complications and readmission would be valuable to guide preoperative planning and postoperative care.

To delineate potential assessment points within the adrenalectomy surgical care plan, we (I) examined independent risk factors of readmission following adrenalectomy in the United States; (II) identified the clinical, demographic, and hospital factors leading to readmission; and (III) estimated the cost burden of preventable readmission on the healthcare system using an extensive, national database. We present the following article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-22-18/rc).

Methods

Data source

A cross-sectional analysis was carried out using the Nationwide Readmissions Database (NRD) for the years 2010–2014. NRD is part of the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality (AHRQ). It is used to assess the cost and quality of healthcare services and analyze the outcomes of treatments. The NRD collects data from approximately fourteen million discharges per year from 21 geographically dispersed states in the United States. Excluded in the NRD is data from federal hospitals and long-term care facilities such as skilled nursing facilities or rehabilitation centers. Patients are tracked by a patient linkage number that allows for discharge and readmission tracking separate from index hospital. The NRD data is publicly available; thus, the institutional review board approval was exempted, and the patient's written consent was waived. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Inclusion and exclusion criteria

The study population included adult patients (≥18 years) who underwent adrenal surgery as the primary admission procedure of either adenoma (functional and non-functional) or malignant adrenal disease (primary and secondary). Patients who died during the index hospitalization, who had additional procedures during time of adrenalectomy, or with missing values used to calculate the days from discharge to readmission were excluded. The generated sample was then surveyed for readmission. Cases are defined as patients who had unscheduled readmission within 30 or 90 days postoperatively. Index events for 30- and 90-day readmission were selected from January to November and from January to September, respectively. Controls are defined as patients who were not readmitted.

Study parameters

The study objective is to (I) assess the risk of readmission following adrenalectomy in the United States; (II) identify the clinical, demographic, and administrative factors

associated with readmission; and (III) determine the burden of readmission in terms of the cost of health services.

Patient factors of interest included age (18–44, 45–64, 65+ years old), gender, state of residence (in-state or out-of-state), type of adrenalectomy (unilateral/partial or bilateral), causes of primary admission (adenoma or malignant neoplasm), number of chronic diseases, and causes of readmission. Comorbidities were identified based on Charlson comorbidity index score. NRD files for 'cost to charge ratio' and hospital charges were used to calculate hospital costs for each patient. The extra burden of 30- and 90-day readmission on the healthcare system was evaluated in the context of postoperative complications (none *vs.* one or more), inpatient mortality during adrenalectomy and readmission, hospital LOS (short stay ≤75th percentile and extended stay >75th percentile), and cost of health service (low-cost ≤75th percentile and high cost >75th percentile).

The study also included the following hospital characteristics: median household income quartile for patient's zip code, hospital procedure volume (low, medium, and high volume: based on ≤25th percentile and >75th percentile), primary insurance type (Medicare, Medicaid, private insurance, and other), hospital ownership (government non-federal, private not-for-profit, and private investor-owned), hospital teaching status (metropolitan teaching, metropolitan non-teaching, and non-metropolitan), hospital bed size (small, medium, and large), and discharge disposition (routine, transfer to short-term hospital, home health care, against medical advice). International Classification of Disease, 9th Revision (ICD-9) was used to define the study variables (Table S1). Clinical Classification Software (CCS) was used to categorize diagnoses and procedures.

Statistical analysis

Data analysis used weighted measurements reflecting the national estimate level. Based on the HCUP user agreement, some variables with a low number of observations were not reported to avoid patient tracking. Unbiased and a priori cut-off values of quantitative variables were set at the median levels. Chi-square, Fisher's Exact, Student's *t*-test, and Mann-Whitney U tests were employed for univariate analysis of each independent factor. Significant variables were considered confounders and were further included in multivariate regression models. Odds ratio (OR) and 95% confidence interval (CI) were estimated. A significance level was set at $P<0.05$. Kaplan-Meier method and log-rank test were performed to generate curves of the probability of being readmission-free within 90 days following the initial procedure. Mean adjusted hospitalization cost and LOS were calculated by linear and binary logistic regression, respectively, to control for other covariates. Statistical data analyses were carried out using SAS 9.4 for Windows (SAS Institute Inc., Cary, NC, USA) and SPSS version 24.0.

Results

Demographic and clinical characteristics of adrenalectomy patients

A total of 20,494 adrenalectomy admissions (patients ≥18 years old) were reported between 2010 and 2014. Workflow for study selection is shown in *Figure 1*. Patients' mean age was 57.4±13.8 years, and 10,267 (50.1%) of them were female. Patients presented with adenomas accounted for 17,502 (85.4%), while malignancy was diagnosed in 2,992 (14.6%) of cohorts. Most cases underwent unilateral and partial adrenalectomy, 17,748 (86.6%) and 2,377 (11.6%) respectively, whereas 369 (1.8%) of patients had bilateral adrenalectomy procedures (*Table 1*).

Risk of complications and in-hospital mortality

Out of a total of 20,494 patients, postoperative complications were reported in 3,156 (15.4%) patients, accounting for one in six to be at risk. Bleeding and renal complications were the most frequent, accounting for 1,558 (7.6%) and 1,066 (5.2%) of complications, respectively (Figure S1). Patients with secondary malignancy were more likely to develop postoperative complications (17% *vs.* 12.4%, OR =1.44, 95% CI: 1.05–1.99) than primary malignancy, particularly technical complications (4.6% *vs.* 1%, OR =5.04, 95% CI: 1.83–13.8). In addition, patients with functional adenomas had a higher risk of renal complications (3.3% *vs.* 2.5%, OR =1.31, 95% CI: 1.5–1.65), bleeding (5.1% *vs.* 3.9%, OR =1.33, 95% CI: 1.1–1.6), and technical complications (2.4% *vs.* 1.1%, OR =2.21, 95% CI: 1.64–2.97). At primary admission, 41 (0.2%) patients died during their hospital stay. These patients all underwent bilateral procedures, and 37 (89.2%) experienced postoperative bleeding and cardiovascular system (CVS) complications (data not shown).

Frequency and risk factors for readmission

A total of 1,463 (7.9%) and 1,959 (12.7%) who were sent

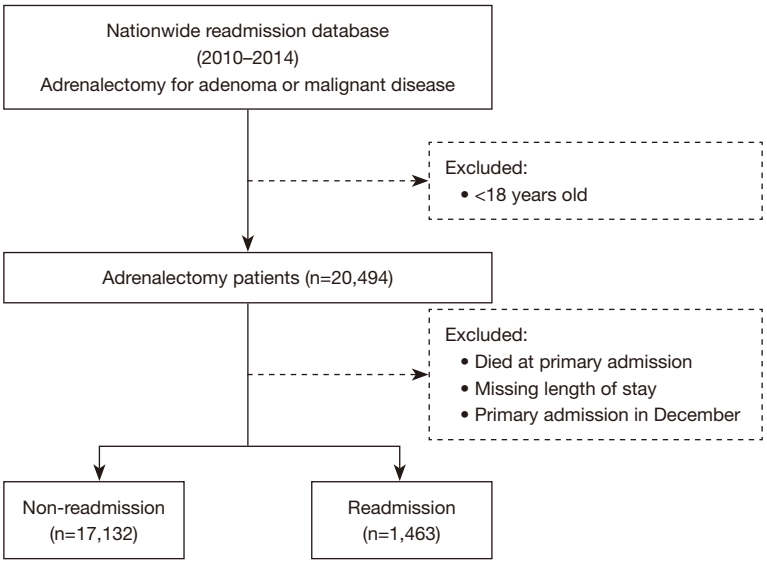

Figure 1 Flow chart for selection of the study population. All numbers are presented as weighted national estimates.

home from the hospital were readmitted within a month and three months, respectively (*Figure 2*). Half of the readmissions occurred within the first 19 days of discharge. The most common reasons for readmission were acute renal failure, postoperative infection, septicemia, glucocorticoid deficiencies, and pneumonia. Characteristics of 30- and 90-day readmitted patients are shown in *Table 2*. Patients with malignancy had a 13% increased risk of 30-day readmission compared to adenoma patients (HR =1.13; 95% CI: 1.03–1.25; P=0.009). Regarding hospital factors, those cohorts that underwent adrenalectomy procedures in metropolitan non-teaching hospitals were associated with 42% more risk of readmission versus metropolitan teaching hospitals (HR =1.42; 95% CI: 1.17–1.74; P<0.001). On the other hand, having an adrenalectomy procedure in a high-volume capacity of more than four operations per year showed a decreased risk of readmission to 25%, reaching as low as a 31% risk decrease in hospitals performing over 13 adrenalectomy procedures in a year (HR =0.75; 95% CI: 0.62–0.91; P=0.003) (*Figure 3*).

Burden of readmission on healthcare system

Readmission cases, on average, had 2.06 days of additional hospital stay, which is 0.54% more than the non-readmission controls. If this value is extrapolated to the national level, readmission resulted in 343.19 days of additional hospital stays. Aligned with LOS, the average additional cost attributed to readmission accounted for $18,529.4. Thus, from a national perspective, these cases were associated with additional hospital costs of $3,087,013.03.

Discussion

The Hospital Readmission Reduction program uses readmission rates as a quality metric, tracking hospital readmission rates through the Nationwide Readmissions database (8). Due to payment incentives and penalties, hospital leaders and clinical researchers are motivated to investigate specific variables that may be attributed to readmission rates (13). By identifying patient risk factors that lead to complications and subsequent readmission, surgeons can alter their surgical care plan, operative approach, or preoperative preparation to account for a higher-risk procedure (9).

In our study, 7.9% and 12.7% of adrenalectomy patients were readmitted at 30 and 90 days after discharge, respectively. Our observed readmission rate is nearly consistent with recent literature, reporting readmission rates between 2–10% (9). Postoperative complications were reported in 15.4% of patients, accounting for one in six at risk. Bleeding (7.6%) and renal complications (5.2%) were the most frequent. A previous national study on adrenalectomies reported a similar complication rate at 16% (5). Previous studies have focused on operational

Table 1 Descriptive statistics of adrenalectomy patients (n=20,494) at primary admission (2010–2014)

Characteristics	%
Age	
18–44 years	18.1
45–64 years	48.4
>65 years	33.8
Gender	
Male	49.9
Female	50.1
Residence of same state	
Non-resident	10.3
Resident	89.7
Household income quartile (percentile)	
0–25th	25.9
26–50th	24.7
51–75th	24.6
76–100th	24.8
Charlson comorbidity index score	
0	61.1
1	27.7
2+	11.2
No. of chronic conditions	
≤6	81.8
>6	18.2
Cause of surgery	
Non-functional adenoma	58.8
Functional adenoma	26.6
Primary malignancy	3.1
Secondary malignancy	11.5
Type of procedure	
Unilateral/partial adrenalectomy	98.2
Bilateral adrenalectomy	1.8
Laparoscopic	
No	97.8
Yes	2.2
Postoperative complications	
None	84.6
One or more	15.4
In-hospital mortality	
Not reported	99.8
Reported	0.2
LOS, days	
Short stay (≤4)	61.7
Prolonged stay (>4)	38.3
Hospital charge, $	
Low charge	75
High charge	25
Hospital cost, $	
Low cost	75
High cost	25
Insurance status	
Private	35.8
Medicare	8.2
Medicaid	49.4
Others	6.6
Hospital bed size	
Small	8.8
Medium	18.2
Large	73.0
Hospital teaching status	
Metropolitan teaching	23.2
Metropolitan non-teaching	73.2
Non-metropolitan	3.6
Hospital volume	
Low	32.6
Medium	45.1
High	22.3

Table 1 (*continued*)

Table 1 (*continued*)

Characteristics	%
Hospital ownership	
Government non-federal	13.8
Private not-for-profit	78.8
Private investor owned	7.4
Urban-rural designation	
Large metropolitan areas	61.6
Small metropolitan	34.8
Micropolitan areas	3.3
Non-core	0.3
Discharge disposition	
Routine	88.8
Transfers	5.6
Home health care	5.6

Data is presented as percentage. All adult patients underwent adrenalectomy during the period between 2010 and 2014 are included in the table. All numbers are presented as weighted national estimates. Cut-off values of hospital charge and cost are 54,165.07 and 15,454.06, respectively. LOS, length of stay.

approach, surgeon specialty training, and intraoperative complications as variables for readmission rates following adrenalectomy (5,9). For our study, we examined the variables of patient demographics, type of adrenalectomy (unilateral/partial or bilateral), causes of primary admission (adenoma or malignant neoplasm), number of chronic diseases, causes of readmission, hospital demographics, and case volume in relation to post-adrenalectomy readmission rates.

Our study demonstrated that surgical complications and subsequent prolonged initial hospital stay were associated with a higher risk of readmission for patients following adrenalectomies. Patients with primary and secondary malignancy had the highest incidence of complications; therefore, patients with primary and secondary malignancy were most likely to be readmitted than patients with an adenoma lesion.

According to our findings, overall complication rates are higher in patients with primary and secondary malignancy, specifically technical and bleeding complications, after an adrenalectomy procedure. Malignancies are associated with increased vascularity, inflammation, immunosuppression, and a limited wound healing process, representing a

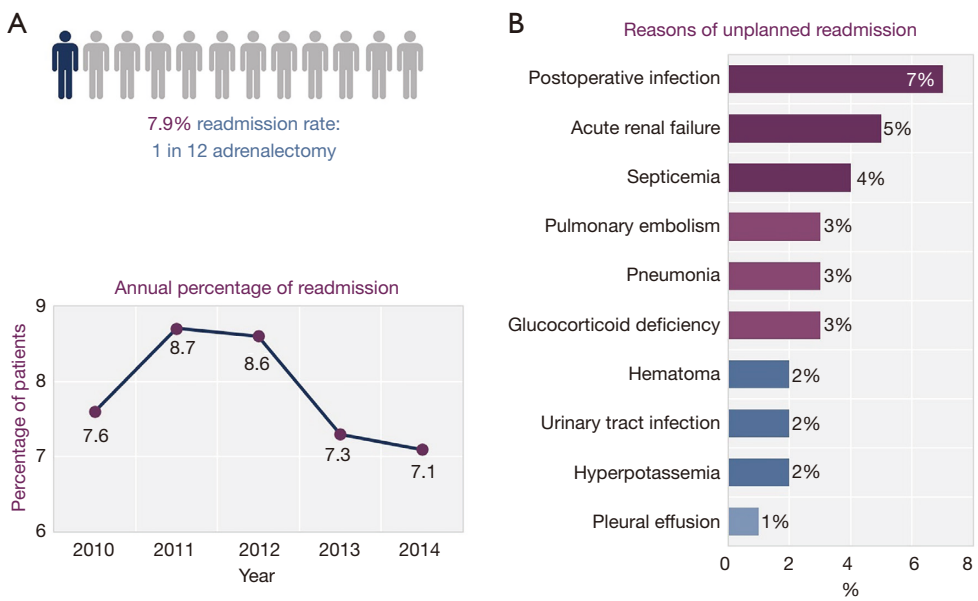

Figure 2 Frequency and causes of readmission following adrenalectomies. Data is presented as percentage. Two-tailed Chi-square was performed between different years. Statistical significance was considered at P value <0.05. All numbers are presented as weighted national estimates. (A) Annual percentage of readmission within 30 days. (B) Causes of 30-day readmission following adrenalectomies.

Table 2 Characteristics of 30- and 90-day readmitted patients at primary admission for adrenalectomy

Characteristics at primary admission	30-day readmission status			90-day readmission status		
	Non-readmission	Readmission	P value	Non-readmission	Readmission	P value
Demographic characteristics						
Age (mean ± SD), years	57.3±13.9	59.2±14.3	<0.001	57±13.8	60±13.7	<0.001
Gender			0.87			0.014
Male	8,522 (49.7)	731 (50.0)		6,710 (49.9)	1,037 (52.9)	
Female	8,610 (50.3)	731 (50.0)		6,732 (50.1)	923 (47.1)	
Household income quartile			<0.001			<0.001
Quartile 1	4,394 (26.1)	403 (28.0)		3,459 (26.2)	460 (23.8)	
Quartile 2	4,147 (24.6)	400 (27.8)		3,259 (24.7)	605 (31.3)	
Quartile 3	4,196 (24.9)	294 (20.4)		3,251 (24.6)	437 (22.6)	
Quartile 4	4,091 (24.3)	343 (23.8)		3,246 (24.6)	429 (22.2)	
Clinical characteristics						
Primary diagnosis			<0.001			<0.001
Non-functional adenoma	5,119 (44.3)	328 (34.8)		4,090 (45.0)	457 (35.8)	
Functional adenoma	4,826 (41.8)	421 (44.6)		3,864 (42.5)	502 (39.3)	
Primary malignancy	320 (2.8)	55 (5.8)		243 (2.7)	57 (4.5)	
Secondary malignancy	1,295 (11.2)	140 (14.8)		893 (9.8)	262 (20.5)	
Adrenalectomy type			0.76			0.84
Unilateral/partial	16,836 (98.3)	1,435 (98.2)		13,216 (98.3)	1,928 (98.4)	
Bilateral	296 (1.7)	27 (1.9)		227 (1.7)	31 (1.6)	
Charlson comorbidity index score			0.005			0.002
0–1	10,448 (61.0)	871 (59.5)		8,261 (61.5)	1,144 (58.4)	
2–3	4,622 (27.0)	445 (30.4)		3,557 (26.5)	592 (30.2)	
4+	2,061 (12.0)	147 (10.1)		1,625 (12.1)	224 (11.4)	
Outcomes						
Complications			<0.001			<0.001
One or more	982 (5.7)	163 (11.1)		747 (5.6)	200 (10.2)	
LOS (mean ± SD)	3.8±3.5	5.8±6.8	<0.001	3.8±3.5	5.6±6.6	<0.001
Total cost, $ (mean ± SD)	8,894±8,925.2	18,470.1±18,996.2	<0.001	8,692.1±8,484.5	18,506.8±20,419.2	<0.001
Hospital factors						
Service payer			<0.001			<0.001
Private	6,080 (35.6)	611 (42.0)		4,650 (34.6)	855 (43.7)	
Medicare	1,382 (8.1)	174 (12.0)		1,073 (8.0)	233 (11.9)	
Medicaid	8,503 (49.7)	571 (39.2)		6,838 (50.9)	746 (38.1)	
Others	1,149 (6.6)	100 (6.8)		871 (6.4)	123 (6.3)	

Table 2 (*continued*)

Table 2 (*continued*)

Characteristics at primary admission	30-day readmission status		P value	90-day readmission status		P value
	Non-readmission	Readmission		Non-readmission	Readmission	
Hospital teaching status			0.001			0.003
MT	3,920 (22.9)	302 (20.6)		3,104 (23.1)	391 (20.0)	
MNT	12,567 (73.4)	1,128 (77.1)		9,827 (73.1)	1,503 (76.7)	
NM	645 (3.8)	33 (2.3)		512 (3.8)	66 (3.4)	
Discharge disposition			<0.001			<0.001
Routine	15,882 (92.7)	1,196 (81.8)		12,494 (93.0)	1,658 (84.7)	
SNICOF	370 (2.2)	96 (6.6)		272 (2.0)	105 (5.4)	
Home care	860 (5.0)	169 (11.6)		663 (4.9)	194 (9.9)	
Annual adrenalectomy volume			0.021			0.036
Low	5,608 (32.7)	509 (34.8)		4,390 (32.7)	678 (34.6)	
Medium	7,329 (42.8)	571 (39.0)		5,759 (42.8)	779 (39.8)	
High	4,195 (24.5)	383 (26.2)		3,294 (24.5)	502 (25.6)	

Data is presented as number (percentage) or mean ± SD or median (quartiles). All numbers are presented as weighted national estimates. Two-tailed Chi-square and Fisher's Exact were used for categorical variables while Student's *t*-test was employed for quantitative data. Statistical significance was considered at P value <0.05. Annual hospital adrenalectomy volume (≤3, 4–13, >13). Categorization of quantitative variables were based on their medians. SD, standard deviation; LOS, length of stay; MT, metropolitan teaching; MNT, metropolitan non-teaching; NM, non-metropolitan; SNICOF, skilled nursing intermediate care other facility.

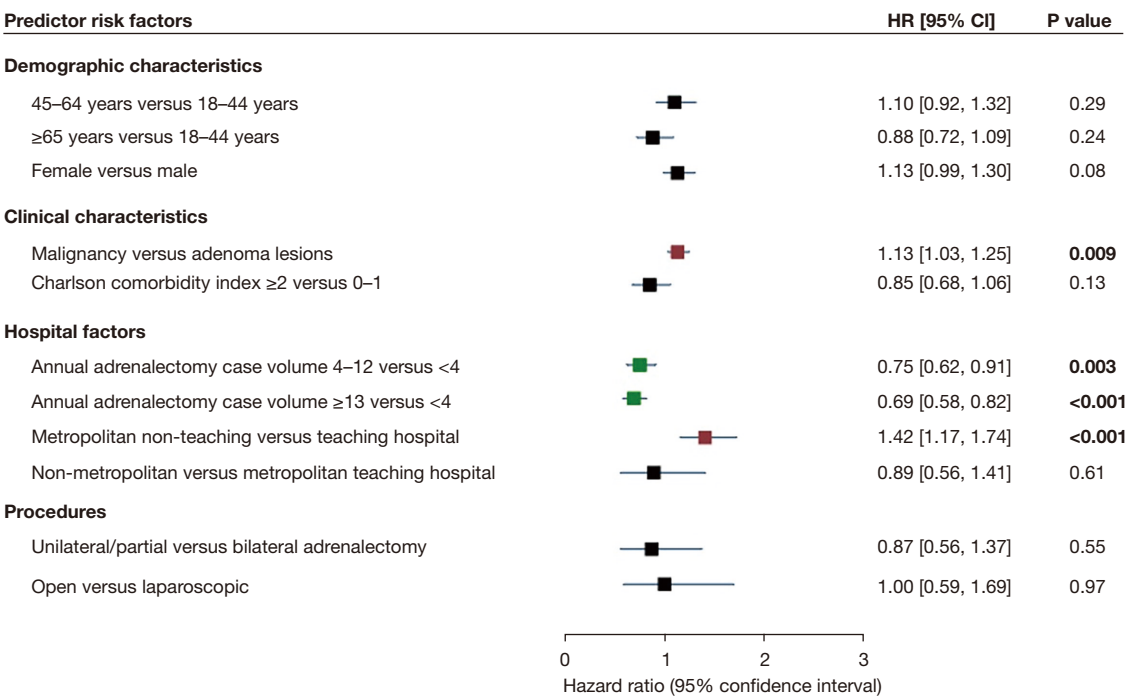

Figure 3 Multivariable analysis of risk factors for readmission. Cox regression analysis was used. HR and 95% CI are shown. HR, hazard ratio; CI, confidence intervals.

complex pathology that may interfere with surgical recovery (14,15). Overall, the literature reports higher complication rates in patients with malignancies in many surgical specialties (14-17). To decrease the risk of complications, surgeons should consider a minimally invasive technique to reduce the risk of infection and complication when designing a surgical care plan (18,19). According to Beck *et al.* (9), open technique is associated with a higher readmission rate, as these patients were also associated with a higher complication rate and need to additional interventions, such as blood transfusion. Complications associated with open procedure included hemorrhage and adrenal injury (9). Surgeons may consider preventative measures such as preoperative administration of antibiotics and monitoring for renal insufficiency, hypercoagulability, and hemodynamic instability in patients with a co-existing metastasis and malignancy (9,20). We encourage researchers to investigate specific types of malignancies as well as the location, and their associated complications, as pathology and proximity may lead to an explanation of the occurrence of the complication and lead to appropriate preoperative prophylactic measures.

High hospital adrenalectomy volume was associated with a lower risk of readmission. Previous literature shows that high-volume surgeons performing adrenalectomy procedures are associated with lower complication rates, shorter LOS, and lower readmission rates (2,5,9). However, only 16% of adrenalectomy-performing surgeons are defined as high-volume, which may influence our reported nationwide complication rate (2). Gray *et al.* (21) reported that only one-third of surgeons had performed at least six adrenalectomies per year. Another study showed that surgeons performing at least six procedures were associated with lower complication rate and decreased hospital costs (22). Metropolitan teaching hospitals were also associated with a lower risk of readmission than metropolitan non-teaching hospitals. Excluding the 'July Effect' during which new interns enter residency after their medical school graduation, major teaching hospitals are associated with annual overall lower mortality rates, increased quality of care, and lower complication rates (23-25). These trends may result from increased oversight due to the presence of trainees and increased patient safety and quality of care initiatives due to government subsidies for graduate medical education. Referring physicians should consider directing their patients to high-volume metropolitan teaching hospitals for adrenalectomy procedures. Further characterization of hospital operational factors and their interaction with complication rate and LOS can identify measures to reduce readmissions rates nationally.

Regarding the cost burden on the healthcare system, we found that readmission following adrenalectomy added an extra 2.06 days to a hospital visit for the average patient, with additional hospital costs of $3,087,013.03. This additional LOS is consistent with the literature, which reports 2–9 days (4). To reduce costs, efforts may be made to ensure the above factors are considered: anticipate and prepare for common complications, define patients with primary malignancy and secondary malignancy as high-risk groups, and perform adrenalectomy cases at high volume, metropolitan teaching hospitals.

This study was conducted specifically for patients undergoing adrenalectomy. A considerable limitation is placed on extrapolating and generalizing the outcomes, given that we studied only one procedure (adrenalectomies), and common surgical complications and their respective risk factors specific to this procedure do not apply to other surgical procedures. Another considerable limitation is erroneous encoding in the database. We are unable to account for an unreported procedure that may have taken place during the adrenalectomy procedure. Limited information is available in database regarding operative approach; therefore, we were unable to include this variable in our analysis. Since this study reflects data from 2010–2014, results may be affected by time and changes that have occurred in the last 6 years. Unfortunately, due to the nature of the Nationwide Readmissions Database, the 2010–2019 data years cannot be combined to create a multi-data year database. Patient and hospital linkage numbers to not track the same patients and hospitals, respectively, across the years.

Conclusions

Hospital readmission rates following adrenalectomy are related to complication rates and initial hospital LOS. Specific adrenal pathologies are at higher risk for complications; therefore, they are at higher risk for readmission. To decrease complication rates and subsequent readmission rates, surgeons should recognize patient comorbidities, categorize risks associated with each adrenal pathology, and anticipate procedure complications specific to adrenalectomies. Referring physicians may also consider directing referrals to high-volume hospitals and metropolitan teaching hospitals. In effect, readmission rates

may be decreased, leading to an increase in quality of care, an increase in patient well-being and satisfaction, and a decrease in unnecessary healthcare spending.

Further studies on the variables that correlate with readmission may provide insight into how hospital leadership and clinicians can deliver safe, quality, and efficient healthcare for hospitalized patients undergoing an adrenalectomy procedure.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-22-18/rc

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-22-18/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-22-18/coif). EK serves as an Editor-in-Chief of *Gland Surgery* from May 2017 to April 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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Table S1 Codes for ICD-9 classification for primary diagnosis and procedures

Characteristic	Codes
Primary diagnosis	
Functional adenomas	2550, 2551, 25510, 25511, 25512, 2553, 2556, 2558, 2559
Non-functional adenomas	2270, 2372
Primary malignancy	1940
Secondary malignancy	1987
Types of procedures	
Partial/unilateral adrenalectomy	0721, 0722, 0729
Bilateral adrenalectomy	073
Technique	
Laparoscopic procedure	5411, 5412, 5419, 5421
Complications	
Bleeding/shock	2851 (acute posthemorrhagic anemia)
	9981 (hemorrhage or hematoma complicating a procedure not elsewhere classified)
	99811 (hemorrhage complicating a procedure)
	99812 (hematoma complicating a procedure)
	99813 (seroma complicating a procedure)
	9982 (accidental puncture or laceration during a procedure, not elsewhere classified)
	E8700 (accidental cut, puncture, perforation or hemorrhage during surgical operation)
Infection/sepsis	0380 (streptococcal septicemia)
	0389 (unspecified septicemia)
	78552 (septic shock)
	6822 (cellulitis and abscess of trunk)
	9983 (disruption of wound, unspecified)
	99831 [disruption of internal operation (surgical) wound]
	99832 [disruption of external operation (surgical) wound]
	99851 (infected postoperative seroma)
	99859 (other postoperative infection)
	99883 (non-healing surgical wound)
	8604 (traumatic pneumohemothorax without mention of open wound into thorax)
Technical complications	9982 (accidental puncture or laceration during a procedure, not elsewhere classified)
	9984 (foreign body accidentally left during a procedure)
	9986 (persistent postoperative fistula)
	9987 (acute reaction to foreign substance accidentally left during a procedure)
	55321 (incisional hernia without mention of obstruction or gangrene)
	5778 (other specified diseases of pancreas)
	415 (acute pulmonary heart disease)
	41519 (other pulmonary embolism and infarction)
	5061 (acute pulmonary edema due to fumes and vapors)
	5069 (unspecified respiratory conditions due to fumes and vapors)
Cardiovascular complications	41000 (acute myocardial infarction of anterolateral wall, episode of care unspecified)
	41001 (acute myocardial infarction of anterolateral wall, initial episode of care)
	41002 (acute myocardial infarction of anterolateral wall, subsequent episode of care)
	41010 (acute myocardial infarction of other anterior wall, episode of care unspecified)
	41050 (acute myocardial infarction of other lateral wall, episode of care unspecified)
	41051 (acute myocardial infarction of other lateral wall, initial episode of care)
	41052 (acute myocardial infarction of other lateral wall, subsequent episode of care)
	41060 (true posterior wall infarction, episode of care unspecified)
	41061 (true posterior wall infarction, initial episode of care)
	41062 (true posterior wall infarction, subsequent episode of care)
	41070 (subendocardial infarction, episode of care unspecified)
	41071 (subendocardial infarction, initial episode of care)
	41072 (subendocardial infarction, subsequent episode of care)
	41080 (acute myocardial infarction of other specified sites, episode of care unspecified)
	41081 (acute myocardial infarction of other specified sites, initial episode of care)
	41082 (acute myocardial infarction of other specified sites, subsequent episode of care)
	41090 (acute myocardial infarction of unspecified site, episode of care unspecified)
	41091 (acute myocardial infarction of unspecified site, initial episode of care)
	41092 (acute myocardial infarction of unspecified site, subsequent episode of care)
	41511 (iatrogenic pulmonary embolism and infarction)
	99702 (iatrogenic cerebrovascular infarction or hemorrhage)
	9972 (peripheral vascular complications, not elsewhere classified)
	99779 (vascular complications of other vessels)
	78559 (other shock without mention of trauma)
	4010 (malignant essential hypertension)
	40509 (other malignant secondary hypertension)
	4275 (cardiac arrest)
	99791 (complications affecting other specified body systems, not elsewhere classified, hypertension)
Renal complications	5845 (acute kidney failure with lesion of tubular necrosis)
	5846 (acute kidney failure with lesion of renal cortical necrosis)
	5847 {acute kidney failure with lesion of renal medullary [papillary] necrosis}
	5848 (acute kidney failure with other specified pathological lesion in kidney)
	5849 (acute kidney failure, unspecified)
	5856 (end stage renal disease)
Pulmonary complications	5180 (pulmonary collapse)
	5181 (interstitial emphysema)
	5184 (acute edema of lung, unspecified)
	5187 (TRALI)
	51884 (acute and chronic respiratory failure)
	5185 (pulmonary insufficiency following trauma and surgery)
	51881 (acute respiratory failure)
	51882 (other pulmonary insufficiency, not elsewhere classified)
	99731 (ventilator associated pneumonia)
	99732 (postprocedural aspiration pneumonia)
	9672 (peripheral vascular complications, not elsewhere classified)
Endocrine complications	2513 (postsurgical hypoinsulinemia)
	2554 (corticoadrenal insufficiency)
	25541 (glucocorticoid deficiency)
	25542 (mineralocorticoid deficiency)
	2555 (other adrenal hypofunction)
	2521 (hypoparathyroidism)
	27541 (hypocalcemia)
	2440 (postsurgical hypothyroidism)
Wound complications	9983 [disruption of external operation (surgical) wound]
	99883 (non-healing surgical wound)

TRALI, transfusion related acute lung injury.

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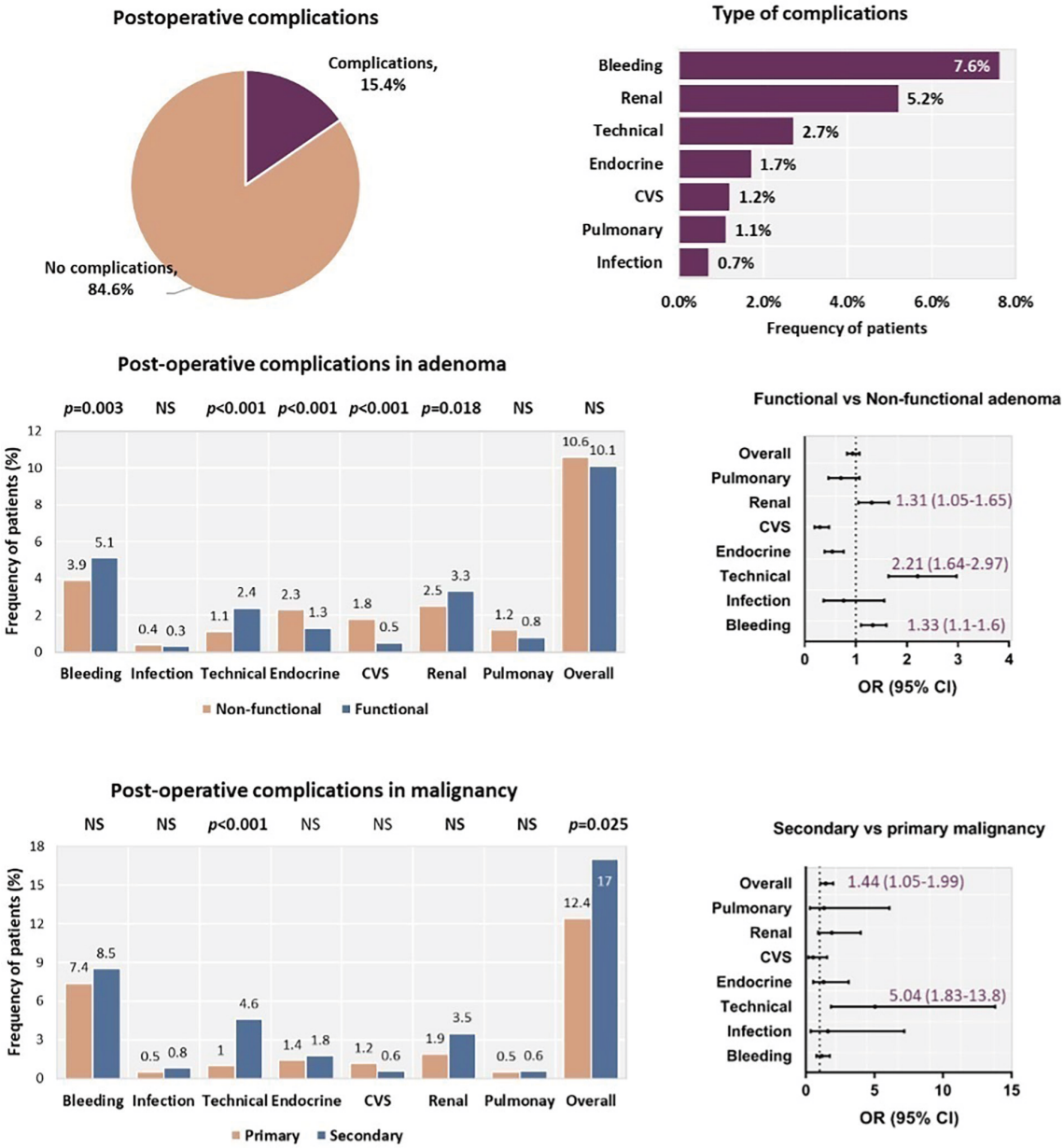

Figure S1 Postoperative complications in patients following adrenalectomy. Significance at P<0.05. Fisher's Exact test was applied. Unadjusted OR and 95% CI are shown. NS, non-significant; CVS, cardiovascular system; OR, odds ratio; CI, confidence interval.

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