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Each procedure matters: threshold for surgeon volume to minimize complications and decrease cost associated with adrenalectomy

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Background. An association has been suggested between increasing surgeon volume and improved patient outcomes, but a threshold has not been defined for what constitutes a "high-volume" adrenal surgeon.
Methods. Adult patients who underwent adrenalectomy by an identifiable surgeon between 1998–2009 were selected from the Healthcare Cost and Utilization Project National Inpatient Sample. Logistic regression modeling with restricted cubic splines was utilized to estimate the association between annual surgeon volume and complication rates in order to identify a volume threshold.
Results. A total of 3,496 surgeons performed adrenalectomies on 6,712 patients; median annual surgeon volume was 1 case. After adjustment, the likelihood of experiencing a complication decreased with increasing annual surgeon volume up to 5.6 cases (95% confidence interval, 3.27–5.96). After adjustment, patients undergoing resection by low-volume surgeons (<6 cases/year) were more likely to experience complications (odds ratio 1.71, 95% confidence interval, 1.27–2.31, P = .005), have a greater hospital stay (relative risk 1.46, 95% confidence interval, 1.25–1.70, P = .003), and at increased cost (+26.2%, 95% confidence interval, 12.6–39.9, P = .02).
Conclusion. This study suggests that an annual threshold of surgeon volume (≥6 cases/year) that is associated with improved patient outcomes and decreased hospital cost. This volume threshold has implications for quality improvement, surgical referral and reimbursement, and surgical training. (Surgery 2017;160:XXX-XXX.)

Adrenalectomy has increased in the United States by nearly 45% during the past 20 years; this increase may be ascribed to a combination of factors, such as more frequent use of computed tomography leading to the detection of incidental adrenal masses, as well as the advent of the laparoscopic approach, which has decreased the threshold for operative intervention.[1,2] Although the adrenalectomy procedure itself has a low mortality rate (<1%), numerous studies have reported postoperative, in-hospital complication rates of ≤20%, with variable hospital durations of stay of 2 to 9 days.[3-7] Experience with the procedure as measured by both surgeon and hospital volumes has been shown in numerous studies to be associated with patient outcomes.[8-11] While studies on the safety of adrenalectomy often come from high-volume centers, national data show that the average surgeon who performs adrenalectomy only does one case on average per year.[1] Given this apparent discrepancy between the literature and observed practice patterns based on claims databases, our aim was to determine if there is a threshold number of adrenalectomies that is associated with improved patient perioperative outcomes. The identification of a volume threshold for surgeons may have direct implications for referring physicians, payers, policy makers, and graduate surgical training.

We hypothesize that there is an annual number of adrenalectomies performed by a surgeon that is associated with the least risk of complications.

Methods

We conducted this retrospective cohort study of hospital discharge data for patients undergoing adrenalectomy between 1998 and 2009 in the Healthcare Cost and Utilization Project National Inpatient Sample dataset (HCUP-NIS). HCUP-NIS is maintained by the

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Agency for Healthcare Research and Quality and represents a 20% stratified sample of all inpatient discharges from acute care hospitals across the United States. HCUP-NIS represents a sample of the larger national population, allowing for an analysis of a more generalizable patient cohort. This database was utilized for a number of reasons, including the presence of surgeon identifiers; data on both benign and malignant pathologies and the self-weighting design of the NIS decreases the margin of error for estimates.

The NIS dataset was used to select adult patients who underwent an adrenalectomy from 1998–2009. Patients were included based on the state and year of their inpatient visit. Patients from the states of Iowa, Kansas, Montana, New Hampshire, New York, North Carolina, Pennsylvania, South Carolina, and Texas were included for all study years. Patients from Maryland, Minnesota, Nebraska, Rhode Island, and Virginia were included for the years of 1998–2000 only; patients from Florida, Arkansas, and Wyoming for 1998–2002 only; patients from South Dakota for 1998–2006 only; patients from Maine for 2000–2009 only; patients from Georgia for 2001–2002 only; patients from West Virginia for 2001–2009 only; and patients from Nevada for 2003–2009 only. Patients from Arizona, Colorado, Kentucky, Michigan, Missouri, New Jersey, Oregon, Tennessee, and Washington were excluded. There were no patients from the states not listed here in this study cohort.

Patient clinical and demographic characteristics such as age, sex, race, and primary payer were obtained from the dataset. Patient comorbidities were characterized using the Charlson Comorbidity scoring system and categorized into 3 groups: 0 (no comorbidities), 1, and ≥2. Total surgeon volume was calculated as the total number of patients who underwent an adrenalectomy by a given surgeon. Annual surgeon volume was calculated as the total volume for a given surgeon divided by the total number of years that that surgeon reported doing at least one adrenalectomy in the patient dataset. In-hospital complications were derived from secondary the *International Classification of Diseases, 9th Revision*, diagnoses and procedures codes corresponding to the index admission (Table I).

Adjusted cost was calculated by multiplying the total charges reported by the treating hospital by the group-averaged, all-payer, inpatient cost-to-charge ratio as defined by HCUP NIS. Costs then were adjusted to 2015 US dollars using rates from the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. The study was granted exempt status by our Institutional Review Board.

Statistical analysis

The primary outcome of this study was the incidence of one or more in-hospital complication(s). Secondary outcomes included the hospital duration of stay and inflation-adjusted hospital costs.

A multivariate logistic regression model with restricted cubic splines (RCS) was used to examine the association of annual surgeon volume and incidence of any complication, after adjustment for known covariates including age, sex, race, insurance status, Charlson comorbidity index, hospital location, hospital type, hospital region, and year of procedure. RCS methodology allows for the functional relationship between a continuous variable and an outcome to be examined without prior knowledge of the shape of the association.[12] With this model, we identified visually a range of values of annual surgeon volume that corresponded to a change in the log odds ratio (OR) of a complication. A bootstrap simulation with a Monte Carlo Markov Chain procedure was then used to estimate the point within this range that corresponded to the maximum change in log OR. The identified value was 5.6 (95% confidence interval [CI], 3.27–5.96). Based on this value, 2 volume groups were created: patients treated by surgeons who performed <6 cases/year and patients treated by surgeons with ≥6 cases/year.[13,14]

Patient and hospital characteristics and complication rates were summarized with *N* (%) for categorical variables and median (interquartile range) for continuous variables. Volume groups were compared using the χ^2 test or Fisher exact test, as appropriate, or Student *t* test. Multivariate logistic regression was used to examine factors associated with treatment by a high-volume surgeon. Multivariate logistic regression also was used to examine the adjusted association between low- versus high-volume surgeons and the incidence of any postoperative complication; negative binomial regression was used to examine the association with hospital duration of stay, and linear regression was used to examine the association with costs. Due to the skewed nature of hospital cost, this outcome was log-transformed prior to modeling, and percentage change was estimated and reported. These models were built in the generalized estimating equation framework to account for within-hospital correlation.

Table I.
Definition of postoperative complications by ICD-9 diagnosis and procedure codes

Bleeding	
39.98 (P)	Control of hemorrhage, not otherwise specified
99.04 (P)	Transfusion of packed cells
998.1	Hemorrhage or hematoma or seroma complicating a procedure
998.11	Hemorrhage complicating a procedure
998.12	Hematoma complicating a procedure
E870.0	Accidental cut puncture perforation or hemorrhage during surgical operation
Wound	
86.04 (P)	Other incision with drainage of skin and subcutaneous tissue
86.22 (P)	Excisional debridement of wound, infection, or burn
682.1	Cellulitis and abscess of neck
998.3	Disruption of wound
998.5	Postoperative infection
998.51	Infected postoperative seroma
998.59	Other postoperative infection
998.13	Seroma complicating a procedure
Respiratory	
96.72 (P)	Continuous invasive mechanical ventilation for ≥96 consecutive hours
512.1	Iatrogenic pneumothorax
462	Acute pharyngitis
518.4	Acute edema of lung unspecified
518.5	Pulmonary insufficiency following trauma and surgery
519.0	Tracheostomy complications
997.3	Respiratory complications
518.7	Transfusion related acute lung injury
Cardiac	
427.5	Cardiac arrest
997.1	Cardiac complications not elsewhere classified
Urologic	
599.0	Urinary tract infection site not specified
997.5	Urinary complications not elsewhere classified
Other	
997.0	Nervous system complications
997.00	Nervous system complication unspecified
997.01	Central nervous system complication
997.02	Iatrogenic cerebrovascular infarction or hemorrhage
997.09	Other nervous system complications
997.9	Complications affecting other specified body systems not elsewhere classified
998.8	Other specified complications of procedures not elsewhere classified
998.89	Other specified complications of procedures not elsewhere classified
998.9	Unspecified complication of procedure not elsewhere classified
999.9	Other and unspecified complications of medical care not elsewhere classified
998.2	Accidental puncture or laceration during a procedure not elsewhere classified
998.4	Foreign body accidentally left during a procedure not elsewhere classified
997.4	Digestive system complications
998.2	Accidental puncture or laceration during a procedure not elsewhere classified

ICD-9, the *International Classification of Diseases, 9th Revision*; *P*, procedure code.

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