Hypothesis: Laparoscopic adrenalectomy (LA) has become standard therapy for benign adrenal masses in adults. The utility of LA in children with adrenal masses is less well defined because of the infrequency and pathologic variability of pediatric adrenal masses, and body size and instrumentation considerations that exist in small children. Evaluation of a case series of children undergoing lateral, transperitoneal LA will reflect the safety and efficacy of this procedure in pediatric patients and identify preferred patient selection criteria.


Setting: Urban tertiary referral pediatric teaching hospitals.

Patients and Interventions: All children with pathologic adrenal masses undergoing LA were included.

Main Outcome Measures: The primary study outcome measures included operative duration, conversions to open adrenalectomy, complications, length of hospital stay, and freedom from recurrence of the original pathologic adrenal mass.

Results: A total of 21 LAs (including a staged, bilateral LA) were performed in 20 patients (13 girls, 7 boys) with a mean age of 6.4 years (range, 14 months to 18 years). Nine patients (43%) had neuroblastic tumors. Operative duration averaged mean ± SD 101 ± 48 minutes, and there was a single conversion to open adrenalectomy in a patient with a left adrenal carcinoma and tumor thrombus extending into the renal vein. There were no perioperative complications, and no patients required blood transfusions. The postoperative hospital stay averaged 1.5 days (range, 1-4.5 days). At a mean ± SD follow-up of 31 ± 17 months, all patients remained clinically (radiologically and/or biochemically) free of their original adrenal disease.

Conclusion: Laparoscopic adrenalectomy can be used to safely treat suspected benign and selected malignant adrenal masses in children.

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Since its initial description more than a decade ago, many clinical reports have affirmed the role of laparoscopic adrenalectomy (LA) in the treatment of benign and selected malignant adrenal pathologic masses in adult patients. In children, the collective clinical experience with LA continues to grow.

See Invited Critique at end of article

While the most common adrenal lesion requiring surgery in adults is a hormonally active tumor, the most common adrenal lesion in children is neuroblastoma, a neural crest-derived tumor that is infrequently amenable to LA at initial diagnosis. In addition to the relative infrequency of adrenal lesions and a variable pathologic spectrum, children, especially infants, present unique challenges related to body size, instrumentation, and the acquisition of laparoscopic experience among pediatric surgeons.

This study details a combined experience of 2 pediatric institutions with LA (to our knowledge, the largest published to date) and reflects the representative spectrum of pathologic adrenal masses facing pediatric health care professionals. The relationship between careful patient selection and patient safety and favorable outcome is emphasized.
information, preoperative diagnostic workup, operative details, adrenal pathologic features, complications, length of hospital stay, and details on clinical (radiographic and biochemical) follow-up.

DIAGNOSTIC EVALUATION OF PATIENTS

Antenatally Diagnosed Adrenal Masses

Fetuses diagnosed with adrenal masses were followed up with antenatal ultrasound and evaluated postnatally by ultrasound and computed tomographic (CT) scan. Urinary screening for neuroblastoma was performed, and suspected cases underwent bone marrow aspiration and radionuclide bone and metadiobenzylguanidine scanning as per Children’s Oncology Group perinatal neuroblastoma protocol (study chairperson, J. Nuchtern, MD, Baylor College of Medicine, Texas Children’s Hospital, Houston, unpublished data). Tumors of 16 mL or more in volume at initial examination or tumors noted to grow on serial imaging were considered for LA.

Postnatally Diagnosed Adrenal Masses

Children with adrenal masses were either diagnosed coincidentally by imaging or by investigation of symptoms suggesting adrenal hormone excess. Abdominal imaging (ultrasound, CT scan, and occasionally magnetic resonance imaging), combined with a thorough endocrine evaluation for neuroblastoma, pheochromocytoma, Cushing syndrome, and other functioning adrenocortical tumors was performed in all cases. In addition to CT and magnetic resonance imaging, patients with suspected adrenal pheochromocytoma underwent metadiobenzylguanidine scanning to screen for multifocal (bilateral and extra-adrenal) tumors. Patients with suspected isolated, noninvasive, and nonmetastatic pheochromocytomas were considered candidates for LA.

SURGICAL TECHNIQUE

A transperitoneal modification of the Gagner technique was used in all patients, who were placed in a lateral decubitus position (operative side upward) over a flank lift to laterally flex the spine and maximally expose the space between the costal margin and iliac crest. Three or 4 cannulas were placed below the costal margin between the midclavicular line and the posterior axillary line, depending on the side (3 generally suffices for left-sided glands). In the smallest patients, an umbilical port was placed first to enable safe insufflation and infracostal port placement under vision, and this port was used subsequently for adrenal vein clip application and specimen retrieval (Figure).

For left adrenalectomy, the camera (3 or 5 mm, 30°) was placed through the anterior port in the midclavicular line, and gland exposure through colon and spleen mobilization was accomplished with either the hook cautery or ultrasonic scalpel. The adrenal gland was then mobilized and the exposed adrenal vein clipped closer to the gland than to the renal vein. For right adrenalectomy, the need for liver retraction to maintain medial-gland exposure mandated the use of 4 ports, which were placed below the costal margin, between the midclavicular line anteriorly and the costovertebral angle posteriorly. The 3 anterior ports were placed first, and the right liver lobe was mobilized by division of the triangular ligament. Median liver retraction was maintained by a retractor placed through the most anterior port, which permitted safe placement on the fourth (posterior) port. The camera was placed through the second anterior port, and gland dissection was accomplished through the 2 posterior (dorsal) ports. For smaller glands, initial identification and division of the short right adrenal vein is desirable, and this was accomplished by dissecting cephalad along the lateral edge of the inferior vena cava, beginning at the level of the right renal vein. Larger glands may require initial lateral mobilization to allow safe exposure of the adrenal vein.

Specimen extraction techniques varied according to tumor size. Large tumors required an abdominal incision to facilitate atraumatic extraction, while smaller tumors were removed using endoscopic bag systems through the umbilical port site. Structural integrity was preserved in all cases to allow proper pathologic interpretation.

RESULTS

A total of 21 LAs (14 left, 7 right) were performed in 20 patients (13 girls, 7 boys) with a mean age of 6.4 years (range, 14 months to 18 years), whose clinical details are summarized in Table 1. Our oldest patient had Cushing disease refractory to 2 hypophysectomies and un-
derwent staged, bilateral LA 3 weeks apart. The youngest patient (age, 14 months) had been diagnosed antenatally with a presumed perinatal neuroblastoma, which was followed up and referred for excision when it showed slight interval growth. The distribution of pathologic diagnoses by size and side is presented in Table 2. Tumor size (expressed as the longest axis on CT scan) averaged 4.6 cm, with a range of 3 to 8.5 cm. The most common diagnoses were neuroblastic tumors in 9 patients (5 neuroblastoma, 4 ganglioneuroma) and nonfunctioning adenoma and Cushing syndrome or disease in 4 patients each. One patient had a pheochromocytoma and 1 had an adrenocortical carcinoma. Laparoscopic adrenalectomy was successful in all but 1 patient; the patient with a left-sided adrenocortical carcinoma was found to have tumor thrombus extending into the left renal vein, which had not been shown on preoperative imaging. Conversion to open adrenalectomy resulted in the uncomplicated removal of an intact tumor with left kidney preservation. Operative duration for all cases was mean ± SD 101 ± 48 minutes. There were no perioperative complications, and no patients required a blood transfusion. The average length of hospital stay after LA was 1.5 days (range, 1-4.5 days). At a mean ± SD follow-up of 31 ± 17 months, all patients remained radio logically and biochemically free of their original adrenal disease.

In contrast to the extensive reported experience with LA in adults, the experience in children consists of a few case series. To our knowledge, our experience with 21 LAs is the largest pediatric series to date and suggests that with careful patient selection and slight modifications in technique for body size, LA can be performed safely in most children. Table 3 summarizes the published case series of pediatric LA containing 9 or more cases.

A fundamental difference that exists between children and adults is the spectrum of adrenal disease requiring surgery. The most common adrenal lesions in children are neuroblastic tumors, which are derived from neural crest cellular rests, and of the 21 patients in our series, 9 had neuroblastic tumors. Neuroblastic tumors exist along a spectrum, ranging from undifferentiated with metastatic potential (neuroblastomas), to differentiated without metastatic potential (ganglioneuromas). The variable biological behavior of neuroblastic tumors is determined by a number of factors including patient age at clinical diagnosis, tumor histologic features, oncogene expression, and cellular DNA content. Neuroblastomas most frequently manifest beyond infancy as large, locally infiltrative adrenal masses with or without metastases. Biopsies are performed on unresectable or advanced-stage tumors, which are then treated with neoadjuvant chemotherapy and undergo open salvage adrenalectomy. In a few patients, the cytoreductive response to chemotherapy is so dramatic that salvage LA may be considered. Although none of the patients with neuroblastoma in our series received neoadjuvant chemotherapy, a total of 4 children with advanced-stage adrenal neuroblastoma treated successfully by salvage LA after chemotherapy have been reported. Neuroblastoma is also notable for its potential for spontaneous maturation and regression. The observation of spontaneous regression of sizable fetal adrenal masses detected by antenatal ultrasound suggests that “perinatal” neuroblastoma can be safely observed (by serial imaging), with resection reserved for those tumors that fail to regress. Although this hypothesis forms the basis for an open Children’s Oncology Group pilot study for infants younger than 3 months with small-volume adrenal neuroblastomas, the availability of LA for infants with small, localized tumors offers an arguably safer alternative to tumor “observation,” especially since observation requires serial CT scans that now confer a defined risk for second malignancies from radiation exposure. Therefore, among

**COMMENT**

### Table 2. Adrenal Gland Side, Size, and Pathologic Characteristics

<table>
<thead>
<tr>
<th>Pathologic Characteristic</th>
<th>No. of Glands</th>
<th>Median Size, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenal hyperplasia</td>
<td>Left</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>2</td>
</tr>
<tr>
<td>Nonfunctioning adenoma</td>
<td>Left</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0</td>
</tr>
<tr>
<td>Functioning adenoma</td>
<td>Left</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td>Left</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0</td>
</tr>
<tr>
<td>Adrenocortical carcinoma</td>
<td>Left</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1</td>
</tr>
<tr>
<td>Neuroblastoma</td>
<td>Left</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1</td>
</tr>
<tr>
<td>Ganglioneuroma</td>
<td>Left</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 3. Summary of Pediatric Series of Laparoscopic Adrenalectomy (LA)

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Patients</th>
<th>Age, y, Mean</th>
<th>No. of Bilateral LAs</th>
<th>No. of Open Conversions</th>
<th>No. of Neuroblastic Tumors*</th>
<th>No. of Pheochromocytomas</th>
<th>No. of Carcinomas</th>
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<tr>
<td>Castilho et al12</td>
<td>13</td>
<td>6.3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>de Lagausie et al14</td>
<td>9</td>
<td>3.2</td>
<td>0</td>
<td>1</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kadamba et al15</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Miller et al13</td>
<td>17</td>
<td>9.8</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Current study</td>
<td>20†</td>
<td>6.4</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*Neuroblastic tumors include neuroblastomas and ganglioneuromas.
†Includes 7 patients from the Miller et al series.
pediatric patients (including infants) with suspected or proven neuroblastic tumors, LA may be considered for small, localized tumors at the time of clinical diagnosis or for large or advanced-stage tumors that have a favorable cytoreductive response to chemotherapy.

The remaining patients in our series had clinicopathologic diagnoses comparable with those in adults (functioning and nonfunctioning adenoma, Cushing syndrome or disease with associated adrenal hyperplasia, phaeochromocytoma, and adrenocortical carcinoma). One patient with Cushing disease refractory to pituitary surgery underwent staged, bilateral LA early in our experience but could have been treated using 1 anesthetic. The safe completion of LA in our single patient with phaeochromocytoma (who did experience controllable hypertension intraoperatively despite preoperative hydration and alpha-receptor blockade) and the limited experience of others suggests that LA is reasonable in the small numbers of children who develop phaeochromocytoma. Children with biochemically suspected phaeochromocytoma should undergo thorough preoperative localization screening (CT, magnetic resonance imaging, metaiodobenzylguanidine scanning) because of the potential for bilateral and/or extraadrenal tumors. Furthermore, the high incidence of syndromic phaeochromocytoma among children favors a routine practice of screening all patients for associated syndromes including multiple endocrine neoplasias (2A, 2B), Sturge-Weber syndrome, tuberous sclerosis, von Recklinghausen disease, and von Hippel Lindau disease.

There are apparent contraindications to LA in children. Our single conversion in a patient with carcinoma and tumor thrombus into the renal vein mirrors the experience in adults, which favors an open approach for those patients suspected of having malignancy on the basis of renal vein involvement or significant retroperitoneal lymphadenopathy. Tumor size is relevant on an individual case basis, depending on the age and size of the child. Other relative contraindications to LA include an uncorrectable coagulopathy or a history of previous splenic (for left-sided adrenal lesions) or ipsilateral renal injury or surgery. For our smallest patients, we made minor modifications to the Gagner transperitoneal technique, including initial placement of an umbilical trocar for insufflation, which allows placement of all infracostal trocars under vision. An available umbilical port also allows clip application (5 or 10 mm) to the adrenal vein, enabling all other ports (including the camera port) to be 3 mm (provided hook cautery is used for dissection). Finally, specimen retrieval can be easily and cosmetically achieved through the umbilical incision.

Laparoscopic adrenalectomy offers safe and effective surgical treatment for many pediatric adrenal lesions, including select cases of neuroblastoma and phaeochromocytoma. While LA may be the procedure of choice for suspected benign lesions and small, localized neuroblastic tumors, more experience and longer follow-up are necessary to determine the role of LA in the treatment of phaeochromocytoma in children.

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REFERENCES