The aim of the study was to present the authors’ four-year experience in employing posterior retroperitoneoscopic adrenalectomy according to Walz (PRA) in surgical treatment of adrenal tumors up to 6 cm in size.

Material and methods. A prospective analysis included 83 procedures of unilateral PRA (40 rightsided and 43 left-sided adrenalectomies) performed in patients (the M:F ratio = 22:61; mean age 58.1±10.3 years; mean tumor size 41±14 mm) operated on in the Department in the period from January 2004 to December 2007. Indications for surgery included: glucocorticoid adenomas (10), aldosteronomas (18), pheochromocytomas (16) and hormonally inactive adrenal cortex tumors (39). The operators used the PRA surgical technique according to Walz. The learning curve was evaluated taking into consideration the operative time, percentage of conversions and complications. The statistical analysis assessed the correlation between the operative time and body mass index (BMI), location and size of the tumor and its hormonal activity. The results of surgical treatment employed in patients with hormonally active tumors were evaluated in a 6-month follow-up.

Results. The mean operative time was 73.7±22.3 min. A single conversion (1.2%) was required, as well as a single early reoperation (1.2%) due to bleeding. Following the initial 20 operations with the mean operative time of 86.5±34.6 min, the mean operative time of the remaining 63 procedures was 69.7±14.9 min (p=0.046) and did not exceed 90 min in any case. No correlation was noted between the operative time and BMI, tumor location and size. The procedures performed in patients with pheochromocytomas were not significantly longer in comparison to operations in hormonally inactive adrenocortical adenomas. Normalization of arterial blood pressure was achieved in all the patients with pheochromocytomas, aldosteronomas and subclinical glucocorticoidism aged below 50 years and with less than one-year history of secondary hypertension.

Conclusions. Despite its seeming complexity resulting from operating in an „upside down” surgical field, the PRA surgical technique is easy to master and safe, also during the learning period. After the surgeon has performed approximately 20 operations, the operative time does not exceed 90 min. PRA is worthy of recommending in the case of adrenal tumors qualified for surgical treatment and not exceeding 6 cm in size.

Key words: posterior retroperitoneoscopic adrenalectomy, laparoscopic adrenalectomy, adrenal pheochromocytoma, glucocorticoid adenoma, aldosteronoma
treating benign and hormonally inactive adrenal tumors, as well as hormonally active tumors, including cases of the most difficult operations in adrenal pheochromocytomas and isolated metastases to the adrenal gland (6-9). Of many available methods of endoscopic adrenalectomy, the lateral transperitoneal approach is the most popular and favored by endocrine surgeons (approximately 80% of all procedures performed), while the posterior retroperitoneal approach is less commonly employed (approximately 15% of procedures), since it is believed by many surgeons to be technically difficult due to the necessity of operating in a considerably smaller operative field as compared to the abdominal approach, and the need to operate in a reversed surgical field, what hinders the sense of direction, especially initially, when experience is only being gained (10-14). Nevertheless, the method allows for a direct access to the adrenal glands that are anatomically situated in the retroperitoneal space, without any need to dissect numerous organs (the liver, pancreas and spleen), what may be of considerable importance, especially in patients after past abdominal procedures (15, 16). The posterior retroperitoneal approach, as it has been proven in reports published to date, is characterized by all the advantages of a minimally invasive procedure, such as minimal intraoperative blood loss, decreased postoperative pain, early postoperative ambulation and decreased duration of necessary hospitalization (17, 18). Moreover, the method is easy to master and safe during the “learning curve” period, which is short and does not exceed the time needed to perform 20 operations, what makes the method an attractive alternative to laparoscopic adrenalectomy in selected patients with adrenal tumors below 6 cm in size (19).

The objective of the present report is to sum up the four-year experience of the authors in employing posterior retroperitoneoscopic adrenalectomy according to Walz (PRA) in surgical management of adrenal tumors up to 6 cm in size.

MATERIAL AND METHODS

Between January 2004 and December 2007, a total of 129 patients with diagnosed unilateral adrenal tumors were treated surgically at the Department of Endocrine Surgery, 3rd Chair of General Surgery, Jagiellonian University College of Medicine in Cracow. Eighty-three of these patients who presented with an adrenal tumor not exceeding 6 cm in the largest diameter were qualified for PRA using the technique developed by Walz. Of the remaining 46 patients, 24 were qualified for lateral laparoscopic transperitoneal adrenalectomy according to Gagner, and 22 for classic transperitoneal adrenalectomy. The patients received detailed information as to the character of the procedure and gave their informed consent. The inclusion criteria for PRA were as follows: an adrenal tumor not exceeding 6 cm in the largest diameter and absence of radiological indications of tumor invasion beyond the adrenal gland as confirmed by abdominal spiral computed tomography. The exclusion criteria for PRA were as follows: a tumor in excess of 6 cm in size, suspected adrenocortical carcinoma, lack of sufficient space in the lumbar region on the operated side for trocar introduction (a gap of 3 cm at the minimum between the apex of the 12th rib and the superior margin of the iliac ala) and a past retroperitoneal surgical procedure involving the kidney or adrenal gland on the ipsilateral side.

Preoperative diagnostic management

In all the reported patients, adrenal tumors were confirmed preoperatively by abdominal spiral computed tomography and their hormonal activity was assessed at the Department of Endocrinology, Jagiellonian University College of Medicine in Cracow in keeping with the current standards (urinary metoxycatecholamines, diurnal cortisol, dexamethasone suppression test, ACTH, DHEAS, blood ions, as well as serum aldosterone concentration and serum renin activity). The following criteria for qualifying a patient for the procedure were adopted: a hormonally active adrenal tumor, a hormonally inactive tumor, but exceeding 4 cm in the largest diameter or – in selected cases – a smaller, hormonally inactive tumor showing signs of dynamic progression in size in subsequent imaging studies during follow-up (an increment of 1 cm at the minimum within 6 months).

In cases of adrenal pheochromocytomas, the patients were prepared for surgery employing high oral doses of α-blockers (phenoxbenzamine at the dose of 2-4 mg/kg per day) for at least 14 days prior to surgery.Patients with aldosteronomas were preoperatively treated
with a potassium-sparing diuretic (spironolactone) and put on oral potassium supplementation. Table 1 presents the clinical characteristics of the surgical patients.

Surgical technique

All the patients were operated on under general anesthesia by the same surgical team. In patients with hormonally active tumors, central venous pressure was monitored intraoperatively and blood pressure was directly measured using an arterial line. The surgical technique was PRA according to Walz (20-23). The patients were placed in the prone position with flexed hip joints on a hollowed out mattress accommodating the abdomen in order to secure the ease of abdominal path ventilation during the procedure. The first cutaneous section was performed transversely 1.5 cm below the apex of the 12th rib. Following the subcutaneous tissue and psoas muscles tunneling, the perirenal (Gerota’s) fascia was exposed and bluntly finger dissected, creating a small space. Subsequently, working under finger control and without any visual control, two trocars were inserted: one of them 10 mm in the paraspinal line and another 5 mm in the central axillary line, at the distance of approximately 4-5 cm from the primary skin incision. Through the opening below the apex of the 12th rib, a blunt 10 mm trocar with an inflatable balloon and adjustable sleeve (T10BT; Origin) was introduced and retropneumoperitoneum was created using the pressure of 20-25 mm Hg (fig. 1). The retroperitoneoscopy was performed using a rigid 10 mm 300 oblique view endoscope. The working space was bluntly increased, dissecting the flabby tissue between the Gerota’s fascia and perirenal fat and promptly obtaining a large cavity bordered by the diaphragm. Subsequently, the upper kidney pole was exposed and the adrenal gland together with the tumor was mobilized through its separation from the upper kidney pole. On the right side, the inferior caval vein and the median suprarenal vein were visualized and the latter was doubly clipped and transected (fig. 2). On the left side, the inferior suprarenal vein that empties to the left renal vein was visualized, doubly clipped and transected. Intraoperative hemostasis was initially achieved by bipolar coagulation in the first 12 procedures performed, and then, starting from procedure 13, the operators employed the ultrasound scissors and harmonic knife (LCSC5 or ACE; Ultracision; Ethicon EndoSurgery, Somerville, NJ, USA). The mobilized adrenal gland was removed through the central trocar port with a latex endocath bag (Endocatch, USSC Norwalk, CT, USA).

In selected cases, the skin section was extended to allow for removing the surgical material. The procedure was finalized with controlling hemostasis in the site of the adrenal gland removal (fig. 3). The fascia and skin were closed with absorbable sutures following the insertion of a 16Fr drain to the perirenal space. The surgical material was then referred to histopathology (fig. 4).

Postoperative follow-up

In the postoperative period, the patients were administered ketoprofen analgesia (4 mg/kg in a continuous IV infusion). Six hours po-

Table 1. Characteristics of patients undergoing PRA

<table>
<thead>
<tr>
<th>Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients</strong></td>
<td>83</td>
</tr>
<tr>
<td>M : F</td>
<td>22 : 61</td>
</tr>
<tr>
<td>Mean age (years) ± SD</td>
<td>58,1±10,3</td>
</tr>
<tr>
<td>BMI (kg/m²) ± SD</td>
<td>25,9±2,5</td>
</tr>
<tr>
<td><strong>Diagnosis</strong></td>
<td></td>
</tr>
<tr>
<td>Aldosteronoma</td>
<td>18</td>
</tr>
<tr>
<td>Glucocorticoid adenoma</td>
<td>10</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td>16</td>
</tr>
<tr>
<td>Non-functioning cortical adenomas†</td>
<td>39</td>
</tr>
<tr>
<td>Mean tumor diameter (mm) ± SD</td>
<td>41,4±14,2</td>
</tr>
<tr>
<td><strong>Unilateral adrenalectomy</strong></td>
<td></td>
</tr>
<tr>
<td>Right-sided : left-sided</td>
<td>40 : 43</td>
</tr>
</tbody>
</table>

† including 2 cases of myelolipoma and 1 case of schwannoma diagnosed in postoperative histopathological examination.
stoperatively, the patients were allowed to receive oral drinks and ambulate. Further analgesia included 100 mg ketoprofen tablets taken every 8 hours, but given entirely on demand. If the patient found analgesia insufficient, he was administered a single IM dose of petidin (1 mg/kg). On day 2 postoperatively, abdominal ultrasonography was performed, the drain was removed from the perirenal region, the dressing was changed and the patient was put on a normal oral diet to restore the gastrointestinal function. As a rule, the patients were discharged on the second postoperative day. The sutures were removed after 7-10 days. Further postoperative follow-up was done 3 weeks after the procedure (with histopathology result available) in the hospital outpatient clinic, and the subsequent follow-up visit was scheduled 6 months postoperatively. The patient was asked about his overall satisfaction with the procedure, the degree of restriction of his life activities in association with the surgery, the effect of the procedure on his blood pressure normalization and the currently taken hypotensive agents (in the case of pheochromocytomas and aldosteronomas) and the necessity of taking hormonal substitution with adrenal cortex preparations (in the case of glucocorticoid adenomas).

Statistical analysis

The data pertaining to the surgical patients and details of the performed procedures were collected prospectively (age, sex, BMI, diagno-
sis, size and left or right location of the adrenal tumor, operative time, intraoperative blood loss, postoperative analgesia, percentage of conversions, postoperative complications, hospitalization time). The operative time was measured from the skin incision to skin closure. The statistical analysis employed the t-student test and the $\chi^2$ test. To assess the effect of BMI, tumor location and size, the Spearman’s rank correlation coefficient was used. $p<0.05$ was accepted as statistically significant. The analysis was performed using a PC computer with commercially available statistical software (STATISTICA; Stat-Soft, Cracow).

RESULTS

The planned PRA procedures were performed in 82/83 (98.8%) of patients. As many as 31/83 (37.4%) patients had had previous abdominal procedures, including 18 individuals with operations involving the upper portion of the abdominal cavity (cholecystectomy, gastrectomy, vagotomy with pyloroplasty, right or left hemicolectomy). In one obese patient (BMI of 31.7), in whom the peritoneum was accidentally opened, conversion to a lateral transperitoneal laparoscopic adrenalectomy was necessary due to considerable gas leak into the peritoneum and inability to create a sufficiently large retroperitoneal working space (patient No. 17, with a hormonally inactive tumor of the left adrenal gland).

The mean operative time in PRA was $73.7 \pm 22.3$ min and was statistically significantly longer in the group of the initial 20 procedures as compared to subsequent 63 operations ($86.5 \pm 34.6$ min vs $69.7 \pm 14.9$ min, respectively; $p=0.046$). The learning curve is presented in fig. 5. No correlation was detected between BMI, tumor size, the side on which the tumor was located and the operative time. No significant difference in the operative time was observed, either, in patients with pheochromocytomas as compared to patients with other adrenal tumors, but the pheochromocytoma group demonstrated a slightly higher intraoperative blood loss, which showed statistical significance ($p=0.001$). A single case of postoperative bleeding was observed, which required reoperation 2 hours following the completion of PRA, and transfusion of 3 units of red cell concentrate (patient No. 17, with a hormonally inactive tumor of the left adrenal gland). No other complications were noted, apart from an intraoperative increase of systolic pressure to values exceeding 200 mm Hg in two patients with pheochromocytomas, who required IV regitine, and transient abdominal wall hypesthesia in the region of the anterior superior iliac spine in five patients, which resolved within 7 to 21 days postoperatively. The mean hospitalization time after the procedure was 2 days. Detailed results are presented in tab. 2.

Histopathology of the surgical material confirmed the preliminary clinical diagnosis in 80/83 (96.4%) of the patients, while in two cases, the tumors were found to be myelolipomas and in one patient, the tumor demonstrated the architecture of a schwannoma. Among the patients operated on employing PRA, the authors did not find any adrenal malignancies, either primary or metastatic.

Based on the follow-up examinations performed 6 months postoperatively, 80 (96.4%) patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean operating time (min) ± SD</th>
<th>Mean intraoperative blood loss (ml) ± SD</th>
<th>Conversions, N$^a$</th>
<th>Complications, N$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pheochromocytoma</td>
<td>Other tumors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>73.7 ± 22.3</td>
<td>72.3 ± 21.3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Mean</td>
<td>54.2 ± 16.8</td>
<td>68.7 ± 17.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraoperative:</td>
<td>Systolic pressure &gt; 200 mm Hg</td>
<td>Postoperative:</td>
<td>Hypesthesia of abdominal wall (transient)</td>
<td>Bleeding requiring reoperation</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
patients were found to be fully satisfied with the surgery, while the other three individuals (3.6%) were relatively satisfied due to periodic paresthesia in the lumbar region on the operated side, what affected their overall lower final rating of the operation. Seventy patients (84.3%) stated that their life activity was better than before surgery, while 13 (15.7%) claimed their life activity to be the same as preoperatively. Of 18 patients with aldosteronomas, 16 with pheochromocytomas and ten with glucocorticoid adenomas, normalization of arterial pressure and the possibility of discontinuing all hypotensive medications was achieved respectively in 10/18 (55.5%), 14/16 (87.5%) and 4/10 (40%). In all the remaining patients, however, postoperatively it was possible to decrease either the dosage or the number of administered hypotensive medications. In all the patients with pheochromocytomas, urine metoxycatecholamine levels normalized postoperatively. Six months after the operation, four patients with preoperative fully symptomatic glucocorticoidism still required substitution therapy with adrenocortical hormones, while in the remaining six individuals with preoperative subclinical glucocorticoidism, substitution therapy could have been discontinued.

DISCUSSION

Laparoscopic adrenalectomy has recently become the golden standard in surgery of small and medium-sized adrenal tumors, both hormonally active and clinically mute. The initially defined upper limit of adrenal tumor size equaling 6 cm and established to allow for minimally invasive surgery to be performed was pushed to 8-12 cm (depending on the surgeon’s experience), and in selected cases even to 15 cm. Yet, with an increasing tumor size, the risk it is malignant also increases and the procedure itself becomes more difficult technically (4, 6, 8, 23, 24). It is presently believed that indications for classic adrenal surgery include giant tumors that are technically impossible to be removed without interrupting their capsules, or which require en block resection due to infiltration of surrounding structures. The most significant criterion in qualifying patients for laparoscopic procedures is lack of aggressive infiltration of the tumor in the tissues surrounding the adrenal gland demonstrated by imaging studies (e.g. abdominal spiral computed tomography). A bridge between laparoscopic and classic procedures is a hand-assisted laparoscopic adrenalectomy (the so called „hand-assisted” technique), which should be taken into consideration in cases requiring conversion (4).

On the other hand, it should be emphasized here that approximately 80% of adrenal tumors that require surgical treatment are tumors up to 6 cm in size (25, 26). In such cases, an attractive alternative for laparoscopic adrenalectomies is posterior retroperitoneoscopic adrenalectomy according to Walz (21). In recent years, the method has undergone significant technical modifications, such as: 1) abandoning the trocar with an inflatable balloon in favor of blunt dissection using a rigid endoscope and surgical instruments under visual control in order to create a working space in the retroperitoneal region, 2) taking advantage of high pressure pneumoperitoneum (20-25 mm Hg) to maintain the working space (without any negative hemodynamic consequences), 3) extensive mobilization of the upper kidney pole, what allows for a direct access to the inferior part of the adrenal gland, 4) excision of perirenal fatty tissue in obese patients in order to achieve optimum exposure of the adrenal gland in the surgical field, 5) introduction of modern hemostasis methods, e.g. the ultrasound scissors and harmonic knife, to dissect and divide vessels other than the main suprarenal veins, 6) abandoning retroperitoneal space drainage in practically bloodless procedures where the harmonic knife is employed. This has allowed for standardization of the PRA technique and recent studies have demonstrated its repeatability and ease in introducing the method to clinical practice in any interested surgical center (19).
The originator of the method has employed the technique in more than 600 operations and contributed to its extensive popularization worldwide, what is supported by a growing number of leading centers of endocrine surgery where the method has been introduced into practice (27). The PRA technique is presently regarded by numerous surgeons to provide the optimum access to the adrenal gland, although the lateral retroperitoneoscopic approach continues to be successfully employed in infrequent centers (12, 13, 28). In prospective randomized trials reported to date, which compare laparoscopic adrenalectomies with PRA procedures, the authors emphasize the advantage of the latter consisting in a significant reduction of the operative time, especially in operations performed on the left side and in the case of small tumors (e.g. aldosteronoma), as well as in obese patients (29). The advantages of PRA also include lack of necessity to dissect abdominal organs, as well as to release adhesions (approximately 30% of adrenalectomy patients have had previous abdominal surgery). Moreover, a bilateral adrenalectomy employing the PRA technique does not require the positioning of the patient to be changed in the course of the procedure, thus contributing to a further significant reduction of the operative time. Practically, the only limitation of PRA is the moderate size of the created working space in the retroperitoneal region, what imposes a limit of 6-7 cm on the size of the tumor that may be safely removed by this technique (10, 23).

In the presented material, the mean operative time of the PRA procedures was significantly longer in the initial 20 procedures. Nevertheless, after this “learning period”, the operative time did not exceed 90 minutes and was comparable in all the patients, regardless of the side where the tumor was located, tumor size, its hormonal activity and BMI. Only intraoperative blood loss was significantly higher in the procedures performed in patients with pheochromocytomas, but from the clinical viewpoint, blood loss greater by 20 ml only is practically negligible. It should be stressed that achieving such good results in introducing a new surgical method into the institution where the authors are employed was possible thanks to individual training of all members of the surgical team at the center of the method’s founder, M.K. Walz, and to his supervision as a tutor in several initial procedures performed independently by the authors. Such a strategy allowed for correcting most errors, the accumulation of which might lead to extension of the operative time or a significantly higher conversion rate; in our opinion, the strategy is worth recommending.

The authors faced the need for conversion only in a single patient with a tumor situated on the left side. Conversion was necessitated by unintentional opening of the peritoneum while creating the working space and by gas leak rendering sufficient exposure of the surgical field impossible. The stage of creating access to the retroperitoneal space is technically more difficult while performed on the left side (what is a consequence of the fact that the left kidney is situated higher than the right) and in slender patients, with narrow retroperitoneal space. Nevertheless, in the discussed case of conversion, after the patient had been repositioned, the procedure was continued employing a minimally invasive technique and successfully performing a lateral laparoscopic transperitoneal adrenalectomy. The scant number of complications included a case of bleeding that required early reoperation and transfusion of red cell concentrate. It should be emphasized that in the course of surgery performed with high-pressure pneumoperitoneum (20-25 mm Hg), veins, even large ones, may not bleed due to being compressed by the pneumoperitoneum and become the cause of bleeding after its evacuation. Hence, careful observation of the surgical field in the final stages of the procedure is recommended, as well as gradual decreasing of the pneumoperitoneum pressure to 10-12 mm Hg, what allows for employing additional hemostasis.

In operations performed using the harmonic knife, surgical wound drainage is not necessary, but in procedures where traditional scissors and coagulation are employed, is should be taken into consideration. Transient cases of abdominal wall hypesthesia (mainly in the region of the anterior superior iliac spine) observed in several patients occurred in procedures lasting more than 2 hours; soft padding of the operating table seems to be an adequate measure to minimize the risk of hypesthesia occurrence.

In the post-PRA postoperative course, no transient impairment of intestinal peristalsis was noted. The patients could receive oral drinks as soon as several hours after surgery and on the following day, they were given a
normal diet, which was well tolerated, were allowed to assume erect position and ambulate. Their pain was slight in consequence of the considerably reduced skin innervation in the lumbar region. None of the patients suffered from shoulder pain syndrome, which is seen in 10-30% of individuals subjected to laparoscopic procedures. Prompt postoperative rehabilitation and discharge home in the second postoperative day gained appreciation of the patients, what was confirmed on follow-up 6 months after the procedure.

The PRA method proved to be successful in treating both hormonally active and clinically mute tumors. A good preparation for surgery consisting in α-adrenergic blockade and a gradual increase of volemia within 10-14 prior to operation in the case of pheochromocytomas allowed for avoiding significant intraoperative hemodynamic complications (apart from increased blood pressure in two patients, who required intravenous regitine infusions). In all the patients with pheochromocytomas, urinary metoxycatecholamine levels normalized after the procedure. The patients with aldosteronomas demonstrated normalization of serum potassium levels within 6 months postoperatively, thus allowing for discontinuation of further treatment with potassium-sparing diuretics. In the patients with subclinical glucocorticoidism, discontinuation of substitution therapy with adrenal cortex preparations was possible after 6 months. On the other hand, the patients with fully symptomatic glucocorticoidism required further substitution therapy after the period of 6 months, since restoration of the physiological hypophyseal-adrenal feedback system as a rule takes 12 to 18 months.

Arterial blood pressure normalization was achieved in all the patients with pheochromocytomas, aldosteronomas or subclinical glucocorticoidism who were aged below 50 years and had a history of secondary hypertension of less than one year. In the remaining patients, in whom the hypertension-underlying mechanism was most likely complex, it was possible to reduce the dosage or the number of administered hypotensive medications. These data are also confirmed by observations of other authors (30, 31).

CONCLUSIONS

In spite of its seeming complexity resulting from the necessity of operating in an „upside down” surgical field, the technique of PRA is easy to learn and safe. In the experience of the authors, after approximately 20 procedures have been performed, the operative time does not exceed 90 minutes. The method is worthy of recommending in the case of adrenal tumors qualified for surgical treatment and not exceeding 6 cm in their largest diameter.

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