NAVIGATION WITH THE USE OF INTRAOPERATIVE ULTRASONOGRAPHY IN VIDEOSCOPIC ADRENAL SURGERY

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The aim of the study was to assess the efficacy of intraoperative ultrasonography during videoscopic adrenalectomy.

Material and methods. The study was conducted in patients undergoing extraperitoneal videoscopic adrenalectomy for adrenal tumours in the Department of Endocrine, General and Vascular Surgery of the Medical University in Łódź in 2008-2011.

Results. The active group consisted of 20 patients in whom navigation with the use of intraoperative ultrasonography (IOUS) was used in the course of surgery. The comparison group consisted of 46 patients operated without the use of IOUS. In the active group, we managed to obtain a shorter time of surgery by almost 20 min (89.44 ± 27.11 min vs 109.12 ± 33.88 min; p=0.034) and a shorter lesion access time by more than 15 min (28.61 ± 14.93 min vs 45.98 ± 20.44 min; p=0.002). Intraoperative blood loss was also significantly lower in the active group (86.11 ± 157 ml vs 169.27 ± 201.04 ml; p=0.037). In contrast, the use of IOUS did not affect the hospitalisation time (4.39 ± 3.27 days vs 3.83 ± 3.67 days; p=0.227), the rate of intraoperative complications (0/18 vs 2/41; p=1) and the conversion rate (2/20 – 10% vs 5/46 – 10.87%; p=1).

Conclusions. 1. Intraoperative ultrasonography is useful for determining the tumour relationship with the surrounding anatomical structures. 2. Intraoperative ultrasonography is a useful technique in the assessment of adrenal tumour infiltration of the surrounding tissues. 3. This technique facilitates finding the pathological lesion, shortening the time of access to the tumour and procedure duration (thus reducing the burden for the patient). 4. Reduced blood loss was also obtained owing to the use of IOUS.

Key words: intraoperative ultrasonography (IOUS), videoscopic adrenalectomy

Reduction of invasiveness, increase of curativeness of surgical procedures and limitation of intraoperative complications with significant shortening of surgery duration have recently become priorities of modern surgery. That is why there is a continuous search for new techniques of minimal invasive surgery, improved surgical armamentarium or better diagnostic imaging techniques.

One of such techniques is ultrasonography. The quality of ultrasound imaging depends on two parameters: sound wave frequency and length. Obtaining a high resolution (and thus higher image quality) requires the use of a head emitting high-frequency waves. If it is necessary to increase the penetration depth, a head emitting lower-frequency waves should be used. Therefore, wavelength reduction results in an improvement of resolution but reduces the penetration depth. In the case of transdermal ultrasound examinations, this quality is limited in a sense. Firstly, because sound waves must overcome an “obstacle” in the form of the skin. That is why transdermal heads must use low resolution to obtain the appropriate penetration depth (1, 2). Secondly, in abdominal ultrasound examinations, the presence of gas in the intestine interferes with ultrasound penetration, which considerably limits the possibility of obtaining images of organs located behind the intestines (1). The use of intraoperative ultrasonography (IOUS) eliminates the above
problems. The head is directly adjacent to the organ operated upon. That is why we may use high-frequency heads (because deep sound penetration is not needed), which improves image resolution and thus its quality.

The objective of this study was to assess the efficacy of IOUS in videoscopic adrenalectomy procedures. This technique is now becoming more and more popular. Almost all adrenal tumors are considered eligible for endoscopic surgery, after appropriate pharmacological preparation. The limitations of this method may be caused by tumour size, presence of numerous adhesions or difficulties related to prior nephrectomy, splenectomy or pancreatectomy (3-7).

The objective of this study was to assess the efficacy of intraoperative ultrasonography in the search for small cancer lesions in the course of videoscopic adrenalectomy procedures. It was assessed if the use of an ultrasonograph during surgery would significantly facilitate the procedure. This might increase surgery effectiveness and shorten its duration. Shortening a surgical procedure reduces the burden on the patient and facilitating to the surgeon finding a pathological lesion in the surgical region reduces the risk of intra- and perioperative complications (such as haemorrhage in the surgical field or damaging important anatomical structures which might be present in the area directly adjacent to the surgical site).

MATERIAL AND METHODS

The study was conducted in patients undergoing surgery for adrenal tumours in the Department of Endocrine, General and Vascular Surgery of the Medical University in Łódź in 2008-2011.

The active group consisted of 20 patients with adrenal tumours undergoing videoscopic surgery, in whom navigation with the use of intraoperative ultrasonography was used in the course of the surgical procedure. The comparison group consisted of 46 patients operated without the use of IOUS. The following parameters were investigated: mean duration of surgery, number and types of postoperative complications, conversion rate, hospitalisation time, lesion access time, blood loss during surgery, histopathological evaluation.

The subjects were randomly assigned to the study groups.

Pro Focus 2202 manufactured by B-K Medical with intraoperative sterilisable heads was used for ultrasonographic navigation. The 8666 head with a movable tip, with a frequency of 5 to 10 MHz and with penetration depth of up to 130 mm (at 5 MHz) was used during surgery (8).

All patients were operated upon by the same surgeon, with the use of the same surgical armamentarium.

Before surgery, blood chemistry was tested to assess the hormonal function of the tumour for Cushing’s syndrome (hypercortisolism) or Conn’s syndrome (primary hyperaldosteronism). In all patients, the blood level of chromogranin A was tested within the framework of pheochromocytoma diagnostics. Imaging studies included ultrasound examination and abdominal computed tomography performed in all patients.

The patient was positioned on the “healthy” side. The lumbar area was elevated in relation to the head and lower limbs. Then 3 – 4 small skin incisions were made, through which trocars were placed. The working space was obtained with the use of a balloon introduced through the first trocar and then inflated with air. Then the working space was maintained by insufflating carbon dioxide at 15-20 mm Hg. Oblique optics at 30° was used for visualisation. After the working space was prepared, a sterile laparoscopic head of 8666 type was placed. In this difficult area for anatomical orientation (large amount of adipose tissue interfering with orientation and surgical preparation), the laparoscopic head facilitated locating important anatomical structures, i.e. the adrenal gland, the upper renal pole, the vena cava inferior and the liver on the right or renal vessels and the spleen on the left.

RESULTS

The active group consisted of 20 patients – 11 women (55%) and 9 men (45%) aged 38-72 years, mean 59.3 ± 9.41 years (tab. 1). In 12 (60%) cases, surgery was performed on a tumour located on the left, which right-side tumours represented 8 (40%) of the cases. Surgery duration ranged from 55 to 155 minutes, mean 89.44 ± 27.11 minutes. The lesion access time
 ranged from 5 to 60 minutes, mean 28.61 ± 14.93 minutes. In 2 (10%) cases, conversion during surgery was necessary. In the first of these cases, the reason for the conversion was bleeding in the operating field, difficult to control with low-invasive techniques. In the second case, numerous adhesions in the surgical site interfered with localisation of anatomical structures. The hospitalisation time ranged from 2 to 16 days, mean 4.39 ± 2.37 days. The maximum intraoperative blood loss was 450 ml. The mean intraoperative blood loss was 86.11 ± 157 ml. In 10 patients, traces of blood were found in the aspirator (in calculations: 0). Two (10%) patients experienced severe pain in the subcostal area, requiring nerve blockade. On imaging examinations, no discernible post-traumatic lesions were found. Apart from the above, no surgical complications were found after the procedures. On histopathological examination, adrenocortical adenoma was diagnosed in 12 (60%) patients. Adrenocortical hyperplasia and adrenal medullary hyperplasia were found in 4 (20%) and 1 (5%) cases, respectively. Moreover, one case of each of the following was found: pheochromocytoma, myelolipoma and adrenal cyst (tab. 1).

On the other hand, the comparison group consisted of 46 patients – 28 women (60.87%) and 18 men (39.13%) aged 27-75 years, mean 54.74 ± 11.34 years. In 24 (52.17%) cases the surgery was performed on a tumour located on the left, and in 22 (47.83%) cases it was performed on a tumour located on the right (tab. 1). Surgery duration ranged from 50 to 180 minutes, mean 109.12 ± 33.88 minutes. The lesion access time ranged from 10 to 90 minutes, mean 44.98 ± 20.44 minutes. In 5 (10.87%) cases, conversion during surgery was necessary. In 2 cases, the reason for the conversion was bleeding in the operating field, difficult to control with low-invasive techniques. In other two cases, conversion was performed in view of untypical anatomical conditions and difficulties with tumour localisation. In the last case, the reason for conversion was the need to terminate the procedure as soon as possible due to a rapid increase in blood pressure and high values of CO₂ blood concentrations. The hospitalisation time ranged from 2 to 16 days, mean 3.83 ± 3.67 days. The maximum intraoperative blood loss was 750 ml. The mean intraoperative blood loss was 169.27 ± 201.04. In 15 (32.61%) patients, traces of blood were found in the aspirator (in calculations: 0). Two (4.88%) patients had surgical complications. In one case, two-stage spleen rupture occurred and the patient was re-operated upon on the second day after surgery. In the second case, the procedure was complicated by a pancreatic fistula. In one case, a complication developed in the form of cardiovascular and respiratory insufficiency. After the symptoms resolved and the clinical status stabilised, the patient returned to the Department from which it was discharged home on the 12th day. On histopathological examination, adrenocortical adenoma was diagnosed in 21 (45.65%) patients. Adrenocortical hyperplasia was found in 10 (21.74%) cases. Moreover, 4 (8.7%) cases of pheochromocytoma were diagnosed. In 2
(4.35%) cases, normal adrenal tissue was found. In 2 (4.35%) patients, pulmonary cancer metastases, and in 1 (2.17%) patient, clear renal cell carcinoma metastasis, were diagnosed. Moreover, one case of each of the following was found: primary adrenocortical carcinoma, myelolipoma, cortical tumour of unsure prognosis, pali-sading intranodal neuroillemoma/schwannoma, endothelial lymphangiomatic cyst and adrenal cyst lined with normal cubic epithelium without atypical signs (tab. 1).

Summing up, in patients in whom IOUS navigation was used, a duration of surgery shorter by almost 20 min (89.44 ± 27.11 min vs. 109.12 ± 33.88 min.; p=0.034) – fig. 1 and a lesion access time shorter by almost 15 min (28.61 ± 14.93 min vs. 45.98 ± 20.44 min; p=0.002) – fig. 2 could be obtained. Also blood loss during surgery was significantly smaller in the active group (86.11 ± 157 ml vs. 169.27 ± 201.04 ml; p=0.037) – fig. 3. On the other hand, the use of navigation had no effect on the hospitalisation time (4.39 ± 3.27 days vs. 3.83 ± 3.67 days; p=0.227), the rate of intraoperative complications (0/18 vs. 2/41; p=1), and the conversion rate (2/20-10% vs. 5/46 – 10.87%; p=1) (tab. 2).

**DISCUSSION**

The first to perform minimally invasive adrenal surgery was Gagner, in 1992 (3). Relatively soon afterwards this method was considered effective and became an extensively used surgical technique. There are numerous scientific reports describing the advantages of videoscopic adrenalectomy, e.g. reduced intraoperative blood loss, reduced pain complaints, shorter hospitalisation and recovery time (8, 9, 10). It is also considered to be the recommended method of choice for surgery of small adrenal tumours (8-11).

There are also reports on the use of intraoperative ultrasonography during these procedures. There are several applications of IOUS related to adrenal surgery: confirmation of the existing status of the adrenal lesion; confirmation that large adrenal lesions do not display malignancy signs, and thus are videoscopically resectable; in adrenal metastases: determination of the level of infiltration of the adrenals and surrounding tissues; to rapidly locate the vascularature of large pheochromocytoma tumours; determination of the organ of origin of large...
Navigation with the use of intraoperative ultrasonography in videoscopic adrenal surgery

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Active group</th>
<th>Comparison group</th>
<th>Inter-group comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surgery duration (minutes)</td>
<td>mean ± standard deviation 89.44 ± 27.11</td>
<td>mean ± standard deviation 109.12 ± 33.88</td>
<td>significant difference (p=0.034)</td>
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<tr>
<td></td>
<td>median 90</td>
<td>median 110</td>
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<tr>
<td>2. Lesion access time (minutes)</td>
<td>mean ± standard deviation 28.61 ± 14.93</td>
<td>mean ± standard deviation 45.98 ± 20.44</td>
<td>significant difference (p=0.002)</td>
</tr>
<tr>
<td></td>
<td>median 25</td>
<td>median 45</td>
<td></td>
</tr>
<tr>
<td>3. Hospitalisation time (days)</td>
<td>mean ± standard deviation 4.39 ± 3.27</td>
<td>mean ± standard deviation 3.83 ± 3.67</td>
<td>no significant difference (p=0.227)</td>
</tr>
<tr>
<td></td>
<td>median 3</td>
<td>median 3</td>
<td></td>
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<tr>
<td>4. Conversion rate</td>
<td>2/20-10%</td>
<td>5/46-10.87%</td>
<td>no significant difference (p=1)</td>
</tr>
<tr>
<td>5. Blood loss during surgery (ml)</td>
<td>mean ± standard deviation 86.11 ± 157.00</td>
<td>mean ± standard deviation 169.27 ± 201.04</td>
<td>significant difference (p=0.037)</td>
</tr>
<tr>
<td></td>
<td>median 0</td>
<td>median 100</td>
<td></td>
</tr>
<tr>
<td>6. Number of postoperative</td>
<td>0/18</td>
<td>2/41-4.88%</td>
<td>no significant difference (p=1)</td>
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<tr>
<td>complications</td>
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symptomatic right flank cysts; determination if small adenomas are technically resectable during partial laparoscopic adrenalectomy (12).

In 1997, a publication appeared presenting the use of IOUS during laparoscopic adrenalectomy (12). The 5-7.5 Mhz laparoscopic B-K head of the 8555 type was used (B-K Medical Systems). The procedure was performed from transperitoneal access. After the adrenal gland was identified by IOUS, its size, echogenicity, presence or absence of capsule and relation to the adjacent organs (kidney, renal hilus, pancreas, vena cava inferior) were assessed. Subsequently, the blood vessels supplying the adrenal were visualised by colour Doppler.

Intraoperative ultrasonography was performed in 19 of 114 laparoscopic adrenalectomy procedures. The mean duration of surgery with and without the use of IOUS was 125 min and 131 min, respectively (no statistically significant difference). The use of his technique did not change the hospitalisation time (the mean hospitalisation time for both groups was 2.4 days) or the overall hospitalisation cost. No complications related to the IOUS procedure as such were found. Moreover, in several particular cases, IOUS was of key importance for success of the procedure.

An interesting indication for adrenal gland surgery is bilateral pheochromocytoma, often present as part of hereditary syndromes, i.e. the Hippel-Lindau or MEN 2 (Multiple Endocrine Neoplasia) syndromes. Pheochromocytoma in the course of such syndromes is very rarely malignant, and that is why in the case of these surgeries resection of the tumour alone while sparing the healthy parenchyma is allowable. This allows to avoid the need for using substitution treatment with adrenal steroid hormones which is associated with a high rate of complications. Owing to intraoperative ultrasonography, the surgeon may mark the tumour resection line and assess the organs located in the retroperitoneal space (6, 13, 14, 15).

Owing to IOUS, local evaluation of advancement of the malignant neoplastic process is possible. In a study of 1998 (Bendinelli et al.), 6 cases of laparoscopic adrenalectomy in patients with non-small cell lung carcinoma were described. Patients after curative lung resection with, with metastatic tumours in the adrenal gland lower than 5 cm in diameter, without signs of adrenal capsule infiltration on preoperative imaging examinations and with good general performance were found eligible for the procedure. At the beginning of the procedure, IOUS was performed to evaluate the cancer stage. If there were no ultrasonographic signs of neoplastic infiltration of the adrenal capsule or of disseminated neoplastic process in the peritoneal cavity, extracapsular adrenal resection was performed. When metastases in the...
peritoneal cavity were found, adrenalectomy was not initiated and the procedure was limited to surgical biopsy of the lesion. On the other hand, when the lesion infiltrated the capsule, conversion was performed (17).

More and more often, surgical procedures are conducted with the use of surgical robots. Also the adrenal glands became an experimental field in surgery. In 2011 (Boris et al.), 13 cases of RALPA (Robot-Assisted Laparoscopic Partial Adrenalectomy) were described. Surgery was performed in patients with hereditary syndromes, i.e. von Hippel-Lindau syndrome, MEN syndrome or neurofibromatosis type 1 (NF-1). In all patients, IOUS was performed in order to determine the limit of tumour resection (partial adrenalectomy sparing the healthy parenchyma) and to assess whether there are no other lesions not detected by preoperative diagnostics. In this study, the usefulness of IOUS in pheochromocytoma surgery in genetically determined (hereditary) syndromes was noted, since multifocal lesions are often present in these cases (18).

The IOUS technique is also useful in atypical cases. In 2004, Vaughn et al. described a case of laparoscopic adrenalectomy in a patient with ectopic pelvic kidney on the tumour side. Without the “reference” which is the normally positioned kidney, finding the adrenal gland without IOUS would be very difficult (19). On the other hand, in the second paper, the authors (Disick, Palese) describe cases of non-adrenal location of pheochromocytoma. They suggest that such lesions can be safely resected in laparoscopic operations with the use of the IOUS navigation (20).

In 1999, results of 42 adrenalectomies performed with the use of laparoscopic technique from transperitoneal access were described. Navigation with the use of IOUS was routinely used – an attempt was always made to visualise the central vein, the adrenal parenchyma and the tumour mass. Intraoperative ultrasonography was found to be useful for localisation of the left adrenal vein, especially when it is covered by a large amount of adipose tissue. It is also helpful at determining adrenal contours and helps at adrenal preparation. There was one case where conversion was necessary – a female patient with metastatic endometrium malignant tumour treated with radiotherapy. As a result, the tumour had adhesions to surrounding tissues. In 6 patients, bilateral adrenalectomy was performed. The mean duration of surgery was 262 min (194 min in the case of unilateral procedures). Mean intraoperative blood loss was 116 ml (108 ml in the case of unilateral procedures). Blood transfusion was necessary only in the case where conversion was performed. In 2 case, intraoperative complications were found. In the first case, a hypotension episode was found, preceding adrenal vein cutting (after intravenous fluid transfusion and pressor administration, the patient’s condition normalised without further consequences). The second complication was a CO2 embolus caused by liver damage by a Veress needle. The mean hospitalisation time after the procedure was 2 days (21).

In our material, in patients in whom IOUS navigation was used, we managed to obtain a shorter time of surgery by almost 20 min (89.44 ± 27.11 min. vs. 109.12 ± 33.88 min.; p=0.034) and a shorter lesion access time by more than 15 min (28.61 ± 14.93 min. vs. 45.98 ± 20.44 min.; p=0.002). Owing to this, the burden on the patient was reduced. The patient was subjected to the negative effects of CO2 pneumoperitoneum for a time shorter by almost 20 min, which is particularly important in the case of surgery from extraperitoneal access where CO2 is insufflated with the use of low pressures (15-20 mm Hg). As a gas soluble in water, plasma and whole blood, CO2 easily penetrates through cellular membranes which results in its penetration to the blood during an operation. Hypercapnia may be associated with numerous negative consequences, including elevated arterial pH causing respiratory acidosis, reduced pH of intracellular and extracellular environment (impairment of cellular metabolic and membrane functions); potent sympathetic stimulation (release of catecholamines and glucocorticosteroids); arythmogenic effects (4).

Also blood loss during surgery was significantly lower in the active group (86.11 ± 157 ml vs. 169.27 ± 201.04 ml; p=0.037), which also contributes to a reduced burden on the patient. In the active group, one case of an extremely high value was observed (fig. 3). It occurred in a 61-year-old female patient with right adrenal adenoma diagnosed by histopathology. Minor vena cava inferior injury occurred during surgery, which could be repaired with the use of a single “Z” suture. Total blood loss dur-
ing surgery was 450 ml. However, this event had no effect on the postoperative course and the patient was discharged home in good general condition on the fifth day after surgery.

CONCLUSIONS
1. Intraoperative ultrasonography is useful for determining the tumour relationship with the surrounding anatomical structures.
2. Intraoperative ultrasonography is a useful technique in the assessment of adrenal tumour infiltration of the surrounding tissues.
3. This technique facilitates finding the pathological lesion, shortening the time of access to the tumour and procedure duration (thus reducing the burden for the patient).
4. Moreover, reduced blood loss was also obtained owing to the use of IOUS – as adrenal contours are visualised and blood vessels are shown using the Doppler technique, resection with a smaller margin and thus with less tissue traumatisation and less intraoperative blood loss can be performed.

REFERENCES

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