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From open to laparoscopic adrenalectomy: thirty years' experience of one medical centre

Od adrenalektomii otwartej do laparoskopowej: trzydziestoletnie doświadczenie jednego ośrodka medycznego

Jerzy Lubikowski[1], Marek Umiński[1], Elżbieta Andrysiak-Mamos[2], Sławomir Pynka[3], Henryk Fuchs[4], Maciej Wójcicki[1, 7], Mikołaj Szajko[1], Piotr Molęda[5], Mariola Post[1], Ewa Żochowska[2], Bartosz Kiedrowicz[2], Krzysztof Safranow[6], Anhelli Syrenicz[2]

[1]*M. Skłodowska-Curie Hospital, Department of General and Transplantation Surgery, Szczecin, Poland*
[2]*Pomeranian Medical University, Department of Endocrinology, Metabolic, and Internal Diseases, Szczecin, Poland*
[3]*M. Skłodowska-Curie Hospital, Diabetes Outpatient Clinic, Szczecin, Poland*
[4]*M. Skłodowska-Curie, Department of Endocrinology, Szczecin, Poland*
[5]*Pomeranian Medical University, Department of Diabetology and Internal Diseases, Szczecin, Poland*
[6]*Pomeranian Medical University, Department of Biochemistry and Medical Chemistry, Szczecin, Poland*
[7]*Pomeranian Medical University, Liver Unit, Szczecin, Poland*

Abstract

Introduction: Laparoscopic adrenalectomy (LA) has become the standardized treatment of benign adrenal lesions over the last two decades, making the indications to open adrenalectomy (OA) limited. The purpose of this study was to show the thirty years of experience in open (OA) and laparoscopic adrenalectomy (LA) gained in one medical centre as well as to compare the results of OA and LA performed for benign adrenal lesions.

Material and methods: Three hundred patients underwent 127 open and 173 laparoscopic adrenalectomies between 1979 and 2009 at M. Curie Hospital in Szczecin, Poland. Analyzed factors included patients demographic data, ASA score, indication for surgery, tumour size and side, characteristics of the removed tumours, intraoperative and postoperative outcome of LA and OA, postoperative pain sensation, intraoperative and postoperative complications, and conversion rate from LA to OA. Tumours with diameter exceeding 8 cm were excluded.

Results: There were no significant differences regarding the analyzed preoperative data in both groups of patients. The mean operative time was longer in the LA group (137 *v.* 82 min., $p < 0.0001$) and the blood loss was lower in LA group (110 *v.* 254 mL, $p < 0.0001$). The mean time until resumption of normal diet was shorter after LA (22 *v.* 44 h), as was the mean time until ambulation (17 *v.* 36 h), mean length of the hospital stay (4.6 *v.* 6.8 days), and mean time until return to normal activities (14 *v.* 23 days, $p < 0.0001$ for each difference). The analgesic requirement on the first and the second day postoperatively was lower in the LA group ($p < 0.0001$). The incidence of intraoperative and postoperative complications did not differ significantly between both analyzed groups. The rate of the conversion from LA to OA was 16%. The histopathological diagnosis was adenoma of the adrenal gland in the majority of cases.

Conclusions: This study shows that LA is a safe, effective, and well-tolerated procedure. It may be recommended as a "gold standard" surgery in a case of benign functioning or non-functioning adrenal tumours with diameter less than 8 cm.

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Key words: *adrenal tumour, laparoscopic adrenalectomy, open adrenalectomy*

Streszczenie

Wstęp: Adrenalektomia laparoskopowa (LA, *laparoscopic adrenaloctomy*) stała się w dwóch ostatnich dekadach standardowym postępowaniem w leczeniu operacyjnym łagodnych guzów nadnerczy, zawężając jednocześnie wskazania do adrenalektomii otwartej (OA, *open adrenaloctomy*). Celem tego badania było przedstawienie 30-letniego doświadczenia w adrenalektomii otwartej i laparoskopowej, zebranego w jednym ośrodku medycznym, jak również porównanie wyników OA i LA wykonanych z powodu łagodnych guzów nadnerczy.

Materiał i metody: Materiał stanowiło 300 pacjentów, u których przeprowadzono 127 otwartych i 173 laparoskopowych adrenalektomii w latach 1979–2009 w Szpitalu im. M. Skłodowskiej-Curie w Szczecinie. Analizowanymi czynnikami były: dane demograficzne pacjentów, wynik skali ASA, wskazanie do operacji, rozmiar guza i jego umiejscowienie, charakterystyka usuniętej zmiany, śródoperacyjne i pooperacyjne wyniki LA i OA, pooperacyjne dolegliwości bólowe, śródoperacyjne i pooperacyjne powikłania, jak również wskaźnik konwersji z LA do OA. Z analizy wykluczono guzy o średnicy przekraczającej 8 cm.

Wyniki: Nie stwierdzono istotnych różnic dotyczących analizowanych danych przedoperacyjnych w obu grupach pacjentów. Średni czas operacji był dłuższy w grupie LA (137 *v.* 82 min, $p < 0,0001$), a utrata krwi była mniejsza w grupie LA (110 *v.* 254 ml, $p < 0,0001$). Średni czas konieczny do wznowienia normalnej diety był krótszy po LA (22 *v.* 44 h), dotyczyło to również średniego czasu uruchomienia chorych (17 *v.* 36 h), średniego czasu hospitalizacji (4,6 *v.* 6,8 dni), i średniego czasu powrotu do normalnej aktywności (14 *v.* 23 dni, $p < 0,0001$ dla każdej zmiennej). Potrzeba stosowania środków przeciwbólowych w pierwszym i drugim dniu po operacji była mniejsza w grupie LA ($p < 0,0001$). Częstość występowania powikłań śródoperacyjnych i pooperacyjnych nie różniła się istotnie pomiędzy obiema

Jerzy Lubikowski M.D., Ph.D., Department of General and Transplantation Surgery, Arkonska St. 4, 71–455 Szczecin, tel./fax: +48 91 454 16 93, mobile: +48 604 062 976, e-mail: lubikowski@neostrada.pl

analizowanymi grupami. Wskaźnik konwersji z LA do OA wynosił 16%. W większości przypadków rozpoznaniem histopatologicznym był gruczolak nadnercza.
Wnioski: Przeprowadzona analiza pokazuje, że LA jest bezpiecznym, efektywnym i dobrze tolerowanym przez chorych zabiegiem. Adrenalektomia laparoskopowa może być rekomendowana jako „złoty standard" w chirurgii czynnych i nieczynnych hormonalnie łagodnych guzów nadnerczy o średnicy mniejszej niż 8 cm. **(Endokrynol Pol 2010; 61 (1): 94–101)**

Słowa kluczowe: *guz nadnerczy, adrenalektomia laparoskopowa, adrenalektomia otwarta*

Introduction

Open adrenalectomy (OA) had been considered the treatment of choice for adrenal tumours for almost 80 years. Regardless of the method of traditional adrenal surgery, it requires a relatively large incision because the adrenal glands are located deeply in the retroperitoneal space.

Since Go [1] performed the first laparoscopic adrenalectomy (LA) in January 1992, many studies have reported morbidity of the procedure to be lower compared to open surgery [2–6]. The adrenal glands appear to be particularly suitable for laparoscopic excision as most adrenal tumours are small and pathologically benign. The benefits of laparoscopic adrenalectomy can include reduced blood loss, lower requirements for analgesia, shorter hospital stay, and quicker recovery. In view of this, it was suggested that minimal invasive adrenalectomy might lead to a better clinical outcome, as compared to the open surgery. However, there are not many single-centre studies in recent literature providing comprehensive analysis of large groups of patients undergoing OA and LA [6–11].

The aim of the study was to show the experience in traditional and laparoscopic adrenalectomy gained in one surgical centre during the last thirty years, including an outcome comparison obtained for OA and LA performed for benign adrenal lesions.

Material and methods

Between 1979 and 2009, 300 patients (222 females), mean age 52 (range 18–80 years) underwent OA (n = 127) and LA (n = 173) in the Department of General and Transplantation Surgery of M. Curie Hospital in Szczecin, Poland. The first OA procedure was done in our department in 1979, and the first LA was performed in 1995. The majority of the patients with adrenal tumour were diagnosed in the Department of Endocrinology, Metabolic, and Internal Diseases, Pomeranian Medical University in Szczecin, Poland. Their health status was classified preoperatively according to the American Association of Anaesthesiology (ASA) score. The standard endocrinological evaluation included the serum level of 17-hydroxyprogesterone, testosterone, androstendione, DHEA-S, aldosterone, ARO, ACTH, cortisol, short test with 1 mg of dexamethasone, and the level of metanephrines in the urine. The overall indications for surgery were non-functioning adrenal tumours (n = 183), pheochromocytoma (n = 36), Conn syndrome (n = 39), Cushing syndrome (n = 39), and congenital adrenal hypertrophy (CAH) (n = 3). The mean diameter of the lesions diagnosed by CT was 4.2 cm (range 1.3–17 cm), and the tumours were found on the left side in 116 cases and on right side in 164 cases while bilateral lesions were present in 20 cases. The malignant adrenal tumours were suspected in 12 cases preoperatively.

Open adrenaloctomy was done employing a transperitoneal (n = 61) as well as a lateral (n = 45) and posterior (n = 21) approach. Although LA was planned to be performed using lateral retroperitoneal (n = 131) and transperitoneal (n = 42) access, it was converted to OA in 28 cases.

We aimed to compare the outcome of OA and LA performed for adrenal tumours in our centre. In order to achieve comparable groups, patients with suspected malignant adrenal tumours or lesions bigger than 8 cm (n = 24) that were not considered for LA in our department were excluded. The patients in whom conversion from LA to OA was required were also excluded from the comparison; however, the influence of the conversion on the outcome of the operation and the postoperative course was also studied.

The following data of open (n = 78) and laparoscopic adrenalectomy (n = 140) as well as the conversion from laparoscopic to open procedure were recorded and analyzed: time of procedure, blood loss, time till resumption of normal diet, time till full ambulation, intraoperative and postoperative complications, hospital stay, and return to normal activity. The postoperative pain sensation was evaluated based on the patient's need for analgesic administration during the first and the second day after surgery using the five grade scale as follows: 0 — no analgesics; I — sporadic oral intake of 100 mg of ketoprofen ; II — one oral dose of 100 mg of ketoprofen every 8 hours; III — parenteral administration of 100 mg of ketoprofen; IV — parenteral administration of narcotic analgesics. Hospital stay was calculated since the day of surgery. The patients were asked about their return to normal activity during the check-up visit in the outpatient department or by telepho-

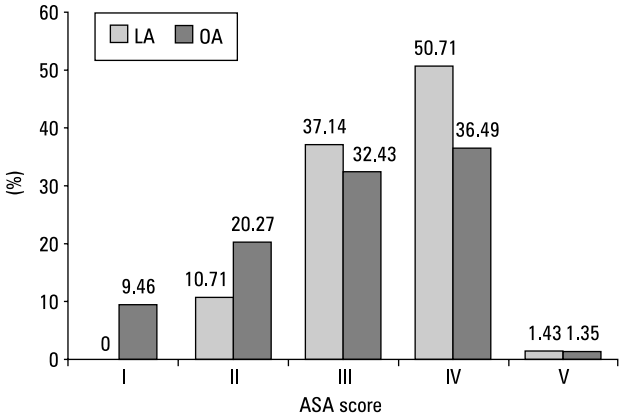

Figure 1. *A comparison of the ASA score in the LA and OA groups; p = 0.0009, χ^2 test*

Rycina 1. *Porównanie wyników w skali ASA w grupach LA i OA; p = 0,0009; test χ^2*

Table I. *The demographic data of the patients*

Tabela I. *Dane demograficzne pacjentów*

	Laparoscopic (n = 140)	Open (n = 78)	p value
Age (years)			
Mean ± SD	54.5 ± 11.9	50.4 ± 11.8	p = 0.042
Sex			
Female	106 (75.7%)	58 (74.4%)	p = 0.88
Male	34 (24.3%)	20 (25.6%)	

ne questionnaire. Each patient was questioned regarding full return to home, work, social, or sport activities.

The data were analyzed with Mann-Whitney test for quantitative variables and Chi-square or Fisher exact test for qualitative variables. The calculations were performed with Statistica 7.1 software.

Results

Classification of the physical status of the patients according to the ASA score for the LA *versus* the OA group is presented in Figure 1. It shows the better preoperative health condition of patients undergoing OA.

The mean age in the LA group (range 18–79 years) was significantly higher compared to the OA group (range 18–71 years), while the ratio of male to female sex was similar in both groups (Table I).

The mean size of adrenal tumour assessed by computed tomography was significantly higher in patients undergoing OA whereas the other preoperative variables were comparable (Table II).

Table II. *Tumour characteristics and indications for surgery*

Tabela II. *Cechy guza i wskazania do zabiegu*

	Laparoscopic	Open	p value
Side	**n = 140**	**n = 78**	
Right	73 (52.2%)	46 (59.0%)	
Left	59 (42.1%)	28 (35.9%)	0.62
Bilateral	8 (5.7%)	4 (5.1%)	
Tumour size (cm)			
Mean ± SD	3.7 ± 1.3	4.5 ± 1.7	< 0.0001
Indication	**n = 140**	**n = 78**	
Incidentaloma	89 (63.6%)	43 (55.1%)	
Conn syndrome	22 (15.7%)	12 (15.4%)	
Cushing syndrome	16 (11.4%)	10 (12.8%)	0.16
Pheochromocytoma	10 (7.2%)	13 (16.7%)	
Cong. adrenal hypertrophy	3 (2.1%)	0 (0%)	

Table III. *Intraoperative and postoperative outcome of LA and OA*

Tabela III. *Śródoperacyjne i pooperacyjne wyniki LA i OA*

	Laparoscopic Mean ± SD (n = 140)	Open Mean ± SD (n = 78)	p value
Duration of surgery [min]	136.6 ± 50.7	81.9 ± 31.7	< 0.0001
Blood loss [ml]	109.8 ± 95.8	254.3 ± 296.9	< 0.0001
Oral intake [h]	21.9 ± 9.7	43.6 ± 14.0	< 0.0001
Ambulation [h]	17.4 ± 6.6	35.9 ± 15.5	< 0.0001
Hospitalisation (days)	4.6 ± 2.2	6.8 ± 3.6	< 0.0001
Return to normal--activities (days)	13.7 ± 7.4	22.8 ± 10.7	< 0.0001

The comparison of intraoperative and postoperative endpoints of laparoscopic and open adrenalectomy is shown in Table III. The differences were statistically significant in all evaluated parameters. Mean duration of LA (range 50–370 min) was almost two times longer than OA (range 35–190 min). However, the average duration of the first 20 laparoscopic procedures was 180 minutes while the last 20 operations were done in a mean time of 90 minutes. The above differences were not observed in the OA Group. The mean blood loss was approximately 150 ml less for LA (range 0–500 ml) compared to OA (range 30–1800 ml). The average blood loss observed in the first 20 and the last 20 LA was 185 and 108 ml, whereas it was 225 ml and 202 ml in the case of the first 20 and the last 20 OA, respectively.

The patients from the LA group were able to resume normal diet after a mean time of 1 day from surgery

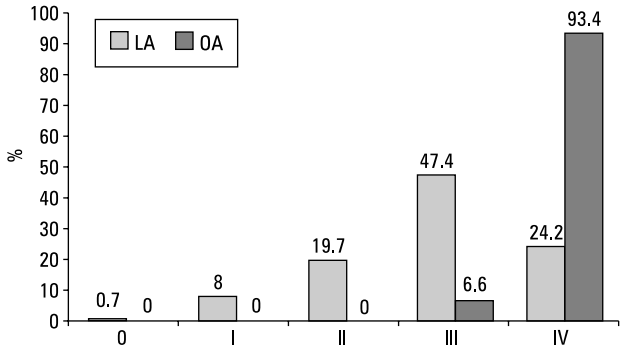

Figure 2. *A comparison of pain sensation evaluated on the first day after surgery using the five grade scale; $p < 0.0001$, χ^2 test*

Rycina 2. *Porównanie dolegliwości bólowych w pierwszej dobie po zabiegu w 5-stopniowej skali; $p < 0{,}0001$, test χ^2*

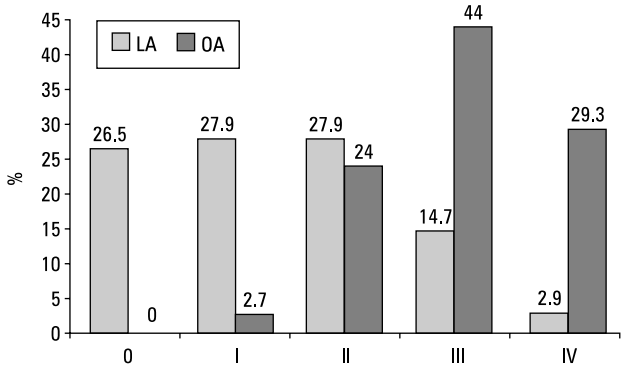

Figure 3. *A comparison of pain sensation evaluated on the second day after surgery using the five grade scale; $p < 0.0001$, χ^2 test*

Rycina 3. *Porównanie dolegliwości bólowych w drugiej dobie po zabiegu w 5-stopniowej skali; $p < 0{,}0001$, test χ^2*

(range 12–48 h) versus 2 days after OA (range 24–72 h). The mean time until full patient ambulation was shorter than 1 day for the LA group (range 6–48 hours) and was approximately 2 days for the OA group (range 12–72 h).

The average time of hospital stay for the LA group (range 1–15 days) was 2 days shorter compared to the OA group of patients (range 2–29 days). The mean time until return to normal activity was half for the LA group (range 4–42 days) compared to the OA group (range 8–60 days).

The postoperative pain sensation, evaluated on the first and the second day after surgery, was significantly higher for the OA group (Fig. 2 and 3). During the first day after surgery, narcotic analgesics (grade IV) were given to 93.4% of patients in the OA group compared to 24.2% of those who underwent LA. Intravenous injections of ketoprofen (grade III) were given in 6.6% of patients following OA whereas they were applied in 47.4% of LA patients. Grade 0–II was not observed in any patient in OA but it was found in 28.4% of patients following LA.

On the second postoperative day the pain sensation was evaluated as grade III and IV in 44% and 29.3% of patients, respectively, following OA compared to 14.7% and 2.9%, respectively, following LA. Pain control without intravenous analgesia (grade 0–II) was possible in 26.7% of patients following OA *versus* 82.3% after LA.

Intraoperative complications were observed in 12.9% (n = 18) of patients undergoing LA versus 15.4% (n = 12) in the OA group (p = 0.68). The specific types of complications are shown in Table IV.

Postoperative complications occurred in 10.2% of LA patients (n = 14) and in 15.5% following OA (n = 12) (p = 0.28). The types of postoperative complications are presented in Table IV.

There was one death in the LA group of patients (0.7%) and one in the OA group of patients (1.3%).

Of the patients undergoing LA, 16.2% (n = 28) needed the conversion to OA. The conversion was done because of difficulties in identifying or preparing the adrenal tumour in 11 (6.3%) cases, due to bleeding from the adrenal gland or the adrenal vein in 7 (4.0%) patients, due to injury of the peritoneum in 3 (1.7%) patients, and following injury of the spleen in 2 (1.2%) cases. In the remaining 5 (0.6% for each case) patients, the causes of the conversion were as followed: injury of the pleura and pneumothorax, size of the adrenal tumour exceeding 8 cm, identification of a malignant adrenal tumour, bleeding from the inferior caval vein, and lesion of the liver capsule.

There were no statistically significant differences found regarding the ASA score, age of patients, the side and size of the adrenal tumour, or the indication for surgery between LA and the converted procedures.

A comparison of intraoperative and postoperative outcomes of LA and OA with converted laparoscopic procedure is presented in Table V. The data show that except for the time of the ambulation and the return to normal activity, the conversion from LA to open procedure resulted in significantly different intraoperative and postoperative outcomes compared to LA and OA. Moreover, in most of the analyzed endpoints of the converted laparoscopic procedure, significantly worse outcomes were observed compared to those of OA.

The pain sensation was significantly higher on the first day after OA compared to the LA and converted laparoscopic procedures (3.9 *v.* 2.9 *v.* 3.5; $p_{O\text{-}C} = 0.013$, $p_{L\text{-}C} = 0.0008$, respectively). On the second postoperative day it differed significantly only between the LA and the converted procedure (1.4 *v.* 3.0, $p_{L\text{-}C} < 0.0001$).

Postoperative complications were observed in 16.0% (n = 4) of patients undergoing the conversion from LA

Table IV. *Intraoperative and postoperative complications of LA and OA*

Table IV. *Śródoperacyjne i pooperacyjne powikłania LA i OA*

	Laparoscopic (n = 139)	n (%)	Open (n = 78)	n (%)
Intraoperative	**Minor complications**	**16 (11.5)**	**Minor complications**	**7 (9.0)**
Complications	Moderate tissue bleeding	6 (4.3)	Moderate tissue bleeding	6 (7.7)
	Adrenal vein lesion	2 (1.4)	Liver capsule injury	1 (1.3)
	Small peritoneum injury	4 (2.9)	**Major complications**	**5 (6.4)**
	Liver capsule injury	3 (2.2)	Caval vein lesion	2 (2.6)
	Gallbladder lesion	1 (0.7)	Left renal artery injury	1 (1.3)
	Major complications	**2 (1.4)**	Right iliac artery injury	1 (1.3)
	Pleura injury (pneumothorax)	2 (1.4)	Pancreas injury	1 (1.3)
Postoperative	**Minor complications**	**9 (6.6)**	**Minor complications**	**9 (11.6)**
Complications	Wound infection	3 (2.2)	Wound infection	4 (5.2)
	Retroperitoneal haematoma	3 (2.2)	Retroperitoneal haematoma	2 (2.6)
	Neuralgia	3 (2.2)	Neuralgia	1 (1.3)
			Anaemia-single transfusion blood	2 (2.6)
	Major complications	**5 (3.6)**	**Major complications**	**3 (3.9)**
	Acute adrenal failure	1 (0.7)	Acute adrenal failure	1 (1.3)
	Ischaemic cardiac disease	2 (1.4)	Acute respiratory failure	1 (1.3)
	Pneumothorax	1 (0.7)	Pancreatic fistula	1 (1.3)
	Peritoneal bleeding — laparotomy	1 (0.7)		

Table V. *The intraoperative and postoperative outcome of LA, OA, and converted LA*

Tabela V. *Śródoperacyjne i pooperacyjne wyniki LA, OA i konwersji z LA do OA*

	Converted LA	p value	
	Mean ± SD (n = 28)	Converted LA *v.* LA	Converted LA *v.* OA
Duration of surgery [min]	150.8 ± 46.8	< 0.0001	< 0.0001
Blood loss [ml]	363.2 ± 318.7	0.0002	0.015
Oral intake [h]	37.7 ± 15.5	< 0.0001	0.041
Ambulation [h]	28.4 ± 15.5	0.0002	0.052
Hospitalisation (days)	8.8 ± 5.7	< 0.0001	0.021
Return to normal activities (days)	26.7 ± 12.4	< 0.0001	0.14

to OA, including wound infections in three patients and haematoma of the retroperitoneal space in one case. The incidence of the postoperative complications did not differ significantly among LA, OA, and converted laparoscopic adrenalectomy.

The most common postoperative histopathological diagnosis was adenoma (Table VI). In three cases the histopathological diagnosis was not available. The specific histopathological diagnoses of benign adrenal tumours were equally distributed in both groups. Two adrenocortical carcinomas were operated on laparoscopically. One of these procedures was converted to open adrenalectomy because of the presence of tumour infiltration of the surrounding tissues. In both cases the adrenal tumour was preoperatively diagnosed as benign.

Table VI. *Postoperative histopathological diagnosis of all removed adrenal tumours*

Tabela VI. *Histopatologiczne rozpoznanie pooperacyjne wszystkich usuniętych guzów nadnerczy*

Histopathology	n (%)
Adenoma	195 (65.7)
Pheochromocytoma	41 (13.8)
Hypertrophia	16 (5.4)
Myelolipoma	8 (2.7)
Cystis	6 (2.0)
Normal glandule suprarenalis	6 (2.0)
Carcinoma	13 (4.4)
Metastatic	3 (1.0)
Other	9 (3.0)
Total	297

Discussion

Indications for adrenal surgery had been well established before the introduction of minimal invasive techniques. Functional adrenal tumours are still common disorders requiring surgery. LA has recently been considered by many authors as a "gold standard" in the removal of benign adrenal functioning tumours [6, 12–14]. Additionally, during the last two decades an increasing number of incidentally discovered adrenal non-functioning lesions accompanied by the availability of LA has prompted a discussion regarding the optimal indications for surgery in such tumours [7, 15]. The increasing number of patients diagnosed with incidentalomas is a direct consequence of the common use of ultrasound, CT, and MRI imaging of the abdominal cavity for various indications. The main indication for removal of a non-functioning benign adrenal tumour is the lesion diameter. However, there is no consensus in the literature regarding the optimal size of the tumour in need of surgical intervention. In our institution, preoperative diagnosis of incidentaloma was the indication to surgery in 64% of patients submitted to LA versus 55% of patients undergoing OA. After ten years of our own experience with LA, and based on the available studies [6, 16, 17], we accept the diameter of incidentalomas between 4 and 8 cm as an indication for preferred laparoscopic approach. Solid, benign, and non-functioning adrenal lesions with diameter of less than 4 cm are considered for surgery only in patients with severe blood hypertension after all the other possible causes of hypertension were excluded [18]. According to our surgical protocol, we perform OA if the diameter of the adrenal lesion exceeds 8 cm. The limited retroperitoneal space and the technical ability of laparoscopic procedure restrict the feasibility of a safe laparoscopic dissection of lesions bigger than 8 cm [6]. Moreover, the incidence of malignancy is higher in cases of lesions of diameter greater than 6 cm [13, 19]. Since minimal invasive surgery was introduced in our institution in 1995, OA has been used to remove only 51 benign adrenal tumours *versus* 171 done by LA. Most of those 51 patients submitted to OA did not agree to be operated on with a laparoscopic approach, and in few cases they had severe contraindications for LA (*e.g.* unilateral adrenal tumour in a patient after nephrectomy or size of the tumour greater than 8 cm).

The optimal choice of surgical approach in adrenal surgery depends on many factors. The most important includes the dimensions of the mass, its location, the endocrine and oncological nature of the lesion, the patient preoperative condition, and the surgeon's experience [13]. Small functioning or non-functioning adrenal adenomas and other benign adrenocortical tumours may be successfully removed by employing LA [16, 20, 21]. The retroperitoneal laparoscopic approach provides direct access to the adrenal gland avoiding preparation of other abdominal organs [22–26]. However, the limited volume of retroperitoneal space restricts the feasibility of access to small adrenal masses. Nevertheless, it should be advocated in patients with a history of previous abdominal surgery [27]. According to the published data and our own experience, transperitoneal laparoscopic adrenalectomy is particularly suitable for pheochromocytoma and lesions ranging between 6 and 8 cm in diameter [21, 28–30]. Posterior retroperitoneal access was also shown to be feasible when applied to the removal of chromaffin tumours [31–33]. This approach enables the ligation of the adrenal vein in the early stages of the procedure. Transperitoneal and retroperitoneal (lateral and posterior) open adrenal surgery has the same advantages and disadvantages with regard to access to the adrenal tumour as laparoscopic approaches. However, a suspicion or definitive preoperative diagnosis of invasive adrenal carcinoma or malignant pheochromocytoma represents, in many centres, a specific indication for open transperitoneal surgery [20, 29, 34–36]. It gives wide operative access to the adrenal tumour as well as allowing the detailed inspection of the surrounding organs and their possible infiltration [37]. Nevertheless, some authors have proved that in carefully selected cases metastatic adrenal lesions or adrenal carcinomas that do not infiltrate surrounding tissue may be treated laparoscopically [12, 13, 29, 34, 35, 38–46). However, in view of our limited experience in laparoscopic removal of malignant adrenal tumours, this indication appears very controversial. We needed to convert LA to OA in one case of malignant lesion due to bleeding from the tumour and its infiltration into the surrounding organs, which was not detected preoperatively.

Laparoscopic adrenalectomy requires a longer operative time compared to OA [6, 8, 13]. It seems to be a major disadvantage of minimal invasive surgery. Our study has also revealed the significantly longer mean duration of laparoscopic versus open adrenalectomy. However, the analysis of our results showed that the time of surgery depends mainly on the experience of the surgeon (or surgical team), expressed as a "learning curve". After our first 30 procedures, the mean time of LA stabilized at a level of approximately 130 minutes, and the last 20 operations were carried out within an average time of 90 minutes. It has been suggested that the "learning curve" reaches a plateau after 25 to 100 LA [33, 34, 47, 48]. In our opinion, the main reason for the longer duration of adrenalectomy, besides the "learning curve", is the difficulty in identifying adrenal tumours during retroperitoneal laparoscopic procedure.

On other hand, the introduction of new and modern laparoscopic equipment (*e.g.* ultrasonic scissors, laparoscopic ultrasound probes, etc.) in the last two decades had a clear influence on the decrease of the duration and blood loss in minimal invasive surgery [34].

Many authors reported reduced blood loss in the case of LA compared to OA [8, 9, 10, 48]. In our analysis, intraoperative bleeding was significantly lower for LA versus OA. We believe that this results from the better visualisation of the adrenal gland achieved by the laparoscopic magnification of the operative field. Moreover, the short distance between laparoscopic optic and adrenal gland, as well as precise dissection, allows a decrease of the blood loss during LA [49]. In our study we also observed the influence of the "learning curve" on the decrease of intraoperative blood loss in LA. The mean blood loss decreased by almost a half after the first 20 laparoscopic procedures. We have noticed a further significant decrease in blood loss since the introduction of harmonic scissors in 2001 in our institution.

The present study shows that LA is advantageous compared to OA in terms of faster recovery, the ability to resume oral diet quickly, short hospital stay, and shorter time until full ambulation and a return to normal activities. Similar outcomes were observed by other groups [6–8, 10]. These advantages of LA may reflect a significant reduction of postoperative pain and limited tissue trauma in the case of minimal invasive surgery [8, 48]. Furthermore, LA limits the duration of the postoperative ileus [48]. Shorter time until ambulation may limit the incidence of postoperative complications such as respiratory disorders or deep venous thrombosis. Shorter hospital stay and quicker return to normal activities may further reduce the economic and social consequences of adrenalectomy [3].

We observed a slightly lower incidence of intraoperative and postoperative complications after LA, compared to OA, although the difference did not reach statistical significance. Most of the intraoperative and postoperative complications of LA and OA were minor ones. The major intraoperative complications were only found in 1.4 and 6.4% of cases of LA and OA, respectively. In two cases of pleura injury observed within the LA, we drained the pleural cavity and accomplished the laparoscopic procedure without the conversion. Serious complications of OA, such as left renal artery and right iliac artery injury as well as the lesion of the pancreas, did not occur in our centre within the last fifteen years, suggesting the possible influence of the "learning curve". Serious postoperative complications were found in 3.6 and 3.9% in cases of LA and OA, respectively. Pneumotorax, peritoneal bleeding, and pancreatic fistula resulted directly from the surgical procedure while the other serious postoperative complications were mainly related to the nature of the adrenal tumour and the patient's general condition prior to surgery.

Pneumothorax was the cause of death of the patient undergoing the converted LA. The patient died on the second postoperative day due to respiratory and circulatory failure. The mortality in the OA group occurred in the third postoperative week due to intraoperative injury of the pancreas leading to pancreatic fistulae and sepsis.

The overall rate of conversion from LA to OA in our study was 16%, while it ranges from 3 to 10% in other reports [50–54]. The most frequent reason for conversion to OA was the technical difficulty in identifying or dissecting the adrenal tumour. This technical problem could be associated with the small retroperitoneal space and the lack of clear anatomical topography of it [25]. Performance of retroperitoneal laparoscopic adrenalectomy was particularly difficult for surgeons who did not have previous experience in other retroperitoneal laparoscopic procedures. Bleeding from the adrenal gland, its surroundings, or adrenal vein could be also difficult to control laparoscopically in the case of retroperitoneal access, mainly because of the lack of retroperitoneal space. This was a common cause of conversion in our series. Injury of the peritoneum during retroperitoneal laparoscopic adrenalectomy resulted in a further decrease of the already small retroperitoneal space making it impossible to continue the laparoscopic procedure in many cases. On the other hand, injury of the spleen as well as the liver capsule resulted in conversion in cases of transperitoneal adrenalectomy. This was due to the need of dissection of the spleen or the liver during the left or the right transperitoneal laparoscopic adrenalectomy. The other complications responsible for conversion were very rare, achieving a rate of less than 3% of all laparoscopic procedures.

As opposed to some other groups, we did not observe any statistically significant influence of the side or size of the adrenal tumour on the conversion rate [52, 53].

Conversion from LA to OA has a significant influence on the intraoperative and postoperative outcome of the adrenalectomy. It is particularly important in the outcome assessment of the primary OA and the conversion. The conversion may be associated with inferior intraoperative and postoperative results as compared to the primary open adrenalectomy. However, the rate of complications of LA, OA, and the converted laparoscopic adrenalectomies was similar. Moreover, there were no serious postoperative complications following the conversion.

Adenoma of the adrenal gland was the most common histopathological diagnosis among the removed adrenal tumours in our centre. It corresponds with the data published by other authors [6, 7, 15, 16]. The rate

of the histopathological nature of adrenal tumours removed by LA or OA did not differ significantly in our series. However, as already mentioned, the malignant adrenal lesions were planned to be removed in our department by open surgery.

Conclusions

This study shows that LA is a safe, effective, and well-tolerated procedure. We recommend laparoscopic adrenalectomy as a "gold standard" in the surgery of both functioning and non-functioning benign adrenal tumours of diameter less than 8 cm.

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