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Minimally invasive resection of adrenal masses in infants and children: results of a European multi-center survey

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Abstract

Background Minimal access adrenal surgery (MAAS) for adrenal pathologies is the standard for many pediatric surgical centers. However, the literature offers few reports and minimal evidence from small case series. The aim of this study was to evaluate the outcomes of pediatric MAAS through a multi-center data analysis.

Method Pediatric patients who underwent MAAS between January 2002 and December 2013 were retrospectively included. Data analysis was conducted using Spss software (Welch's t-test, X-square, Fisher tests, multiple regression model).

Results Six European centers participated, 68 patients were included with mean age of 5.2 years (2 months–16 years). Lesion volume was of 18.1 cc (0.78–145.6), with a mean diameter of 2.8 cm (1.1–6.5). Localization was 50% left-sided masses, 45.6% right-side masses, and 4.4% bilateral. Histological examination revealed 36 neuroblastomas, 15 adenomas, nine pheochromocytomas, three ganglioneuromas, two ganglioneuroblastomas, one bilateral hyperplasia, one adrenocortical carcinoma, an alveolar sarcoma, and a calcification. Surgical access was transperitoneal in 63 (92.6%) and retroperitoneal in 5 (7.4%). Mean operative time was 170 ± 87 min (285 ± 30 min for bilateral lesions). Mean hospital stay was 4.2 ± 2.5 days. Complications included blood loss requiring transfusion in five patients (7.4%) and a diaphragmatic tear. Infiltration of surrounding structures correlated with intraoperative complication rate ($p = 0.027$) and operative time ($p < 0.01$). No mass rupture, conversion, or post-operative complications were observed. Median follow-up was 52 months (1–161). Two recurrences occurred in patients with pheochromocytoma. Age, weight, symptoms, characteristics at imaging, chemistry, volume, or histology, did not influence operative time, hospital stays, or complication rate.

Conclusions Pediatric MAAS was safe adopted for masses up to 145.6 cc, with a very low rate of complication. Conversion to open is not necessary even in the presence of infiltrations. MAAS should represent the first-line treatment for selected cases in centers experienced in laparoscopy.

Keywords Minimally invasive surgery · Adrenal mass · Laparoscopic adrenalectomy · Children · Neuroblastoma

The original version of this article was revised: The correct family name of the ninth author is "Sarnacki".

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Adrenal surgery in children is mainly performed for neoplastic masses arising from both the medulla or cortex.

Primary medullary neoplasms include neuroblastomas (NBs) and pheochromocytoma/paraganglioma (PHE). NB represents the most common extracranial solid neoplasm in children, accounting for 10% of all pediatric neoplasms and 15% of all childhood mortality from neoplasm [1, 2]. NB is treated per protocols dictated by dedicated international study groups [3]. PHE is an uncommon pediatric neoplasm, that has a major role in secondary hypertension [4]. Neural crest tumors are located in the adrenal gland in 50 and 80% of all NB and PHE, respectively [5, 6]. Neoplasms that arise from the cortex (ACT) are extremely rare, representing less than 0.2% of all pediatric neoplasms and accounting for 6% of all adrenal tumors in children [7]. Other lesions, such as congenital adrenal hyperplasia (CAH), can occasionally be of surgical interest, when the condition is refractory to medical management [8]. Furthermore, the incidence of adrenal lesions as incidental findings is increasing and neuroblastoma is the most common adrenal mass found in children [9].

Since the laparoscopic adrenalectomy was first described in 1992 [10], Minimal Access Adrenal Surgery (MAAS) has become the gold standard in adult patients. The first MAAS in children was performed in 1996 [11]. However, the small size of patients, large dimension of masses, and the prevalent malignant nature of tumors might have delayed the dispersion of minimally invasive techniques in the pediatric population. In addition, no data have been published regarding the learning curve for pediatric MAAS or the overall laparoscopic experience needed to perform MAAS safely.

The transperitoneal approach continues to be the most widespread among the options, because it allows a large working space and a good exposure of the adrenal gland and the surrounding structures. Indications for MAAS are not univocal despite its safety and feasibility having been advocated. Furthermore, the literature mainly offers single center experiences or small case series. The absence of vascular infiltration, or Image-Defined Risk Factors (IDFRs) for NB, represents an accepted prerequisite for MAAS [12, 13]. Vessel encasement of the tumor has also been shown to correlate with an increased conversion rate and bleeding risk [14, 15]. Tumor dimension has not been unanimously considered as a predictive factor of MAAS outcome in pediatric patients [5, 13, 16, 17].

A further element of inhomogeneity among pediatric series in the literature has been the pre- and intraoperative management of Pheochromocytomas.

We conducted a multi-center retrospective evaluation of patients undergoing pediatric MAAS, in order to verify in a large cohort of patients the aspects mentioned above. The primary aim was to define the characteristics of masses approached via minimally invasive techniques in the participating centers. Secondary aim was to identify possible factors influencing the outcome with attention to the complications.

Materials and methods

Ethical committee approval was obtained for this multicenter study. Data of patients of minimally invasive surgery of adrenal masses in six European Pediatric Surgery tertiary centers between 2002 and 2015 were retrospectively collected, based on a protocol. Subjects older than 18, patients with previous history of abdominal surgery, or patients with incomplete data were excluded. Data were recorded regarding center characteristics, such as the total volume of minimally invasive procedures per year (MIS/y) and adrenalectomies per year (MISa/y), and patient characteristics, such as demographic, clinical presentation, diagnostic laboratory results and imaging, presence of genetic syndromes, surgical technique details, pathologic findings, complications, and outcome.

When appropriate, data were recorded as mean ± SD. Welch's t-test, ANOVA, X-square, and Fisher tests were used for statistical analysis. A stepwise regression model has been created for independent variables influencing the outcome. A p value below 0.05 was considered significant. Data analysis was conducted using SPSS software version 22.0 (IBM Corporation, Armonk, NY).

Results

Six European Centers (Azienda Ospedaliera-Università Padova, Italy, Hospital Universitario Materno Infantil Las Palmas, Spain, Ospedale Bambino Gesù Rome, Italy, Federico II University Naples, Italy, Ospedale Gaslini Genoa, Italy, and Hôpital Necker-Enfants Malades Paris, France) collected complete data for a total of 71 minimally invasive adrenalectomies performed from April 2002 to April 2015 in 68 patients (29 females, 39 males; F:M ratio = 1:1.34), with a mean ± SD age of 5.2 ± 4.8 years (range, 2 months–16 years), and a mean ± SD weight of 22.1 ± 18 kg (range 5–104 kg). Age distribution identified two clusters: 41 patients with early presentation (mean ± SD age of 2.04 ± 1.8 years), and 27 with late onset (8.76 ± 4.60 years).

All patients in the first group had neuroblastic tumors. Three patients with pheochromocytomas were affected by Von Hippel–Lindau syndrome and one girl by neurofibromatosis type I. Three patients with adrenocortical mass were respectively affected by Li–Fraumeni, Rubinstein–Taybi, and Prader–Willi syndromes. Two patients had hypospadia, two left hemihypertrophy, and one frontal hypoplasia.

The most common symptom at the time of presentation was hypertension in 13 patients (19.1%), followed by virilization in 9 (13.2%), headache in 9 (13.2%), sweating in 6 (8.8%), obesity in 5 (7.4%), and opsoclonus

myoclonus syndrome in 3 (4.4%). Palpable mass was reported in seven patients (10.3%) at presentation. Half of the patients were asymptomatic (53%). Clinical details are summarized in Table 1.

Pre-operative management

Most patients were tested for hormonal profile, which was correlated with histology (Table 3). Imaging evaluation included ultrasonography (performed in 67 patients, 98.5%), Computed Tomography (CT) (54, 79.4%), and Magnetic Resonance Imaging (MRI) (29, 42.6%). CT and MRI were both performed in 16 patients (23.5%). Adrenal scintigraphy was performed in 43 patients (63%), abnormal uptake of MIBG in 28 patients contributed to the diagnosis of 22 neuroblastomas, four pheochromocytomas, one ganglioneuroma, and one adrenal carcinoma. Six patients underwent PET scan, resulted positive in four pheochromocytoma and in one ganglioneuroma.

Laterality included 31 (45.6%) right lesions, 34 (50%) left lesions, and three (4.4%) bilateral lesions. The mean volume of lesions, estimated by ellipsoid volume $(a \times b \times c) \times 0.52$, was 18.1 ± 27.6 cm^3 (range 0.78–145.6 cm^3) with a mean diameter of 2.8 ± 1.22 cm (range 1.1–6.5 cm). Mass characteristics at imaging and post-operative histology are summarized in Tables 2 and 3.

Patients with hypertension and/or accelerated cardiac rhythm (nine pheochromocytomas, two adenomas, one carcinoma) were pharmacologically prepared prior to surgery with alpha-blockers only (36%, 4/11), CCBs (calcium channel blockers) only (18%, 2/11), or an association of alpha or CCBs plus beta-blockers (45%, 5/11). Mean time for blood pressure stabilization was 12.7 days.

Table 1 Symptoms at presentation

Patients	68 (M 57.4, F 42.6)
Age (±SD) (year)	5.2 ± 4.8
Weight (±SD) (kg)	22.1 ± 18
Asymptomatic	36 (53)
Hypertension	13 (19.1)
Virilization	9 (13.2)
Headache	9 (13.2)
Sweating	6 (8.8)
Obesity	5 (7.4)
Opsoclonus mioclonus	3 (4.4)

Percentage in brackets

SD standard deviation, *M* male, *F* female

Surgery

Surgical approach was transperitoneal in 63 patients (92.8%) and retroperitoneal in 5 (7.4%; three left sided, two right sided). The mean number of ports used was 4.15 (range 3–5), including an average of four for left-sided lesions, 4.03 for right-sided lesions, and 7.33 for bilateral lesions. The most common sealing devices were the *LigaSure Vessel Sealing System*® (Valleylab Inc., Covidien, Boulder, CO, USA) in 76.5% of patients, the *Ultracision*® (Ethicon Endo-surgery Inc., Cincinnati, OH, USA) in 19.1%, the *Starion*® device (Microline

Table 2 Masses histology and secreting activity

	Number	Secreting	Mean size (cm)
Neuroblastoma	36 (52.9)	16/27 (59)	2.5
Cortical adenoma	15 (20.6)	10/10 (100)	3.2
Pheochromocytoma	9 (13.2)	9/9 (100)	3.0
GN/GNB	5 (7.3)	np	3.2
Bilateral hyperplasia	1 (1.5)	1/1 (100)	–
Cortical carcinoma	1 (1.5)	1/1 (100)	3.7
Alveolar sarcoma	1 (1.5)	np	3.8
Adrenal calcification	1 (1.5)	np	2.2

Percentage in brackets

GN ganglioneuroma, *GNB* ganglioneuroblastoma

Table 3 Mass characteristics at imaging

Laterality	
Left	34 (50)
Right	31 (45.6)
Bilateral	3 (4.4)
Mean volume (cm^3 ± SD)	18.1 ± 27.6
Mean diameter (cm ± SD)	2.7 ± 1.2
Density	
Solid	62 (91.1)
Cystic	1 (1.5)
Intermixed	5 (7.4)
Irregular margins	5 (7.4)
Vascularized	22 (32.4)
Calcifications	19 (27.9)
Adjacent structure invasion	6 (8.8)
Renal pedicle	4
Superior mesenteric artery	1
Cava vein	1
Other	2

Percentage in brackets

SD standard deviation

Surgical Inc., Beverly, MA, USA) in 2.9%, or bipolar in 1.5%. Laparoscopic clips were used in 42.6% of patients. Intraoperative US was used for two bilateral pheochromocytomas.

Operative time was 170 ± 87 (mean ± SD) min for unilateral lesions and 285 ± 30 min for bilateral lesions. Association of mean operative time and different variables is summarized in Table 4. Significantly longer times were found for bilateral lesions (285 ± 30 vs. 170 ± 87 min; $p < 0.01$) and masses with vascular infiltration (301± vs. 157±; $p < 0.01$). Age, weight, symptoms, histology, and mass volume did not influence operative time.

Intraoperative complications included blood loss requiring transfusion in five patients (7.4%, all affected by neuroblastoma), mass rupture in one neuroblastoma infiltrating the left renal pedicle, and one small diaphragmatic tear immediately repaired. There were no conversions to open surgery (Table 5).

Cumulative intraoperative complications (blood loss and mass rupture) were influenced by tumor infiltration of surrounding structures, such as vascular invasion ($p = 0.03$). No influence of age, weight, symptoms at presentation, mass volume, laterality, histology, or surgical technique was found.

Table 4 Operative time depending on different variables

	Min (±SD)	*p*/ of Pearson/*p* ANOVA
Center (1–6)	–	*p* ANOVA < 0.01
Sex (M/F)	165 ± 73/179 ± 104	$p = 0.59$
Weight	–	$p = 0.06$
Age (continuous)	–	$p = 0.02$
≤1 year/>1 year	147 ± 76/179 ± 90	$p = 0.15$
Symptomatic (yes/no)	175 ± 97/166 ± 79	$p = 0.38$
Laterality		
Left/right	180.7 ± 73/158 ± 99	$p = 0.31$
Unilateral/bilateral	170 ± 87/285 ± 30	$\mathbf{p < 0.01}$
Volume	–	$p = 0.12$
Solid/cystic/mixed	–	*p* ANOVA = 0.39
Regular/irregular	173 ± 88/137 ± 68	$p = 0.38$
Vascularized (yes/no)	182 ± 83/165 ± 89	$p = 0.49$
Calcifications (yes/no)	201 ± 102/157 ± 78	$p = 0.10$
Vascular invasion (yes/no)	301 ± 113/157 ± 73	$\mathbf{p < 0.01}$
Histology	–	*p* ANOVA = 0.34
Malignity (yes/no)	181 ± 94/155 ± 81	$p = 0.25$
Ports (3, 4, 5, >5)	–	*p* ANOVA = 0.60
Ligasure/ultracision/other	–	*p* ANOVA = 0.16
Clip (yes/no)	–	$p = 0.91$

SD standard deviation, *M* male, *F* female, *Min* minutes

Table 5 Post-operative complications and follow-up

Blood loss requiring transfusion	5 (7.4)
Conversion to open	0 (0)
Mass rupture	1 (1.5)
Diaphragmatic tear	1 (1.5)
Follow-up (months)	52
Relapse	2 (2.9)
Death	0 (0)

Percentage in brackets

Post-operative course

Mean hospital stay was 4.5 ± 2.5 days. Statistical different lengths of hospital stays were observed in symptomatic patient at diagnosis ($p = 0.02$), presenting virilization (7.2 vs. 4.1; $p < 0.01$) and sweating (5.7 vs. 4.4; $p = 0.01$), both of them associated with hormonally secreting masses. An increase in port number correlated with a longer stay, as shown in Table 6. Gender, weight, mass characteristics at imaging, mass volume, or histology, did not influence days of hospital stay. Interestingly, this result does not change when comparing benign versus malignant masses.

The mean follow-up was of 52 months (range 1–161). Two patients (2.9%) had a recurrence, both of them affected by VHL syndrome and treated for pheochromocytoma. One recurrence was into the preserved parenchyma of a patient who underwent cortical-sparing surgery for bilateral lesion. The second suffered from a para-aortic paraganglioma. No further post-operative complications or mortalities were observed (Table 5). Both patients, who had cortical-sparing procedure due to bilateral pheochromocytoma did not need supplementation of corticosteroids after surgery.

Neuroblastoma stages and oncological outcomes are summarized in Table 7.

Center variability

Patient volume was variable among centers (range 3–22 patients). Statistical analysis showed significant differences between centers in operative time (*p* ANOVA < 0.01) and days of hospital stay (*p* ANOVA < 0.01). The centers' experience in MIS (overall number of MIS procedures per year) had a moderate negative correlation with respect to the mean operative time (Pearson's correlation coefficient −0.605). There was no correlation between MAAS/y and operative time (Pearson's correlation coefficient −0.003).

Multivariate analysis

Stepwise regression showed that, other conditions being equal, operative time depended on the presence of bilateral

Table 6 Days of hospital stay and associated variables

	Days (±SD)	*p*/*p* of Pearson/*p* ANOVA
Center (1–6)	–	***p* ANOVA < 0.01**
Sex (M/F)	4.2 ± 2.3/4.9 ± 2.7	$p = 0.21$
Weight	–	$p = 0.17$
Age (continuous)	–	$\rho = 0.25$
≤1/>1 (year)	4.05 ± 2.1/4.7 ± 2.6	$p = 0.31$
Symptomatic (yes/no)	5.3 ± 2.5/3.9 ± 2.3	***p* = 0.02**
Virilization (yes/no)	7.2 ± 3.2/4.1 ± 2.1	***p* < 0.01**
Sweating (yes/no)	5.7 ± 0.8/4.4 ± 2.6	***p* = 0.01**
Laterality		
Left/right	4.8±/3.9±	$p = 0.15$
Unilateral/bilateral	4.4 ± 2.5/7.0 ± 1.0	***p* = 0.02**
Volume	–	$\rho = 0.05$
Solid/cystic/mixed	–	p ANOVA = 0.27
Regular/irregular	4.5 ± 2.5/4.6 ± 2.3	$p = 0.94$
Vascularized (yes/no)	5.4 ± 2.5/4.1 ± 2.4	$p = 0.06$
Calcifications (yes/no)	4.3 ± 1.8/4.6 ± 2.7	$p = 0.63$
Vascular invasion (yes/no)	5.2 ± 2.4/4.5 ± 2.5	$p = 0.50$
Histology	–	p ANOVA = 0.57
Malignity (yes/no)	4.4 ± 2.3/4.7 ± 2.7	$p = 0.69$
Ports		
3	2.7 ± 1.8	***p* ANOVA < 0.01**
4	4.2 ± 1.9	
5	6.4 ± 3.1	
>5	7 ± 0.7	
Ligasure/ultracision/other	–	***p* ANOVA = 0.77**

SD standard deviation, *M* male, *F* female, *Min* minutes

Table 7 Staging and oncologic outcomes of neurogenic malignant tumors

Stage	Number	Chemo pre	Average follow-up (year)	Outcome
S1	22 (61.1)	3/22 (13)	7.1	22 complete remission
S3–4	11 (30.5)	11/11 (100)	5	5 deceased, 2 metastatic, 4 complete remission
S4s	3 (8.3)	1/30 (33.3)	3.6	3 complete remission

Percentage in brackets

Chemo Pre pre-operative chemotherapy

lesions, adjacent structure invasion, and use of clips (coefficient of determination R-squared = 0.728). Presence of adjacent invasion prolonged the mean operative time by 91 min, use of clips of 35 min. Hospital stay was influenced by individual center, number of ports, obesity at presentation, presence of bilateral lesions, and hereditary syndromes (R-squared = 0.559). Multivariate analysis of intra- and post-operative complications was not possible because of the small number of events.

Discussion

Two multi-center studies have been previously published to date on MAAS, one in the US [18] and other in France [16]. To the best of our knowledge, the present study represents the largest European analysis on the topic. The study protocol offers a level 4 of evidence, the predominant level for publications in pediatric minimally invasive surgery (71.46%) [19, 20].

In the adult literature, the learning curve for MAAS has been reported to plateau around 30–50 procedures [21–23]. Experience in minimally invasive surgery has been found to be the most relevant factor for successful pediatric adrenalectomies [24]. The present study confirms this previous observation. It showed a negative correlation between MIS procedures per year and mean operative time in MAAS (Pearson's correlation coefficient −0.605). However, the small number of centers, variability in the number of patients among centers, and the retrospective nature of the study, weaken the significance of this result.

Histology of masses is not equally distributed between centers, where neuroblastic tumors being the most treated neoplasia in centers with more cases. This group of 41 patients presents peculiar characteristics, such as younger age at presentation (mean age 2.04 ± 1.8 vs. 8.76 ± 4.6 years). 90% (17/19) of the patients treated at the age younger than one year belong to this group. They did not show increased complications and had shorter operative times. This may further confirm that the MIS approach is reasonable if the surgeon is confident with the technique, as previously reported [25, 26].

The laparoscopic approach to neuroblastomas and other malignant lesions is being increasingly applied in selected cases [13].

There is no current agreement about the criteria of MAAS eligibility for neuroblastoma. Some authors recommend MIS for small masses (<5 cm) in the absence of surgical risk factors and if pre-operative investigation suggests a low grade histology (such as GN or GNB) [17]; others consider the presence of IDRFs (Imagine Defined Risk Factors) as a unique contraindication, such as vessel encasement by the tumor [27]. IDRFs would relate to a greater risk of intraoperative bleeding and higher conversion rate [5, 13]. In the present series, masses up to 145.6 cc (mean diameter 6.5 cm) have been successfully excised via MAAS with no correlation between tumor size and outcomes. The presence of adjacent structure invasion prolonged the operative time (mean increase of 91 min) and increased the risk of mass rupture (1/5) and bleeding (1/5), but did not relate

to the conversion to open surgery, post-operative complications, or recurrences. Neuroblastomas in this series were isolated adrenal masses without lymph node extension and those with IDRF (in these cases, it was the contact with the renal pedicle) received first chemotherapy. The persistence of this sort of surrounding tissue invasion after chemotherapy was not a contraindication of MAAS and in this case the volume of the lesion was considered, as demonstrated by the mean volume of lesions.

Surgery represents the treatment of choice for ACT, with chemotherapy playing a secondary role [28]. Cortical carcinomas often present with necrotic, hemorrhagic, or fibrotic areas, which make lesions particularly susceptible to rupture, bleeding, peritoneal and trocar site seeding even in the absence of local infiltration [29]. Therefore, an open approach is considered mandatory. Cecchetto et al. proposed that MIS should be limited to patients >5 years, with a mass <5 cm without signs of infiltration, where it can be radically removed avoiding any risk of mass rupture [17]. In this series, only one 3.8-year-old girl had an adrenocortical carcinoma of 3.7 cm, vascularized, with irregular margins, and solid characteristic at imaging. No rupture or conversion to open surgery occurred.

Historically, the use of MIS for pheochromocytoma (PHE) has been questioned due to concerns of increased morbidity and negative hemodynamic sequelae. Nevertheless, outcomes of MIS for PHE are comparable with MIS for other adrenal pathologies, only with an increased conversion rate [30]. Therefore, presently MIS represents the first-line treatment for adrenal localized PHE, whether unilateral or bilateral [5, 31]. In bilateral PHE, a cortical-sparing adrenalectomy should be considered in gland with minor tumor involvement, reducing the need of life-long hormonal replacement therapy in 78–90% of patients [32]. In this series, intraoperative US was successfully used in two bilateral cases where the adrenal-sparing approach was desirable. Preserving a rim of normal adrenal cortex, sufficient to hormonal production, can lead to an increased risk of recurrence up to 38% [33]. In children with an SDHB mutation, the tumors are malignant in two-thirds of cases, and total adrenalectomy is often advocated as the gold standard In patients with VHL and MEN-2, the risk of malignancy is low, and cortical-sparing adrenalectomy is a reasonable option [5]. In our study three patients presented VHL syndrome. Two of them had a bilateral lesion and underwent cortical-sparing adrenalectomy, and one experienced a local recurrence. The third, operated for unilateral PHE, experienced an extra-adrenal paraganglioma.

Surgical approach was transperitoneal in 92.8% of patients and retroperitoneal in 7.4%.

The transperitoneal approach permits good exposition, bilateral control, abdominal lymph node sampling, and is more familiar to most surgeons [5].

The retroperitoneal approach gives direct access to the gland and avoids the need for colon mobilization with a low risk of intra-abdominal organ damages [34]. Some authors suggest avoiding retroperitoneal access in right-sided and bilateral lesions, major bleeding control being more demanding [25, 35]. In our series five lesions were treated with retroperitoneal approach, two of them were right sided, and presented no complications and a similar operative time to left sided.

The number of ports varied between three and five for unilateral lesions, 7–8 for bilateral, including the optical system. The multivariate analysis demonstrated that the number of ports correlates with the hospital stay (increase in one port leads to a mean increase of 1.7 days of hospital stay). Nevertheless, more ports could reflect the surgeon's prudence in the unilateral cases, which can influence the time to discharge as well. The retrospective nature of our data does not allow deeper speculation. The literature does not offer conclusive results regarding this aspect even when analyzed for common procedures such as laparoscopic cholecystectomy [36].

Dissection and sealing of adrenal blood vessels is generally considered technically demanding due to their multiplicity and fragility. Studies with a large number of patients reported an intraoperative bleeding rate of 1.4–2.2% [16, 18] and a conversion rate of 9–10% [16, 18, 24]. In the past decade, instrumentation such as the *LigaSure*® and the *Ultracision*® have been shown to give a bleeding control comparable to clips or ligatures [37–39]. In our series, a clip-less procedure was adopted in 58.4% of patients with a mean decrease of 35 min with respect to the group with clips. Five (12.8%) patients experienced blood loss requiring transfusion, but none required conversion. Similar results were reported by Simforoosh et al., which presented a series of 12 pediatric patients treated for adrenal masses only using bipolar cautery. Avoiding clips has been reported to allow acceptable operative time and safe resection even in large tumors [40].

Intraoperative blood loss requiring transfusion occurred in 7.4% of patients in our study, with a conversion rate of 0%.

In this study the mean operative time was of 170 ± 87 min for unilateral lesions, 285 ± 30 min for bilateral lesions, while retroperitoneoscopic MAAS had a mean operative time of 199 ± 51 min. These durations are slightly longer with respect to other studies published [16, 25, 41–44]. The retrospective characteristic of this series does not allow speculation on this aspect and it represents one weakness point of the study.

The present series represents one of the largest on the minimally invasive approach to the adrenal glands in pediatric patients. The results show that MAAS can be safely offered to infants and children with masses up to 145 cc.

The presence of IDRFs at diagnosis and the persistence of disease at the renal pedicle after chemotherapy, did not represent in this series an absolute contraindication. MAAS has proven to be safe from the oncological view point for selected cases of NB in the present series. Furthermore, our results may sustain the systematic minimally invasive removal of persisting lesions in infants, for which the current protocols indicate to actively monitor instead, to avoid any potential secondary evolution.

The weakness point of the study is represented by the histological characteristics of the masses which make the population heterogeneous. Nevertheless, the small number of complications confirms that the technique can be considered the approach of choice for a widening spectrum of adrenal diseases in the pediatric population.

Compliance with ethical standards

Disclosures Drs. Francesco Fascetti Leon, Giovanni Scotton, Luca Pio, Raimundo Beltrà, Paolo Caione, Ciro Esposito, Girolamo Mattioli, Amulya K Saxena, Sabine Sarnaki and Piergiorgio Gamba have no conflicts of interest or financial ties to disclose.

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