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ORIGINAL ARTICLE

Costs analysis of laparoendoscopic, single-site laparoscopic and open surgery for cT1 renal masses in a European high-volume centre

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Abstract

Objective To analyse intraoperative costs and healthcare reimbursements of partial/radical nephrectomy in open and minimal invasive surgery (MIS), as laparoscopy and laparoendoscopic single-site surgery (LESS), for the treatment of renal tumour.

Materials and methods In a non-randomized retrospective study, we selected 90 patients who underwent (01/2010–12/2011) partial and radical nephrectomy for clinical renal masses $\leq$7 cm (cT1N0M0) and divided them into laparoscopic [laparoscopic partial nephrectomy (LPN), laparoscopic radical nephrectomy (LRN)], LESS [laparoendoscopic single-site partial nephrectomy (LESS-PN), laparoendoscopic single-site radical nephrectomy (LESS-RN)] and open groups [open partial nephrectomy (OPN), open radical nephrectomy (ORN)]. Patients were matched for age, sex, body mass index, ASA score and tumour side. Primary endpoints were evaluation of intraoperative costs (general, laparoscopic, sutures, haemostatic agents, anaesthesia, and surgeon/nurses fee), total insurance and estimated daily reimbursement.

Results MIS showed longer operative time ($p \leq .02$) and shorter hospital stay ($p \leq .04$). Total costs were higher ($p \leq .03$) in MIS (LRN: 4,091.5 €; LPN: 4,390.4 €; LESS-RN: 3,866 €; and LESS-PN: 3,450 €) if compared with open (OPN: 2,216.8.8 €, ORN: 1,606.4 €). Laparoscopic materials incised mainly in total costs of MIS (38–58.1 %). Reusable instruments reduced LESS laparoscopic costs (LESS-PN: 1,312.2 € vs. LRN: 2,212.2 €, $p < .0001$). Intraoperative frozen section and DJ ureteric stenting (general costs) ($p \leq .008$) and haemostatic agents use ($p \leq .01$) were higher in nephron sparing surgery (NSS), due to more frequent use of ancillary procedures necessary for a safe management of such an approach. Estimated anaesthesia costs and doctor/nurses fee were higher in MIS ($p \leq .02$). Whereas total final reimbursements were comparable ($p \geq .8$), estimated daily reimbursements were lower in MIS ($p < .001$) due to higher intraoperative costs and longer operative time.

Conclusion Well-known advantages offered by MIS/NSS face higher total intraoperative costs and ‘paradoxical’ reduced healthcare reimbursement. We believe that local health systems should consider a subclassification with different compensations, which will incentive NSS and MIS approaches.

Keywords Diagnosis-related groups reimbursement · DRG · Laparoendoscopic single-site surgery · Laparoscopy · LESS · Open surgery · Renal cell carcinoma · Nephron sparing surgery · Surgical costs

Abbreviations

MIS	Minimally invasive surgery
RN	Radical nephrectomy
RCC	Renal cell carcinoma
NSS	Nephron sparing surgery
SRM	Small renal masses
LESS	Laparoendoscopic single-site surgery
G-DRG	German diagnosis-related groups
ORN	Open radical nephrectomy
OPN	Open partial nephrectomy

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LRN	Laparoscopic radical nephrectomy
LPN	Laparoscopic partial nephrectomy
LESS-RN	Laparoendoscopic single-site surgery radical nephrectomy
LESS-PN	Laparoendoscopic single-site surgery partial nephrectomy
LoS	Length of stay
ASA	American Society of Anesthesiology
BMI	Body mass index
DJ	Double-J catheter

Introduction

Nephron sparing surgery (NSS) has been increasingly recommended by international guidelines over radical nephrectomy (RN) for the management of small renal masses (SRM), based on improved renal functional outcomes without sacrifice of oncologic effectiveness [1, 2], increased life expectancy and reduced cardiovascular morbidity [3–5]. NSS may be accomplished via a variety of techniques. Whereas open-approach represents the gold standard [5], with the refinement of intracorporeal suturing, and the availability of haemosealant substances, minimally invasive surgery (MIS), such laparoscopy, has gained popularity showing as well long-term oncologic and functional outcomes [6]. Recent developments have been directed towards further reduced morbidity and improved cosmetic outcomes, and laparoendoscopic single-site surgery (LESS) has shown comparable results [7, 8].

Both NSS and MIS are considered more complex than RN and open approach by increasing the need for surgeons' subspecialization/training. Accordingly, laparoscopic NSS is classified as 'very difficult' procedures in the European Guideline [9].

Since 1999, the German government announced the introduction of a prospective payment system based on diagnosis-related groups (G-DRG) [10]. Hospitals receive a fixed rate for each admission depending on a patient's diagnosis [11]. High efforts have been made in order to improve coding of complex cases; however, NSS/MIS still determines the same refund regardless of the technique performed without taking into account expensive costs and longer operative time required [12].

Purpose of this work is to evaluate intraoperative costs, total and estimated daily healthcare reimbursement of RN/NSS performed in an open, laparoscopic and LESS approach for cT1L0M0 renal cell carcinoma (RCC).

Materials and method

Study

An institutional review board-approved datasheet was constructed. We performed a retrospective analysis of ninety consecutive patients with cT1N0M0 RCC, who underwent with curative intent NSS/RN in an open (OPN: 15 patients; ORN: 15 patients), laparoscopic (LPN: 15 patients; LRN: 15 patients) and LESS approach (LESS-PN: 15 patients; LESS-RN: 15 patients) between January 2010 and December 2011.

The six groups were matched for age, sex, body mass index (BMI), American Society of Anaesthesiology (ASA) score and tumour side.

Patient selection

All patients were informed that the offered procedure would be the most suitable approach related to clinical stage, PADUA score and comorbidities. Pictures displaying all available surgical options with detailed pros and cons were routinely adopted. Strengthened by the available literature [1–5], we always tried to offer a NSS with primary emphasis on patient's and oncologic safety. RN for cT1 was performed for central-located masses with higher PADUA score or suspicion of renal sinus, renal calyces involvement or closeness to vascular pedicle. Since 2010, all patients suitable to LRN were also offered the LESS-option, focusing on the purely aesthetic benefits [13]. Elective indication for NSS was solid localized tumour $\leq$7 cm. LESS-PNs were offered in case of low-risk, laterally based, away from the renal hilum, SRM $\leq$ 4 cm (cT1a), and PADUA score $\leq$7. The exclusion criteria for MIS included ASA > 3, severe cardiac insufficiency and decompensated pulmonary function that cannot tolerate pneumo-peritoneum. None of the patients received neoadjuvant therapy.

We excluded patients with (a) tumour >7 cm, (b) clinical suspicion of lymphatic/metastatic involvement, (c) bilateral synchronous masses and (d) pre-existing chronic kidney disease (e-GFR < 60 mL/min/1.73 m^2).

Data collection

Primary endpoints included evaluation of intraoperative total costs, total and estimated daily reimbursement. Demographic data included age, gender, BMI, renal function, previous abdominal surgery, Charlson comorbidity index, clinical tumour stage, tumour side and characteristics (PADUA score). Additional variables comprised pre- and postoperative serum haemoglobin/creatinine, DJ stent insertion, warm ischaemia time (WIT), operative time, length of hospital stay (LoS), pathological stage/grade and surgical margins' status. Specimens were analysed according to TNM-2009 [14]. Short-term kidney function was evaluated by measuring pre-, postoperative day 4 serum creatinine and estimated GFR. Long-term function was not analysed because it was not the main aim of this study and has already reviewed elsewhere [6]. According to the modified Dindo–Clavien classification, complications occurring at any time after surgery were captured [15].

Surgeries were performed by three experienced surgeons (FG, PF and NM). LESS was performed by one surgeon (FG) who had completed at least 70 LESS.

Follow-up included physical examination/ultrasonography performed every 3 months and CT/MRI every 6 months in the first postoperative year and yearly for the subsequent 4 years.

Intraoperative costs and reimbursement analysis

Detailed intraoperative costs and insurance reimbursement were retrieved from the digital patient's chart, ORBIS NICE® (AGFA-Healtcare, Mortsel, Belgium), routinely used in the university hospital of Halle/Salle. Costs of instruments did not change in the analysed period. Direct costs related to surgical supplies were divided into (a) *general* (e.g. surgical drapes, glows, drains, etc., and endoscopic equipment for double-J catheter [DJ] insertion), (b) *suture*, (c) *disposable laparoscopic* (e.g. Verres needle, camera drape, Endopath Xcel trocars [Ethicon], forceps, scissors, retractors, entrapment bag, clip appliers, bipolar forceps, Ligasure [Valley Lab], Endo-Gia stapler) and (d) *haemostatic agents costs* (e.g. Tabotamp® [Johnson & Johnson Wound Management, Ethicon GmbH], Tachosil® [Nycomed Pharma GmbH], Tissucol® [Baxter Bioscience]). Intraoperative frozen-section costs were included in general costs. The latest report from our finance department allowed us to estimate intraoperative anaesthesia costs (3.5 €/min.) and surgeon/nurse fees (10 €/min.). Total reimbursement fee was electronically reckoned by the ORBIS-NICE® through the DRG-coding system of main/secondary diagnosis, complication (International Statistical Classification of Disease and Related Health Problems codes [ICD]) and performed procedure (Operationen-und Prozedurenschluessen [OPS]). The daily refund fee was obtained by subtracting the intraoperative costs from the total refund fee, all divided by day of hospitalization.

Surgical techniques

Open surgery and MIS for RN/NSS have previously been described [6, 8, 16, 17]. In NSS, a DJ ureteric stent was pre-operatively placed in case of special tumour morphology, especially when central-located or close to urinary-collecting system. In case of intraoperative collecting system opening or gross haematuria in drainage catheter bag, a DJ was retrogradely placed at the end of the procedure.

In case of warm ischaemia in NSS, the exposition of vascular pedicle allowed performing, whenever possible, a selective arterial clamping. A clampless MIS was achieved in case of favourable laterally and superficial tumour. Clampless OPN was as well accomplished in polar tumours by acting a parenchymal compression 1–2 cm away from margin of resection with Satinsky vascular forceps coated with a soft layer of gauze. Intraoperative ultrasound was routinely used to achieve tumour localization. The excision was carried out with cold scissors, and in some cases, a tumour enucleation was as well attempted [18]. Samples of resection bed were always sent to frozen section analysis. A resection bed suture was subsequently followed by 'Lahodny' parenchymal renorraphy: the needle was inserted approximately 1 cm away from the resection edge and at the level of the contralateral edge the suture line was secured with a PDS-clip. An early unclamping technique [19] was performed in MIS by taking advantage of forced pneumoperitoneum; after parenchymal suturing of resection bed, the remainder renorraphy was carried out in the revascularized kidney. Haemostatic agents could be added according to the intraoperative surgeon's choice. In case of positive surgical margins, an enlargement of the bed of resection was performed and resent to frozen analysis. Pedicle section in LRN/LESS-RN was performed with an Endo-Gia-stapler.

Statistical analysis

Statistical analysis, independent *t*-test and repeated measure ANOVA-test were performed using GraphPad-Prism, 6.0v. statistical software. The quantitative data were expressed as mean (M) and standard deviation (SD), and statistical significance was accepted at $p < .05$.

Results

Baseline characteristic (Table 1)

Age, sex, tumour side, BMI and ASA score were comparable. LESS showed a lower Charlson index ($p \leq .01$). PADUA score was lower for MIS-NSS ($p \leq .03$).

Peri- and postoperative outcomes (Table 2)

DJ stents were placed only in NSS and among them more frequently in OPN ($p > .03$). No difference was noticed in complete, segmental and 'zero' ischaemia ($p \geq .06$). A

Table 1 Patients demographic

	ORN	OPN	LRN	LPN	LESS-RN	LESS-PN	p
Number patient	15	15	15	15	15	15	/
Age (*M*, SD)	69.4 ± 9.5	68.5 ± 8.0	69.1 ± 9	63.8 ± 11.4	63.2 ± 10.3	65.8 ± 7.6	$p \geq .32$
Male patients	8	9	9	8	8	8	$p \geq .63$
Right side	7	8	7	8	7	7	$p \geq .80$
BMI (kg/m^2, *M*, SD)	26.6 ± 3.8	27.4 ± 4.2	28.7 ± 4.1	29.0 ± 6.15	29.4 ± 4.8	25.4 ± 3.6	$p \geq .52$
ASA (*M* score, SD)	2.2 ± 0.8	2.1 ± 0.8	2.3 ± 0.7	1.9 ± 0.7	2.3 ± 0.9	1.8 ± 0.5	$p \geq .09$
Charlson comorbidity index (score, SD)	10.4 ± 1.3	9.5 ± 2.0	7.5 ± 1.5	7.3 ± 1.9	5.2 ± 0.8	4.8 ± 1	
	ORN > LRN $p = .002$*; ORN > LPN $p = .001$*; ORN > LESS-RN $p = .0003$*; ORN > LESS-PN $p = .0001$*; OPN > LRN $p = .008$*; OPN > LPN $p = .006$*; OPN > LESS-RN $p = .0005$*; OPN > LESS-PN $p = .0004$*; LRN > LESS-RN $p = .008$*; LRN > LESS-PN $p = .004$*; LPN > LESS-RN $p = .02$*; LPN > LESS-RN $p = .01$*						
Previous abdominal operation, n° (%)	10 (66.6)	12 (80)	7 (46.6)	4 (26.6)	7 (46.6)	7 (46.6)	OPN > LPN $p = .04$*
PADUA (M score, SD)	10 ± 1.9	8.7 ± 1.0	9.5 ± 1.0	7.2 ± 1.1	8.7 ± 1.5	6.8 ± 1	
	LPN < LRN $p = .0001$*; LPN < ORN $p = .0002$*; LESS-PN < LRN $p = .0003$*; LESS-PN < ORN $p = .0004$*; LESS-PN < OPN $p = .009$*; LESS-PN < LESS-RN $p = .008$*; LESS-RN < LPN $p = .03$*						

ORN open radical nephrectomy, *OPN* open partial nephrectomy, *LRN* laparoscopic radical nephrectomy, *LPN* laparoscopic partial nephrectomy, *LESS-RN* laparoendoscopic single-site surgery radical nephrectomy, *LESS-PN* laparoendoscopic single-site surgery partial nephrectomy, *ASA* American Society Anesthesiologist, *DM* diabetes mellitus, *BMI* body mass index, *M* mean value, *SD* standard deviation

* Significative statistical difference

parenchymal compression allowed a 'zero-ischaemia' in 4 OPNs (26 %). Segmental ischaemia was performed in one case for each group. No differences were detected in WIT ($p \geq .09$). Operative time (Fig. 1a) was longer in MIS ($p \leq .02$). Hb drop was comparable in all groups ($p = .07$). Postoperative creatinine increase and GFR decrease were less frequent in NSS ($p \leq .0002$). LoS was shorter in MIS ($p \leq .04$) (Fig. 1b).

Oncological outcomes (Table 2)

Clear-cell RCC was predominant in all groups. pT1a was most frequent in MIS ($p \geq .02$). Surgical margins were negative in all patients. With a mean follow-up comparable in all groups, all patients were alive and without sign of recurrence.

Complications (Table 3)

The small cohort of patients did not allow any statistical conclusions. Early and Clavien grade 1–2 complications were more representative in all groups.

Costs (Table 4)

Total costs (Fig. 1c) were higher ($p \leq .03$) in MIS (LRN: 4,091.5 €; LPN: 4,390.4 €; LESS-RN: 3,866 €; and LESS-PN: 3,450 €) when compared with Open (OPN: 2,216.8.8 €, ORN: 1,606.4 €). Laparoscopic materials incised mainly in total costs of MIS (38–58.1 %). Reusable instruments reduced LESS laparoscopic costs (LESS-PN: 1,312.2 € vs. LRN: 2,212.2 €, $p < .0001$). NSS showed higher use of intraoperative frozen section and DJ ureteric stent (both classified in general costs) ($p < .008$) and haemostatic agents ($p < .01$), due to more frequent need of ancillary procedures performed for a safe management of such an approach. No difference was noticed in suture use. Estimated anaesthesia costs and doctor/nurses fee were higher in MIS ($p \leq .02$).

Reimbursement (Table 4)

The total reimbursement was 5,931 € for all cases. Postoperative complications such as sepsis, aspiration pneumonia and deep vein thrombosis of legs provided a higher refund of 1,071 €; however, without affecting the mean total reimbursements comparison ($p \geq .8$). Estimated mean daily refund (Fig. 1d) was higher in open procedures (ORN: 503.9; OPN: 379.7; $p \leq .007$) and LESS-PN (396.7; $p \leq .02$) when compared with others (LRP: 228.2; LPN: 197.1; LESS-RN: 279.1).

Discussion

NSS and MIS are ideal options in terms of safety and reduced morbidity in SRM treatment [20–22]. However,

Table 2 Intra-, peri- and postoperative data and pathology results

	ORN	OPN	LRN	LPN	LESS-RN	LESS-PN	p
Number of patients	15	15	15	15	15	15	
DJ stent insertion	0	6	0	4	0	2	OPN > LESS-PN $p = .03$*
Pre-operative	–	3 (50 %)	–	2 (50 %)	–	1 (50 %)	$p > .86$
Warm ischaemia							
Complete	–	10 (66 %)	–	11 (73 %)	–	7 (46 %)	$p > .3$
Segmental	–	1 (6.6 %)	–	1 (6.6 %)	–	1 (6.6 %)	$p = 1.0$
Zero Ischaemia	–	4 (26 %)[§]	–	3 (13 %)	–	7 (46 %)	$p > .06$
Warm ischaemia time, min, SD	–	13.7 ± 6.1	–	17.2 ± 5.6	–	15.1 ± 3.7	$p > .09$
OP time (min, M ± SD)	106.5 ± 37.9	112.6 ± 42.9	134.4 ± 34.1	157.4 ± 31.8	151.2 ± 29.3	135.0 ± 24.7	
	LESS-RN > ORN $p = .009$*; LESS-RN > OPN $p = .02$*; LPN > ORN $p = .005$*; LPN > OPN $p = .003$*						
Postoperative Hb decrease (mmol/l, M ± SD)	1.6 ± 0.9	2.7 ± 0.8	1.8 ± 0.9	2.0 ± 0.7	1.3 ± 0.7	1.8 ± 1.1	$p > .07$
Postoperative creatinine increase (mmol/l, M ± SD)	51.0 ± 40.5	26 ± 26.2	44.7 ± 17.6	20.7 ± 20.2	44.9 ± 32.6	10.6 ± 12.3	
	LESS-PN < ORN $p = .003$*; LESS-PN < LESS-RN $p = .02$*; LESS-PN < LRN $p = .02$*						
Postoperative GFR decrease mL/min/1.72 m 2	20.8 ± 10.7	7.4 ± 6.1	19.2 ± 7.4	3.8 ± 1.8	19.9 ± 9.3	2.7 ± 1.9	
	ORN > OPN $p = .00005$*; LRN > OPN $p = .0002$*; ORN > LPN $p < 0001$*; ORN > LESS-PN $p < .0001$*; LESS-RN > OPN $p < .0001$*; LRN > LPN $p < .0001$*; LRN > LESS-PN $p < .0001$*; LESS-RN > LESS-PN $p < .0001$*						
Hospital stay (days, M ± SD)	8.3 ± 1.7	9.3 ± 2.7	6.4 ± 1.8	6.1 ± 1.5	6.9 ± 3.8	5.3 ± 1.1	
	LESS-PN < OPN $p = .0001$*; LPN < OPN $p = .002$*; LRN < OPN $p = .008$*; LESS-PN < ORN, $p = .004$*; LPN < ORN $p = .04$*						
Pathology, stage pT1a	7	13	5	14	12	14	
	LESS-PN > LRN $p = .001$*; LPN > LRN $p = .001$*; OPN > LRN $p = .0049$*; LESS-RN > LRN $p = .02$*; LESS-PN > ORN $p = .02$*; LPN > ORN $p = .02$*						
pT1b	7	2	10	1	3	1	
Positive margin	0	0	0	0	0	0	–
RCC clear cell	11 (73.3 %)	13 (86 %)	12 (80 %)	12 (80 %)	12 (80 %)	13 (86 %)	$p > .7$
RCC papillary	3 (20 %)	2 (13.3 %)	2 (13.3 %)	1 (6.6 %)	2 (13.3 %)	–	/
RCC cystic multilocular	1 (6.6 %)	–	–	–	–	–	/
RCC and angiomyolipoma	–	–	1 (6.6 %)	1 (6.6 %)	1 (6.6 %)	–	/
RCC chromophobe	–	–	–	1 (6.6 %)	–	2 (13.3 %)	/
Fuhrman Grading I, II (n)	13 (86 %)	13 (86 %)	12 (80 %)	15 (100 %)	13 (86 %)	14 (93.3 %)	$p > .5$
Fuhrman Grading III, IV (n)	2	2	3	0	2	1	$p > .5$
Follow-up (months, SD)	26.6 ± 3.8	22.5 ± 6.2	19.3 ± 3.9	21.8 ± 6.7	27.4 ± 4.1	23.8 ± 6.3	$p > .6$
Follow-up							
Alive	15	15	15	15	15	15	
Recurrence n (%)	0	0	0	0	0	0	

ORN open radical nephrectomy, *OPN* open partial nephrectomy, *LRN* laparoscopic radical nephrectomy, *LPN* laparoscopic partial nephrectomy, *LESS-RN* laparoendoscopic single-site surgery radical nephrectomy, *LESS-PN* laparoendoscopic single-site surgery partial nephrectomy

[§] OPN: zero ischaemia is performed through parenchymal compression

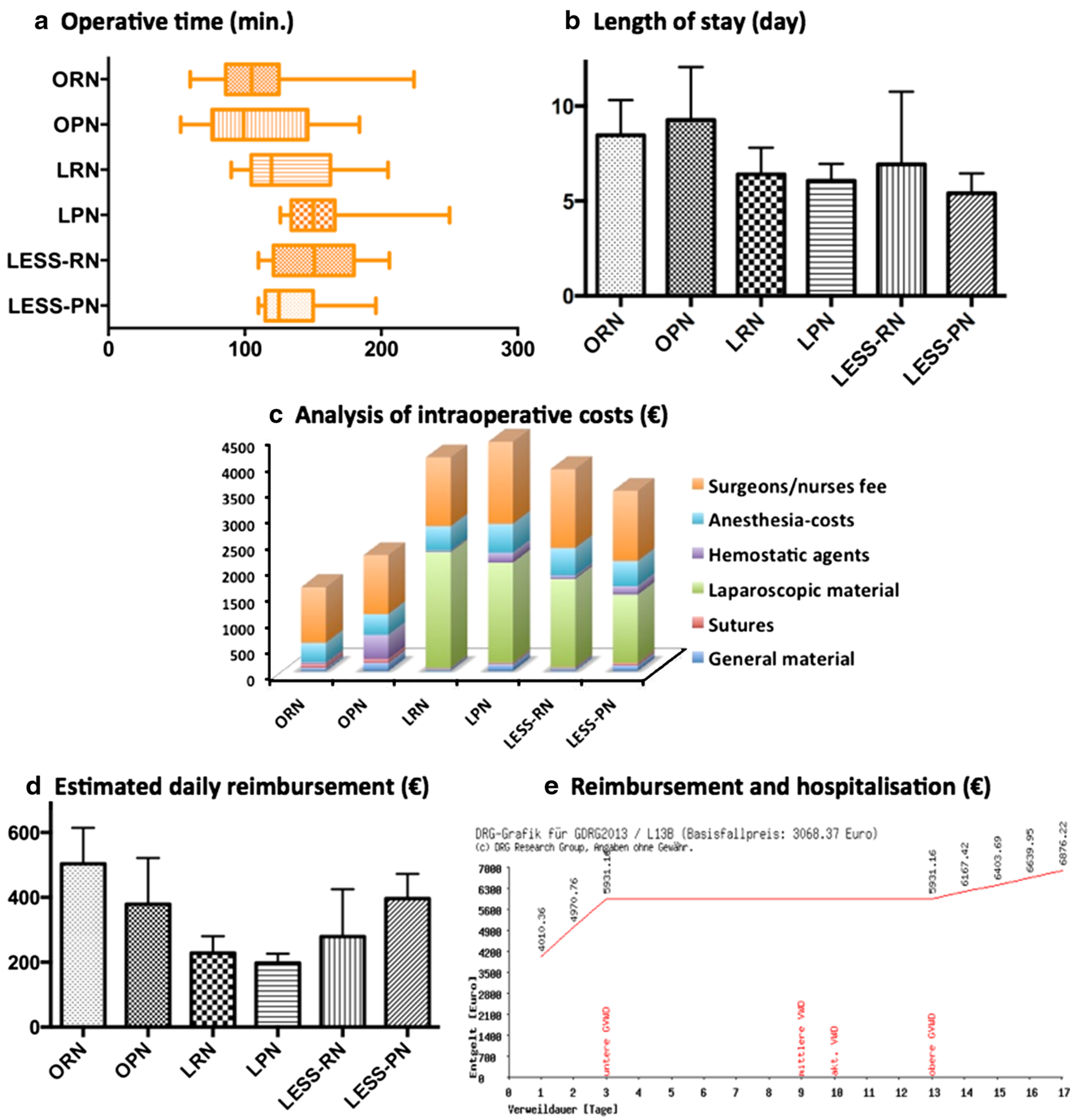

Fig. 1 **a** Operative time (min.). **b** Inpatient length of stay. MIS showed shorter inpatient length. **c** Intraoperative costs analysis in Euro. **d** Estimated daily reimbursement was higher in open procedures ($p \leq .007$) and LESS-PN ($p \leq .02$) when compared with others. **e** Effect of the hospitalization length on total reimbursement fee. The graph provided by the programm-ORBIS-NICE® shows how the total reimbursement for a given standard uncomplicated case is influenced by the length of the inpatient stay. Between postoperative day 3 and 13, it remains the same (5,931.16 €), but from postoperative day 14 an additional fee of 236.6 €/day is granted

even if almost 50 % of early-diagnosed RCC in US are SRM (cT1a) [23], less than half of them have been managed with NSS [24]. Many reasons can be addressed as follows: steeper learning curve, higher operating time, increased mental/physical stress and higher costs [9]. Therefore, proper surgical training and available budget should be taken into consideration. Besides, fiscal responsibility, cost-control measures and even patient's sociodemography (race, gender, income, education) [25] have become important healthcare issues [12].

Some authors have already quantified the overall benefits of MIS in order to compare cost-efficacy ratio [10, 26].

Table 3 Complications

	ORN	OPN	LRN	LPN	LESS-RN	LESS-PN	*p*
Complications (%)	9	12 (80 %)	5 (33 %)	6 (40 %)	6 (40)	5 (33 %)	$p \geq .06$
[Patient with complication]	[7, 60 %]	[9] 1,3	[5]	[5]	[6]	[5]	
Clavien Grade 1–2, no	7 (77.7 %)	10 (83.3 %)	5 (100 %)	5 (83.3 %)	5 (83.3 %)	4 (80 %)	$p \geq .21$
Early (≤1 mo)	6 (66.6 %)	9 (75 %)	5 (100 %)	5 (83.3 %)	6 (100 %)	5 (100 %)	$p \geq .15$
Clavien grade 1							
Prolonged abdominal/flank pain	1 (late)	1 (late)	0	0	0	0	
Seroma/wound infection	1	1	0	0	0	0	
Gross Haematuria	0	0	0	1	0	0	
Fever	1	2	1	3	2	2	
Haematoma	0	1	1	1	0	0	
Clavien grade 2							
Anaemic state (blood transfusion)	3	4	2	2	2	2	$p \geq .83$
Urosepsis (IV prolonged antibiotics)	1	0	0	0	0	0	
Atrial tachycardia (medical management)	0	1	0	0	0	0	
Thromboflebitis	0	0	0	0	1	0	
Clavien grade 3b							
Aspiration pneumonia (intubation)	0	1	0	0	0	0	
Wound infection (negative-pressure wound therapy)	1 (late)	0	0	0	0	0	
Hernia repair	1 (late)	0	0	0	0	0	
Urinary leakage (DJ stent)	/	1 (late)	/	1	/	1	
Bleeding (operative revision)	0	1	0	0	0	0	

Clavien grade 1: no need of pharmacological treatment or surgical, endoscopic interventions. Clavien grade 2: requiring pharmacological treatment with drugs other than, such allowed for grade 1. Blood transfusion and total parenteral nutrition are also included; Clavien grade 3: requiring surgical or endoscopic or radiological intervention; grade 3a: intervention not in general anaesthesia; grade 3b: intervention under general anaesthesia; Clavien grade 4: life-threatening complication (including CNS complication) and requiring IC/ICU management; grade 4a: single-organ dysfunction (including dialysis); grade 4b: multi-organ dysfunction

Unfortunately, G-DRG is calculated using a complex method of encoding related to peri- and postoperative complications and hospitalization time, without any distinction of surgical approach, blood transfusions, pre-/perioperative DJ stenting and intraoperative frozen section [10, 27].

The above-mentioned findings are evident in our study where the total reimbursing parcel remained almost unmodified among all groups. A detailed analysis showed that intraoperative high costs of MISs have been 36–60.1 % higher than their open counterparts. A primary factor has been the use of disposable laparoscopic material able to affect up to 54.1 % (range 25–81 %) of the total costs. It is interesting to note that MIS-NSSs have shown lower laparoscopic costs than MIS-RNs and basically because of technical reasons as reduced use of endoscopic stapler. The NSSs were also more expensive due to higher use of general materials (intraoperative frozen section, DJ ureteric stent), increased use of haemostatic agents (2.6–5.6-fold higher than RNs), and estimated anaesthesia and surgeons/nurses fees directly affected by longer operating time. The incidence of higher haemostatic agents and DJ ureteric stent use reflects the complexity of the procedure, with consequently greater risk of bleeding and openings of the renal calices, as showed by 1.5 and 2.1 points higher PADUA score tumour treated by OPN respect MIS–NSS.

Analysing the estimated daily reimbursement, we found higher refund in case of ORN and LESS-PN: the former is due to lower intraoperative total costs (2.4–2.5-fold less expensive that MISs and 1.3–2.1-fold less expensive than NSSs) and the latter is due to a combination of contained intraoperative costs (reusable single-port and pre-bented instruments granted up to 900 € saving costs) and shorter LoS, due to a new internal policy carried out in management of low SRM complexity (PADUA score 6.8), which allowed easier and smoother surgery.

In the presence of an inadequate reimbursement, a cost compensation could be allowed by restraining reusable materials and shortening operative time and hospital stay. Therefore, we have constantly improved our techniques in order to increase cost-efficacy ratio. For example, reusable trocars could be a solution to further reduce prices, as suggested by our LESS-experience. Nevertheless, the blunt

Table 4 Intraoperative total costs, total reimbursement and estimated daily reimbursement from healthcare system

	ORN	OPN	LRN	LPN	LESS-RN	LESS-PN	
Patients	15	15	15	15	15	15	
Intraoperative costs							
General material €, $M \pm SD$ (%)	62.4 ± 41.5 (3.9 %)	157.3 ± 32.9 (7.1 %)	41.3 ± 10.8 (1.0 %)	130 ± 42.7 (2.9 %)	52.5 ± 29.7 (1.3 %)	110 ± 52.0 (3.2 %)	
	OPN > ORN $p < .0001$*; LESS-PN > LRN $p < .0001$*; OPN > LESS-RN $p < .0001$*; LESS-PN > LESS-RN $p = .0006$*; LESS-PN > ORN .008*; OPN > LESS-PN .0085*; LPN > LRN $p < .0001$						
Sutures €, $M \pm SD$ (%)	68.1 ± 22.8 (4.2 %)	67.4 ± 22.3 (3.0 %)	18.2 ± 11.6 (0.4 %)	29.5 ± 15.0 (0.7 %)	22.6 ± 13.2 (0.6 %)	41.5 ± 12.5 (1.2 %)	$p \geq .2$
Laparoscopic material €, $M \pm SD$ (%)	–	–	2,212.2 ± 429.7 (54.1 %)	1,914.0 ± 772.4 (43.6 %)	1,686.9 ± 288.4 (43.6 %)	1,312.2 ± 131.4 (38.0 %)	
	LESS-PN < LRN $p < .0001$*; LESS-PN < LPN $p = .006$*; LESS-RN < LRN $p = .03$*						
Haemostatic agents €, $M \pm SD$ (%)	38.0 ± 81.8 (2.4 %)	472.1 ± 227.2 (21.3 %)	34.2 ± 66.2 (0.8 %)	192.5 ± 87.3 (4.3 %)	63.7 ± 87.8 (1.6 %)	164.1 ± 108.4 (4.7 %)	
	OPN > ORN $p < .0001$*; OPN > LRN $p < .0001$*; OPN > LPN $p < .0001$*; OPN < LESS-RN $p < .0001$*; OPN < LESS-PN < .0001*; LPN < ORN $p = .015$*; LPN < LRN $p = .012$*						
Estimated anaesthesia costs (3.5 €/min.) €, $M \pm SD$	372.9 ± 137.2 (23.1 %)	394.1 ± 155.2 (17.8 %)	463.1 ± 123.3 (11.3 %)	550.9 ± 115.3 (12.5 %)	529.2 ± 106.1 (13.7 %)	472.5 ± 89.4 (13.7 %)	
	LPN > ORN $p = .008$*; LESS-RN > ORN $p = .02$*; LPN > OPN $p = .01$*						
Estimate OR surgeons/nurses fee (10 €/min.) €, $M \pm SD$	1,065 ± 392.1 (66.4 %)	1,126.3 ± 443.4 (50.8 %)	1,323.2 ± 352.2 (32.3 %)	1,574.0 ± 329.3 (35.8 %)	1,512.0 ± 303.1 (39.1 %)	1,350.0 ± 255.5 (39.1 %)	
	LPN > ORN $p = .008$*; LESS-RN > ORN $p = .02$*; LPN > OPN $p = .01$*						
Total intraoperative costs, €, $M \pm SD$	1,606.4 ± 828.5	2,216.8 ± 1,058.7	4,091.5 ± 995.0	4,390.4 ± 1,360.0	3,866.0 ± 812.2	3,450.0 ± 605.1	
	ORN < LRN, ORN < LPN, ORN < LESS-RN, ORN < LESS-PN, OPN < LRN, OPN < LPN $p < .0001$*; OPN < LESS-PN $p = .0004$*; ORN < OPN, LPN < LESS-PN $p < .007$*; LESS-PN < LRN $p = .03$*						
Total insurance reimbursement	5,787.4 ± 517.8	5,747.4 ± 433.7	5,553.2 ± 0	5,553.2 ± 0	5,769.4 ± 631.5	5,553.2 ± 0	$p \geq .8$
Estimated daily insurance reimbursement	503.9 ± 111.1	379.7 ± 142.3	228.2 ± 51.6	197.1 ± 29.1	279.1 ± 145.5	396.7 ± 76.1	
	ORN > LRN, ORN > LPN, ORN > LESS-RN, LESS-PN > LRN and LESS-PN > LPN $p = .0001$*; OPN > LPN $p = .0009$*; ORN > LESS-PN, OPN > LRN and LESS-PN > LESS-RN $p = .001$; ORN > OPN $p = .03$*						

ORN open radical nephrectomy, *OPN* open partial nephrectomy, *LRN* laparoscopic radical nephrectomy, *LPN* laparoscopic partial nephrectomy, *LESS-RN* laparoendoscopic single-site surgery radical nephrectomy, *LESS-PN* laparoendoscopic single-site surgery partial nephrectomy tip of disposable trocars habitually adopted in our hands allows an easier access by minimizing vascular parietal lesions and abdominal organs perforation. We must always keep in mind that in a university high-volume centre with usual residents rotation standardization the use of safe material is essential from the patient's perspective.

A containment of haemostatic agents use, in the absence of clear international guidelines and questioned by some studies [28], may allow a further cost reduction. In our centre, sealants do not play any standardized-role and remain surgeon-dependent choice in relation to intraoperative difficulties/major bleedings. This was confirmed by the fact that haemostatic agents are most frequently used during NSS for higher PADUA score masses.

Estimated anaesthesia and doctors/nurses fees are directly related to the operative time and for obvious reasons, a more rapid surgery might reduce these charges. However, although our series incorporates expert surgeons' activity, we cannot forget that a university clinic must also take into account residents' training and that faster operative time does not mean superior quality surgical care.

The graph provided by the programm-ORBIS-NICE® (Fig. 1e) shows how the total reimbursement for a given standard uncomplicated case is influenced by the length of the inpatient stay. Between postoperative day 3 and 13, it remains the same (5,931.16 €), but from postoperative day 14 an additional fee of 236.6 €/day is granted. Our small cohort showed such a long inpatient stay only in a few open cases (6.6–13.3 %), and therefore, it would be ridiculous to postpone the discharge of MIS just to get an additional 236.6 €/day. By the other hand, an earlier discharge will allow an increase in the daily insurance reimbursement. The LESS-PN, new born technique in our clinic for management of uncomplicated SRM, has allowed us to follow a new philosophy with reduced hospital stay. Nevertheless, this approach cannot always be done, because of variable patient's physical conditions, wishes and regional/local backgrounds.

In conclusion, even in the presence of complications the mean total reimbursement did not affect statistically. Perhaps only by analysing individual case, such an additional reimbursement would be enough to cover ancillary requested procedure, but will anyhow not stimulate any rapid spreading of NSS and MIS.

There are several limitations to the present study. Primarily, this was a retrospective single-institution study with small cohort of patients. The group was probably enough to reflect costs, surgical and inpatient time, but maybe not adequate to mirror real complication rates: higher transfusion, urinary leakage and surgical revision rates [3, 6–8, 13, 17, 20, 29] may further increase the costs. The cost evaluation is influenced by a mix of departmental/economical forces, so far unique and hardly reproducible. Lastly, the fact that the surgical techniques have been developed and standardized in a high-volume university centre could lead to instrument selection bias.

Conclusion

Well-known advantages offered by MIS/NSS face higher total intraoperative costs and 'paradoxical' reduced healthcare reimbursement. We believe that local health systems should consider a subclassification with different compensations, which will incentive NSS and MIS approaches.

Conflict of interest All authors disclose any commercial associations that might create a conflict of interest in connection with the submitted manuscript.

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