Robotic adrenalectomy: evaluation of cost-effectiveness

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Abstract: Laparoscopic adrenalectomy (LA) is the preferred treatment option for adrenal lesions, considering the improved patients outcomes, due to the reduced postoperative morbidity and postoperative pain, the faster recovery and the shorter length of hospital stay. The widespread diffusion of robotic technology led to the development and standardization of robot-assisted approach to adrenalectomy. However, to date, no clear benefit from the use of the robot-assisted approach has been found. The higher costs remain an important drawback and limit the implementation of robot-assisted adrenalectomy (RA) programs. This review summarizes the current available data regarding RA including its operative outcomes, advantages and drawbacks in comparison with conventional LA, evaluating its cost-effectiveness.

Keywords: Robotic adrenalectomy; minimally invasive adrenalectomy; adrenal tumours; cost-effectiveness; personalized medicine

Introduction

Adrenalectomy is a technically demanding procedure which requires careful and meticulous dissection around major vessels and organs in a relatively narrow space as retroperitoneum is.

Laparoscopic adrenalectomy (LA) has become the preferred treatment option for adrenal lesions since first being performed in 1992 by Gagner *et al.* (1), considering the improved patients outcomes, due to the reduced postoperative morbidity and postoperative pain, the faster recovery and the shorter length of hospital stay (2-5).

Currently LA is the "gold standard" treatment for the management of most adrenal surgical diseases, with an overall postoperative complication rate of about 10% (4-7). The growing experience with LA and the excellent results of this procedure have led several authors to propose it also for large and potentially malignant adrenal tumors (8-10). However, the experience is limited and no conclusive data are available yet (10-13).

In 1999, Piazza *et al.* (14) and Hubens *et al.* (15) reported the first cases of robot-assisted adrenalectomy (RA) using the ZEUS AESOP (Computer Motion, Inc., Santa Barbara, CA, USA). After the introduction of the da Vinci system (Intuitive Surgical, Sunnyvale, CA, USA), several series of robotic surgical procedures have been reported.

The widespread diffusion of robotic technology has led to the development and standardization of robot-assisted

approach to adrenalectomy (16). RA has been proved to be feasible and safe in several Centers (16-24). The perceived advantages of RA can be considered the improved ergonomics, the stereoscopic vision, the tremor filtration, and greater range of motion within the operative field (25), potentially resulting in an ameliorated surgical dexterity and theoretically, maximizing the surgical efficiency of conventional LA. Indeed, it has been reported that RA may improve the performance of surgeons without extensive laparoscopic experience who wish to perform minimally invasive adrenalectomy (26).

Moreover, several variables, such as BMI (17,20), previous abdominal surgery and tumor size (27) have been evaluated in different clinical settings, in order to figure out whether the RA approach is preferable to the conventional LA approach in selected complex patients and/or in selected complex adrenal masses. However, to date, no clear benefit from the use of the RA approach has been found (24), and cost increase still represents a major drawback correlated to RA (24,27,28).

This review summarizes the current available data regarding RA including its operative outcomes, advantages and drawbacks in comparison with conventional LA, evaluating its cost-effectivity.

Robotic adrenalectomy: operative and post-operative outcomes

Operative time

It is acknowledged that the operative time of RA at the beginning of the experience is longer with respect to the conventional laparoscopic approach (28). First of all, the docking step can prolong the operative time by 15–40 minutes and can be as long as 1 hour at the start of the experience with RA (18,25,29). Indeed, in some experiences it has been specifically addressed that docking time is responsible for the significant increase of operative time in RA (30,31). Moreover, several variables, as keeping the robotic platform in a dedicated operating room, completing the preparations of the robotic platform during the anaesthesia time and the familiarity of the surgical team with the robotic surgery, can significantly affect the operative time (28). On the other hand, extensive experience with laparoscopic surgery and previous exposure to robotic procedures are able to significantly reduce the learning curve of RA (18,28). Several series identified in 20 cases the number of RA procedures needed to achieve similar outcomes to LA (17-19,32,33). Brunaud *et al.*, in a

prospective series of 100 RA, reported a significant decrease of operative time after the first 50 cases (9) and observed no significant difference with the conventional laparoscopic counterpart after reaching the threshold of 20 cases (17). Similarly, different thresholds as 5 (34) and 10 cases (35) have been indicated by other authors for a significant decrease in the operative time in RA.

On the other hand, the application of robotic technology to more complex patients and tumors seems to be favourable in terms of operative time. Indeed, in a retrospective series comparing RA and LA (both with transabdominal and posterior retroperitoneoscopic approach) for adrenal tumors larger than 5 cm, the application of robotic technology significantly shortened the operative time (159.4 ± 13.4 *vs.* 187.2 ± 8.3 min, respectively for RA and LA) (35). Accordingly, in a case-control study RA showed potential benefits compared to conventional LA, in particular on patients with nodules tumors ≥6 cm, BMI ≥ 30 kg/m^2, and with previous abdominal surgery (23).

In the case of bilateral adrenalectomy, RA had similar mean operative times with respect to conventional transabdominal lateral adrenalectomy (25). However, in a multicenter study comparing laparoscopic versus posterior retroperitoneoscopic versus robotic approach for synchronous bilateral adrenalectomy for Cushing's Syndrome, Raffaelli *et al.* (36), reported a significantly shorter operative time in the group of patients who underwent posterior retroperitoneoscopic adrenalectomy (PRA), since this approach eliminates the need to reposition the patient.

Intra- and post-operative complications

The majority of studies have demonstrated that RA is a safe technique with acceptable perioperative complications (21,22,24,37). The average complication rate reported for RA is difficult to evaluate because of the lack of standardized definitions through the different studies. However, the average complication rate has been reported between 0 and 20% (22,25,37). Several meta-analyses concluded that patients who underwent RA may experience lower postoperative complications with respect to those who underwent conventional LA (21,24). Nevertheless, a recent monocentric series of 303 unilateral RA showed a postoperative complication rate of about 10% (27), comparable to that of previous large studies evaluating conventional LA (4-7). Moreover, in the same study (27), four independent predictors for intraoperative and postoperative complications were identified: history of

previous surgical procedures (upper GI and retroperitoneal), tumor size, patient's age, and conversion.

The average reported rate of capsular rupture during RA is about 3% (18,19,24,27), especially in patients with large adrenal masses (18,19). The observed rate of capsular rupture is similar to previous large series evaluating conventional LA (4-6).

Similar to conventional LA, bleeding and local tumor adherence are the most frequent causes of conversion, which ranges from 0 to 11% (19,23,27,34). However, technical difficulties (limited visualization and poor port placement) have also been described (29). It can be argued that the conversion rate can be lowered as the learning curve is reached (25,29).

Overall, morbidity and mortality rates are considered to be comparable between RA and conventional LA (5,25). Post-operative complications associated to RA include haemorrhage, hematoma, wound infection, urinary tract infection, adjacent organ injury, ileus. In a recent meta-analysis by Economopoulos et al. (24) analysing 27 studies (13 comparatives and 14 non-comparative) RA and LA had similar intraoperative complications rate [odds ratio (OR): 1.20; 95% CI, 0.33–4.38], postoperative complications (OR: 0.69; 95% CI, 0.36–1.31), mortality (OR: 0.42; 95% CI, 0.07–2.72), conversion to laparotomy (OR: 0.51; 95% CI, 0.21–1.23) and conversion to laparotomy or laparoscopy (OR: 0.73; 95% CI, 0.32–1.69).

Agrusa et al. (37) compared 379 patients who underwent RA vs. 419 patients who underwent LA. In the RA group a significantly inferior blood loss and a shorter hospital stay were observed. Accordingly, in their analysis of LA vs. RA, Economopoulos et al. (24) observed a shorter length of hospital stay in the robotic group, whereas they failed to find significant differences in terms of blood loss between the two groups.

According to the network meta-analysis by Heger et al. (38), comparing open versus minimally invasive adrenalectomy (both with conventional laparoscopic and robotic approach), the robotic approach, has the highest probability of being the treatment inducing the lowest intraoperative blood loss.

Are there specific situations in which the robotic approach to adrenalectomy could be potentially superior to laparoscopic adrenalectomy?

Obesity

The effect of obesity with a body mass index ≥30 has been

previously reported as a risk factor for complications in LA (39). However, more recently, it has been demonstrated that obesity does not impact either on the complication rate or on the prolonged length of hospital stay in LA, but it significantly affects the operative time (40,41).

Similarly, the influence of obesity on operative outcomes of RA has led to discordant results with a relative scarcity of available data regarding this topic. Recently, Aksoy et al. (20) evaluated the effects of BMI >30 comparing 42 RA to 47 LA. Despite no significant differences in terms of operative outcomes were found between the two groups, the conversion rate was significantly higher in LA (5.2%) vs. RA (0%). Therefore, the authors concluded that the application of robotic approach in a challenging category of patients, as the obese are, is able to overcome the technical difficulties in terms of exposure and dissection (20).

In a recent retrospective case-control study, Morelli et al. (23) compared 41 RA to 41 conventional LA. The authors observed that robotic approach seemed to decrease mean operative time in the obese patient (BMI >30 kg/m^2). Similarly, Brunaud et al. (18) confirmed the advantages offered by the robotic approach in obese patients without additional risk factors for procedural complexity.

In a recent retrospective comparative analysis (42) between obese (BMI >30) and non-obese (BMI <30) patients who underwent RA, no significant difference was found between the two groups in terms of operative outcomes. In conclusion, despite the paucity of data regarding perioperative outcomes of RA in obese patients, some evidence suggests that the robotic approach is safe in this challenging group of patients without a significant increase of postoperative morbidity rate.

Large tumor size

Large tumor size is generally associated with difficult dissection during LA, potentially leading to the risk of capsular effraction and impairment of oncologic outcome because of local recurrence (8-11). Currently, different threshold sizes have been considered to be "large" ranging from 5 to 10 cm with a general consensus of 6 cm (8-11).

Several studies showed that adrenalectomy is feasible with both laparoscopic and robotic approaches in patients with large adrenal tumors (25). From a theoretical point of view, if the interposition of the surgeon-computer interface can maximize the efficiency of the surgical procedure, RA would be more appropriate in this situation. Indeed, Morelli et al. (23) observed a shorter operative time in patients

with tumor size > 6 cm who underwent RA. Similarly, other authors (29) observed a significantly decreased mean operative time in the group of patients with larger tumor size. As in conventional LA, also in RA the transabdominal route would be advisable in the subset of large adrenal lesions, because of the wider working space (25,29). Thompson *et al.* (43) used the Swedish database including 659 adrenalectomies (250 were robotically assisted) and evaluated the role of the robotic approach in patients with large tumors, with the strategy of applying the robotic approach preferably in tumor with larger size.

In a recent revision of the National Cancer Database, Mishra *et al.* (44) compared the operative outcomes of 38 LA and 51 RA for adrenal malignancies with a median tumor size of 6.5 cm. The study showed a significantly higher conversion rate in the LA group (17.2%) with respect to the RA group (5.9%).

Ball *et al.* reported that no prospective studies have been published on robotic approach in patients with large tumors including adrenocortical carcinoma (45). Furthermore, the results of retrospective studies comparing laparoscopic versus open approach for adrenocortical carcinoma were controversial. However, it could be argued that the oncologic outcome of ACC treated with endoscopic or robotic approach in referral centers is not inferior to that achieved with open adrenalectomy, when strict selection criteria and the principles of oncologic surgery are observed (5,10).

Cost-effectiveness of robotic adrenalectomy

The increased costs of RA remain one of its main drawbacks. Brunaud *et al.* pointed out that the cost of RA was 2.3 times superior with respect to LA in their center (respectively, €4,155 *vs.* €1,799) (17).

This finding is similar to that of other authors' experiences. Indeed, Winter *et al.* reported median operative charges of $8,645 for RA, $6,414 for conventional LA, and $3,666 for open adrenalectomy (46). However, median hospital charges did not differ significantly (12,977$, 11,599$, and $14,600 for RA, LA, and OA, respectively) thanks to shorter length of hospital stay of patients who had undergone minimally invasive surgery (46). Also, in the randomised controlled trial by Morino *et al.* (47) costs for the RA were higher compared to LA ($3,466 *vs.* $2,737, respectively). The charge difference was ascribed to the cost of the semi-disposable robotic instruments and to the longer operative times observed in the RA group. In addition, the cost difference did not consider the initial expense for the

da Vinci system purchase (47).

Several studies have reported that patients who undergo adrenal surgery by low-volume surgeons are more likely to experience post-operative complications compared to their counterparts operated upon by high-volume surgeons (48). In addition, it has been observed that if low-volume surgeons' cases were managed by high volume surgeons, there would be savings of 8.1%, since management costs were $14,263 for high-volume surgeons and $16,437 for the low-volume (49). These data, which refer to the LA, might be applied in the setting of RA, but controlled trials are needed.

On the other hand, increasing the number of robotic procedures performed per year is an effective depreciation modality of robotic system and consequently may bring a cost decrease (28). Indeed, Winter *et al.* calculated that if a centre performs over 500 robotic operations per year, then capital and maintenance costs for the robot would be $380 per procedure (46). In accordance with these data, RA could become more sustainable in high-volume robotic surgery centers (24).

Since some studies have reported that robotic operative packs (comprehensive of instruments and of sterile drapes) may cost up to 900–950 $ per procedure, a limitation of the robotic instruments used during each procedure will probably bring an economic benefit (47,50,51).

Similarly, Feng *et al.* (52) recently reported their strategies in order to reduce the cost correlated to RA with respect to LA. The calculated costs were $3,527 for RA and $3,430 for LA, with the average consumables fees being similar between the two groups ($1,106 and $1,009 respectively for RA and LA). The authors concluded that by limiting the number of robotic instruments and energy devices and utilising an experienced surgical team, the costs of RA can be kept similar to those of LA (52).

Overcosts due to the use of the robotic system could also be balanced by shortening the hospital stay, patients' referral increase, improved postoperative outcomes in more difficult patients (28).

However, to date, there are no available strong clinical data that could balance overcosts associated with the use of the robotic system (28).

The financial model of reimbursement has an important impact on the choice and feasibility of different techniques. But it is hard to compare these data considering the different systems adopted in various countries: this also explains, at least in part, the inhomogeneity of literature on the subject of costs of RA, and the need for more studies and data concerning its indications and benefits.

Table 1 Comparative cost analysis among PRA, LTA and RA (Study period: January 2017–September 2019)

Technique	PRA[†]	LTA[§]	RA[‡]
N°	39	80	12
Mean hospital stay (pre-op and post-op) (days)	5.4	5.1	6
Mean Intensive Care Unit stay (days)	0.1	0.06	0.08
Mean Operating Room occupation time (min)	120.6	138.8	163.1
Mean surgical time (min)	57.2	72.2	93.3
Mean medical procedure cost (€)	196.1	185.6	234.05
Mean DRG [¶] (€)	7,695.1	7,656.6	7,695.1
Mean hospital stay cost (€)	1,714.9	1,640	1,920
Mean Intensive Care Unit cost (€)	123.08	75	100
Mean Operating Room occupation cost (€)	1,004.6	1,166.7	1,386.5
Mean medical devices cost (€)	775.1	706.1	1,769.6
Mean cost margin (€)	3,881.4	3,836.4	2,284.9

[†], posterior retroperitoneoscopic adrenalectomy; [§], laparoscopic transabdominal adrenalectomy; [‡], robot-assisted adrenalectomy (transabdominal); [¶], diagnosis-related group. PRA, posterior retroperitoneoscopic adrenalectomy; LTA, laparoscopic transabdominal adrenalectomy; RA, robot-assisted adrenalectomy.

Although there are no available data on the reimbursement of adrenalectomy techniques based on the different providers, some authors have stated that flat reimbursement is not favourable in the use of new techniques, such as robotic surgeries, because they are often more expensive (28).

In this context, we evaluated the cost-effectiveness of RA with respect to other endoscopic approaches [laparoscopic lateral transabdominal adrenalectomy (LTA) and the PRA] in a public national health systems (NHS) in which inpatient care reimbursements are based on diagnostic-related groups (DRG) and the reimbursement for robotic procedures is the same as that for the classical laparoscopic procedures.

Among a series of 731 adrenalectomies performed at a single third-care referral institution (91 RAs, 199 LTAs, 229 PRAs and 212 open adrenalectomies), 131 consecutive patients undergoing unilateral adrenalectomy between January 2017 and September 2019 were considered (39 PRA, 80 LTA and 12 RA). We performed a cost analysis including anesthesia and surgery professionals' fees, operating room costs, consumables materials and devices, hospital stay costs, prospectively collected for every single patient in the Institutional administrative database. Overall costs were subtracted to the DRGs reimbursement for adrenalectomy (€7,695) in order to calculate the operating margins for PRA, LTA and RA. Mean operating room

(OR) occupation time was 120.6, 138.8, and 163.1 minutes, respectively for PRA, LTA and RA; while mean procedure time (skin to skin) was 57.2, 72.2, and 93.3 minutes, respectively for PRA, LTA and RA (*Table 1*). Mean post-operative stay was 4.0, 3.9, and 4.6 days, respectively for LTA, PRA, and RA. Median overall hospital costs per procedure were 3,813.71€, 3,773.41€, and 5,410.10€, respectively for PRA, LTA and RA. Thanks to our analysis of the cost margin, we saw that it was positive for all the approaches: 50.4%, 50.1%, and 29.7%, respectively for PRA, LTA and RA (*Figures 1-3*). Specifically, the mean margin was 3,881, 3,836, and 2,285 euro for PRA, LTA, and RA, respectively (*Table 1*). In the subgroup analysis evaluating the impact of lesion size, the difference in marginality between RA and the other approaches decreased of about 20% for lesions ≥40 mm.

Although in Italy the reimbursement is the same for laparoscopic and robotic surgeries (flat reimbursement), the cost margin for adrenalectomy was positive in our experience, even when the robot-assisted approach was used.

In our experience the increasing surgical load results in a proportional improvement of the cost margin. This effect is realised because of several factors, namely the significant decrease of the operative time, but also the effective employment of the operating room and of its resources.

The possibility to perform adrenal surgery with the three
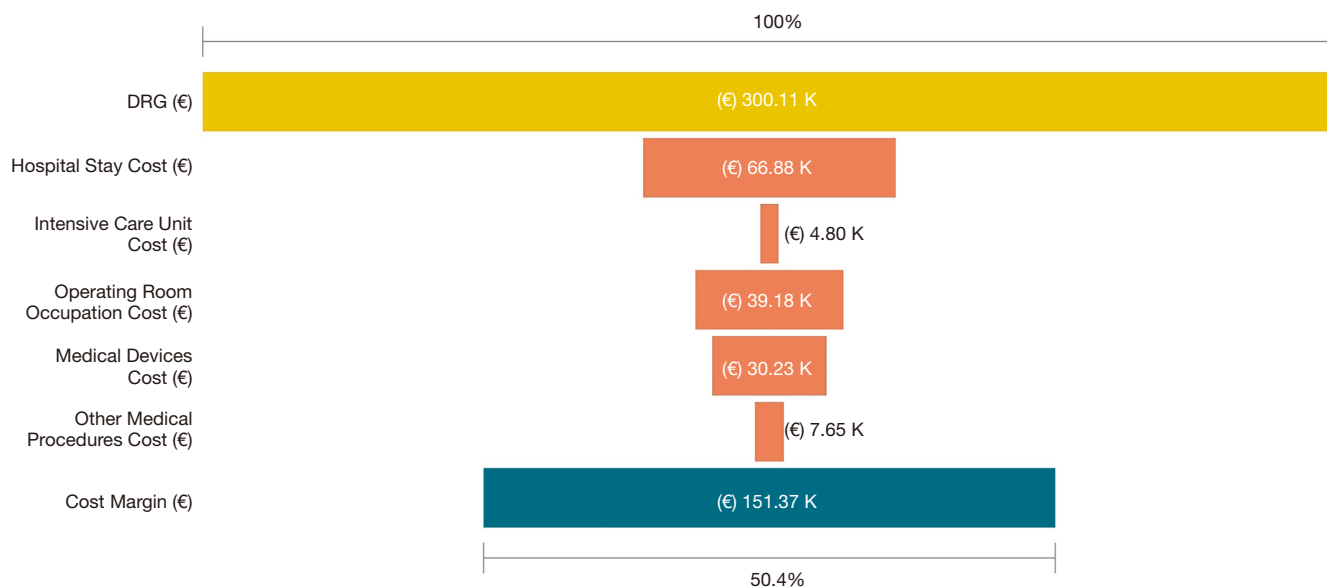
Figure 1 Overall costs and cost margin of posterior retroperitoneoscopic adrenalectomy (personal institutional experience).
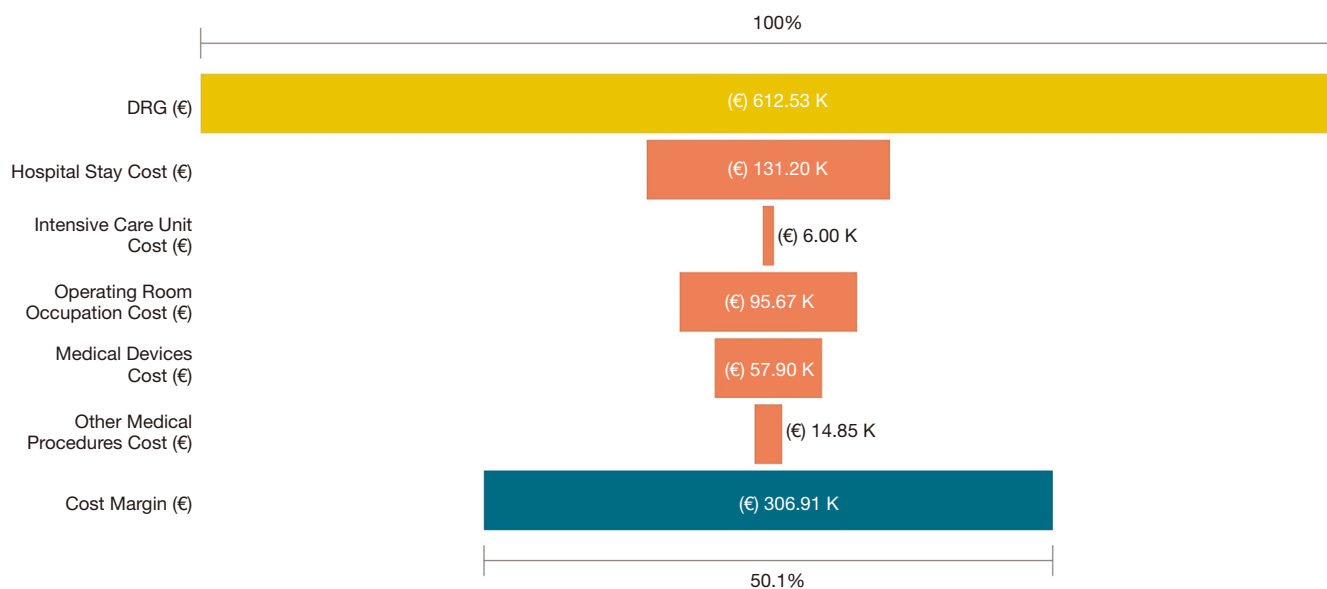
Figure 2 Overall costs and cost margin of lateral transabdominal adrenalectomy (institutional personal experience).

mentioned approaches offers an essential instrument to warrant the best possible equilibrium between economic sustainability and patient benefit.
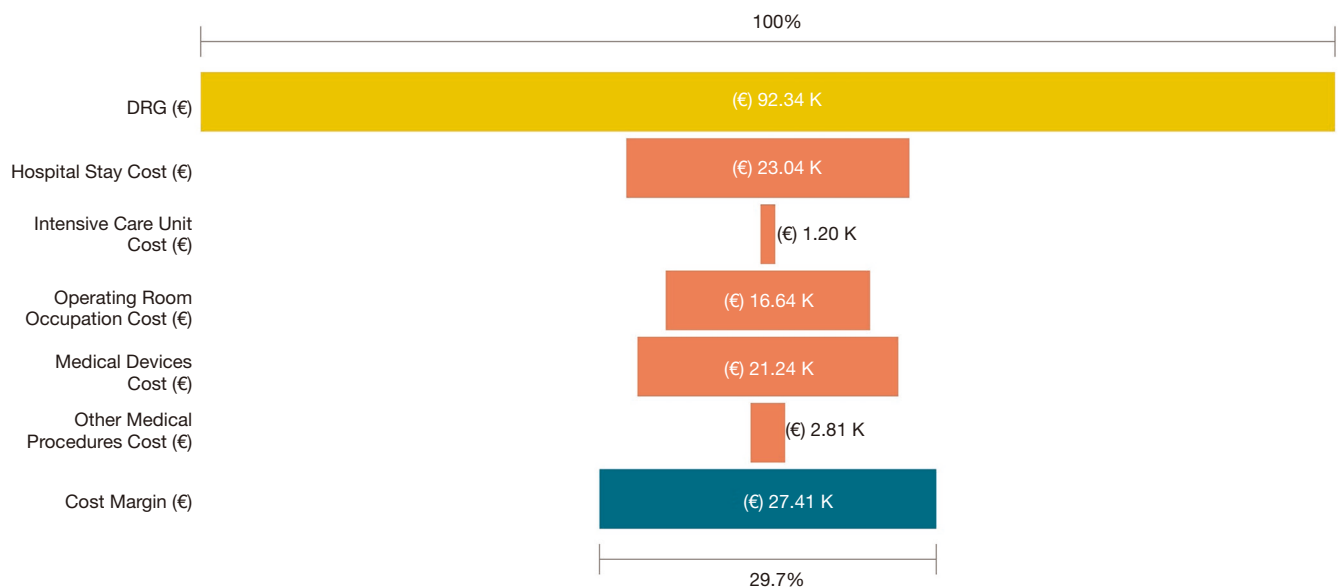
Conclusions

Despite the higher cost, RA appears to be cost-effective and sustainable in a DRG-based reimbursement system in

our experience. If reserved to larger and more challenging lesions, for which more benefits are expected by RA, the cost-effectiveness increases, and the differences with other techniques significantly reduce.

Acknowledgments

Figure 3 Overall costs and cost margin of robot-assisted adrenalectomy (personal institutional experience).

Footnote

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