European Journal of Surgical Oncology xxx (xxxx) 1–8

Contents lists available at ScienceDirect

European Journal of Surgical Oncology

journal homepage: www.elsevier.com/locate/ejso

Cost-analysis of robot-assisted radical cystectomy in europe: A cross-country comparison

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ARTICLE INFO

Article history:
Received 30 April 2022
Received in revised form 22 July 2022
Accepted 31 July 2022

Keywords:
Bladder
Cost-analysis
Cystectomy
Robotics
Cancer

ABSTRACT

Background: Robotic-assisted radical cystectomy (RARC) with intracorporeal urinary diversion (ICUD) is surging worldwide. Aim of the study was to perform a multicentric cost-analysis of RARC by comparing the gross cost of the intervention across hospitals in four different European countries.
Methods: Patients who underwent RARC + ICUD were recruited from eleven European centers in four European countries (Belgium, France, Netherlands, and UK) between 2015 and 2020. Costs were divided into six parts: cost for hospital stay, cost for ICU stay, cost for surgical theater occupation, cost for transfusion, cost for robotic instruments, and cost for stapling instruments. These costs were individually assessed for each patient.
Results: A total of 490 patients were included. Median operative time was 300(270–360) minutes and median hospital length-of-stay was 11(8–15) days. The average total cost of RARC was 14.794€ (95%CI 14.300–15.200€). A significant difference was found for the total cost, as well as the various subcosts above-mentioned, between the four included countries. Different sets and types of robotic instruments were used by each center, leading to a difference in cost of robotic instrumentation. Nearly 84% of costs of RARC were due to hospital stay (42%), ICU stay (3%) and operative time (39%), while 16% of costs were due to robotic (8%) and stapling (8%) instruments.

https://doi.org/10.1016/j.ejso.2022.07.023
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Conclusion: Costs and subcosts of RARC + ICUD vary significantly across European countries and are mainly dependent of hospital length-of-stay and operative time rather than robotic instrumentation. Decreasing length-of-stay and reducing operative time could help to decrease the cost of RARC and make it more widely accessible.

1. Introduction

In the recent decade, there has been a paradigm shift towards minimally invasive surgery in all surgical specialties, especially urology. Robot-assisted radical cystectomy (RARC), lately combined with intracorporeal urinary diversion (ICUD), has gained popularity in the treatment of bladder cancer. The reason behind this is that RARC, like other robot-assisted surgeries, is associated with reduced blood loss and shorter hospital stay compared to open radical cystectomy (ORC) [1–3], with no significant difference on progression-free-survival compared to ORC [4,5].

In a recent randomized controlled trial done on 338 patients, RARC with ICUD offered more days alive and out of the hospital within 90 days of surgery, less thrombo-embolic complications and wound complications, and a better quality of life at 5 weeks, compared to ORC [6]. All this was achieved while preserving oncological outcomes, with a comparable rate of cancer recurrence. No difference was observed in the risk of overall mortality at 18.4 months [6].

Despite these advantages, RARC is not yet widely adopted in clinical practice internationally: this due to a higher operative time compared to open surgery [7,8], a steep learning curve [9] and significantly higher costs compared to ORC [10,11], but most importantly the cost associated with the procedure. RARC is more expensive than ORC, mainly due to cost of hospital stay and surgical theater occupation [12]. Moreover, in a recent multicenter prospective medico-economic study, similar effectiveness via quality-adjusted life years was found for the two approches, although RARC was "much more" expensive [13].

While numerous studies in the literature evaluate cost-analysis of RARC [13–17], these studies are mainly monocentric, as such exploring costs in a single country. To our knowledge, there is no study comparing the cost of RARC + ICUD, unraveling its subcosts, across different countries.

Therefore, we aimed to perform a multicentric cost-analysis of RARC + ICUD, by comparing the cost of the intervention, according to each individual patient data, across hospitals in four different European countries.

2. Materials and methods

The current project was launched by the European Association of Urology - Young Academic Urologists (EAU-YAU), Urothelial carcinoma working group, in October 2020. Data were collected from a European multicentric database of eleven European centers in four European countries (Belgium, France, Netherlands and UK), comprising patients who underwent RARC with ICUD by trained surgeons (14 trained surgeons, with maximum two surgeons per center), between 2015 and 2020. All included centers had a local prospective registry of patients. Only patients who underwent neobladder or ileal conduit as urinary diversion were included. Patients who underwent ureterostomy or continent cutaneous urinary diversions (e.g. Indiana pouch) were excluded. All surgeries were performed on Da Vinci Si or Xi (Intuitive Surgical®) robot.

Data on demographic and operative parameters were collected in a standardized manner and included: age, sex, BMI, smoking status, Charleson index, operative time, blood loss, transfusion, number of red blood cell (RBC) packs transfused, type of urinary diversion, intra-operative and post-operative complications, total hospital length-of-stay, and length of stay at intensive care unit (ICU).

Regarding cost-analysis, costs were divided into six main categories:

1) Cost for hospital stay
2) Cost for ICU stay when patients were admitted to ICU
3) Cost for operative room (OR)
4) Cost for transfusion
5) Cost for robotic instruments
6) Cost for stapling instruments.

Cost of hospital length-of-stay and ICU stay were individually assessed for each patient, by multiplying the length-of-stay (in days) by the average cost of one day according to each country included. Cost of readmission days due to complications during the 30 days after surgery were also included in the cost of hospital length-of-stay. ICU stay cost included post-operative stay in some centers (most centers do not admit their patients to ICU after surgery) and stay due to severe post-operative complications (Clavien IV-V). Cost of OR timewas also assessed for each patient by multiplying the time spent in the OR (in minutes) by the average cost of an OR minute, which was obtained from local health autorities. Transfusion cost was obtained by multiplying the price of a RBC pack in each center by the number of packs received by each patient.

As for cost for robotic instruments, given that each hospital negotiates a price with providers, European listing price of each instrument was used and was obtained from the provider; total price depended on which type of instruments were used for each patient in each center (scissors, maryland forceps, fenestrated bipolar, prograsp forceps, cadiere forceps, needle driver, bowel grasper and/or vessel sealer). As for stapling, a robotic or laparoscopic stapler was used according to each center's habitude; the number of staple throws was also dependent from the type of urinary diversion, and from each center's habitude [18]. The European listing price of stapling instruments were also obtained from the corresponding providers.

Cost data from UK were converted from british currency to euros at the mean exchange rate for 2021 (1£ = 1.1632€).

Descriptive statistics were assessed for demographics, operative parameters and cost-analysis parameters, for each country. In order to evaluate the difference of continuous variables between the four countries included, Kruskal-Wallis test was used. When this was statistically significant, post-hoc analysis was done. Chi^2 test was used to compare categorical variables between countries. Finally, since cost of robotic instruments depended on the number and type of instruments used by each center, and in order to see if cost of surgical instruments was correlated with surgical outcomes, Spearman's correlation was used. Correlations were also assessed between use of vessel sealer (most expensive robotic instument) and the abovementioned surgical outcomes. All statistics were done using SPSS® (IBM v.20). A p-value <0.05 was considered as statistically significant.

3. Results

A total of 501 patients were initially included. After excluding patients who had a ureterostomy and those who were operated by a urinary diversion other than neobladder or ileal conduit, 490 patients (67 ± 11 years old; M:F 5:1) were finally included in our study: 160 patients (four centers) from Belgium, 155 patients (four centers) from

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France, 69 patients (one center) from the Netherlands, and 106 patients (two centers) from the UK. Demographic and operative characteristics are shown in Table 1. Median operative time was 300 (270–360) minutes and median hospital length-of-stay was 11 (8–15) days. Sixty-two patients (12.7%) were readmitted to hospital within 30 days from surgery, mainly due to infectious (7.3%) or gastrointestinal complications (2.0%); median length of hospital readmission stay was 7 (4–11) days (Table 1). Median number of days alive and out-of-hospital within 90 days was 79 (74–82) days.

Regarding the type of urinary diversion, a significant difference ($p < 0.001$) was found between the different countries:

- Belgium: 28.8% neobladder and 71.2% ileal conduit
- France: 50.4% neobladder and 49.6% ileal conduit
- Netherlands: 33.3% neobladder and 66.7% ileal conduit
- UK: 12.3% neobladder and 87.7% ileal conduit

Table 1
Demographic and operative characteristics of the study population.

Variable		Value
Age, years (median, IQR)		67 (60–74)
Sex, n(%)	M	404 (82.4%)
	F	86 (17.6%)
BMI, Kg/m2 (median, IQR)		26 (24–29)
Country, n (%)	Belgium	160 (32.7%)
	France	155 (31.6%)
	Netherlands	69 (14.1%)
	UK	106 (21.6%)
Charlson comorbidity index (median, IQR)		4 (2–6)
Urinary diversion, n(%)	Neobladder	160 (32.7%)
	Ileal Conduit	330 (67.3%)
OR time, mins (median, IQR)		300 (270–360)
Blood loss, ml (median, IQR)		300 (200–500)
Intra-operative transfusion, n(%)	Yes	28 (5.7%)
Post-operative transfusion, n(%)	Yes	51 (10.4%)
Hospital length-of-stay, days (median, IQR)		11 (8–15)
ICU admission (%)		153 (31.2%)
Readmission, n(%)		62 (12.6%)
Length of readmission stay (median, IQR)		7 (4–11)
Cause of readmission, n(%)	Infection	36 (7.3%)
	Gastrointestinal	10 (2.0%)
	Anastomotic leak	4 (0.8%)
	Stent obstruction	5 (1.0%)
	Acute renal failure	2 (0.4%)
	Other (COVID-19)	1 (0.2%)
Number of days alive and out-of-hospital within 90 days, days (median, IQR)		79 (74–82)
Highest Clavien-Dindo complication, n(%)	I	35 (7.1%)
	II	135 (27.6%)
	IIIa	28 (5.7%)
	IIIb	40 (8.1%)
	IVa	6 (1.2%)
	IVb	4 (0.8%)
	V	4 (0.8%)

A significant difference ($p < 0.001$) was found for operative time between the four countries. This difference was mainly between Belgium and France (336 vs. 304 min; $p = 0.010$), France and Netherlands (304 vs. 358 min; $p = 0.001$), Netherlands and UK (358 vs. 297 min; $p < 0.001$), and Belgium and UK (336 vs. 297 min; $p = 0.001$).

Details about the number of instruments used by each center, and the respective cost of each set of instruments, is shown in Fig. 1.

As for stapling instruments, a laparoscopic stapler was used for 273 patients(55.7%) while a robotic stapler was used for 217 patients (44.3%). Regarding staple throws, 4–5 staple throws were used for a neobladder, while 2–5 staple throws were used for ileal conduit.

A significant difference ($p < 0.001$) was found for hospital length-of-stay between the four countries. This difference was mainly between Belgium and UK (15.7 vs. 9.7 days; $p < 0.001$), France and UK (14.6 vs. 9.7 days; $p < 0.001$), Belgium and Netherlands (15.7 vs. 10.7 days; $p < 0.001$) and France and Netherlands (14.6 vs. 10.7 days; $p < 0.001$).

Details about the individual costs of hospital stay, ICU stay, OR time, and costs of instruments are shown in Supplementary Tables 1 and 2 The total cost of RARC + ICUD averaged 14.794€ (95%CI 14.300–15.200€). It averaged 16.383€ (95%CI 15.600–17.100€) in Belgium, 11.947€ (95%CI 11.100–12.800€) in France, 16.635€ (95%CI 15.629–17.640€) in Netherlands and 14.214€ (95%CI 13.500–14.900€) in UK. Kruskal-Wallis showed statistically significant difference for total cost between the different countries ($p < 0.001$). Post-hoc analysis is shown in Fig. 2.

Cost distribution between different domains has shown that globally and on average, 42.0% of costs were due to hospital stay, 3.4% to ICU stay, 38.6% to operative time, 0.1% to transfusion, 7.9% to robotic instruments, and 8.0% to stapling instruments (Table 2). Proportions of cost distribution in the different countries are equivalent and shown in Fig. 3.

When comparing costs according to the type of urinary diversion, a significant difference was found for total cost of RARC between neobladder and ileal conduit (16.084€ vs 13.790€; $p < 0.001$). Cost for hospital stay was significantly higher for neobladder compared to ileal conduit (7.342€ vs 5.748€; $p < 0.001$), as well as cost of stapling instruments (1.577€ vs 976€; $p < 0.001$). No significant difference was found for the cost of OR time (5.650€ vs 5.303€; $p = 0.258$).

Statistically significant differences were found for all the subcosts between included countries ($p < 0.001$). Regarding cost of hospital stay, main difference was found with UK ($p < 0.001$); no statistically significant difference was found between Belgium, France and Netherlands ($p > 0.05$). Cost of ICU stay, operative time and stapling instruments differed significantly between nearly all four countries, except for France vs Netherlands (for ICU and stapling cost) and Belgium vs Netherlands (for operative time cost). Significant differences were also found for cost of robotic instruments ($p < 0.001$). Details on these differences are illustrated in Fig. 2. Details about values of subcosts and costs are shown in Fig. 2 and Table 2.

The total cost of robotic instruments was negatively albeit very weakly correlated with occurrence of bleeding ($\rho = -0.165$; $p < 0.001$), occurrence of a complication ($\rho = -0.178$; $p < 0.001$), and Clavien-Dindo highest grade of complication ($\rho = -0.155$; $p = 0.001$); a slightly non-significant inverse correlation of total robotic instruments with operative time ($\rho = -0.085$; $p = 0.057$) was also found. Similarly, the use of a vessel sealer was negatively but very weakly correlated with occurrence of bleeding ($\rho = -0.135$; $p = 0.003$), occurrence of a complication ($\rho = -0.116$; $p = 0.010$), and Clavien-Dindo highest grade of complication ($\rho = -0.099$; $p = 0.028$); a slightly non-significant inverse correlation of the use of a vessel sealer with operative time ($\rho = -0.087$; $p = 0.054$) was also found.

4. Discussion

This is the first study to compare costs of RARC + ICUD between European countries. We report that costs of RARC vary significantly across these countries, with cost of surgical theater occupation and hos-

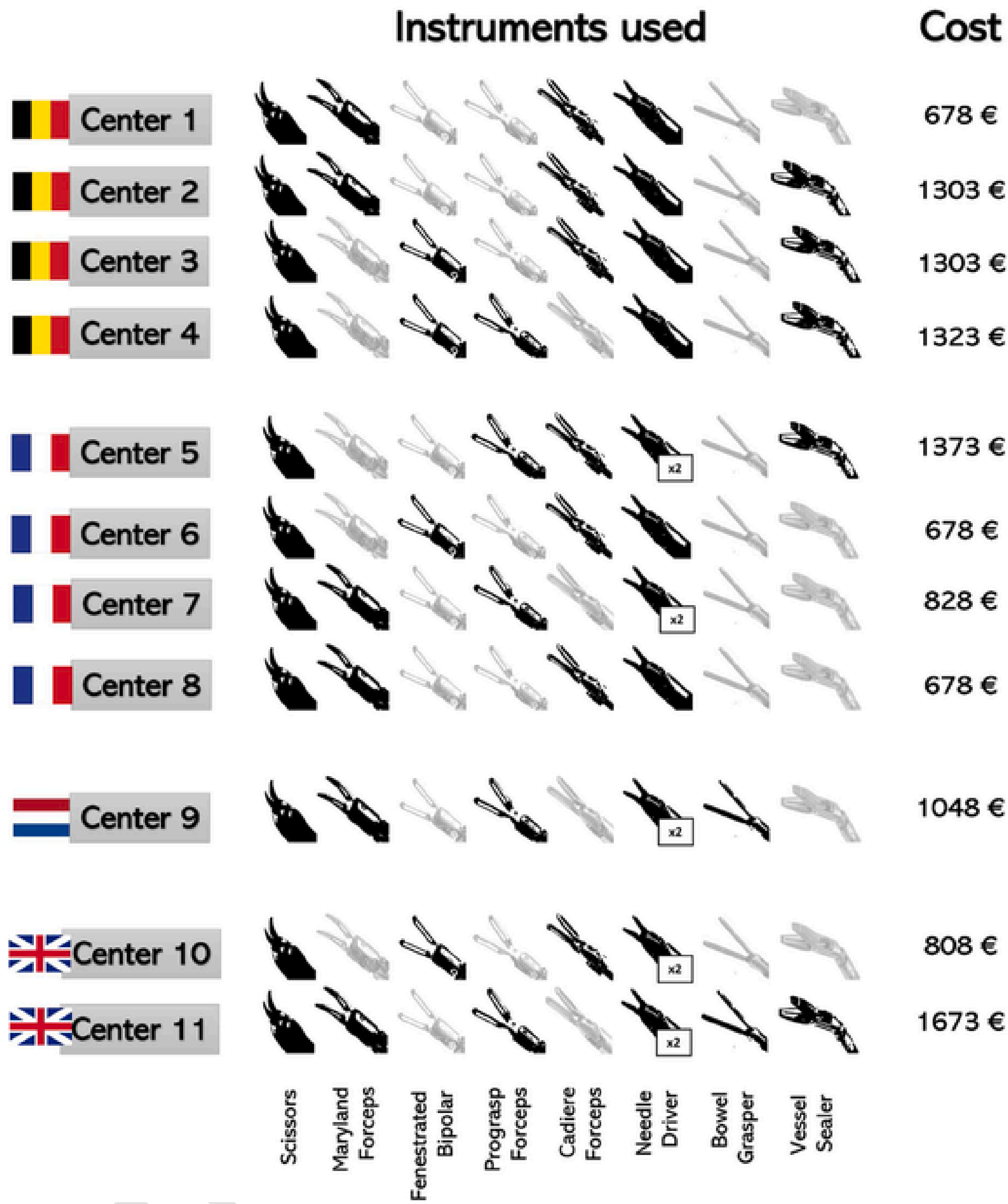

Fig. 1. *Robotic instruments used by each included center, and their corresponding cost. Black instrument = used. Gray instrument = not used.*

pital stay accounting for the major differences across analyzed countries.

Median operative time, median hospital length-of-stay and rate of transfusion were comparable to those published in the literature [13,19].

Mean cost of RARC was demonstrated in our study to be 14.773€. This cost is comparable to other countries worldwide outside Europe. Cost of RARC in the USA varies between 12.792€ and 31.631€ in different published studies in the literature [1,7,10,11,16,20]. This cost is quite comparable to Europe in some centers while it is much more expensive in others. Su et al. have shown that mean cost of RARC in China is 13.404€ [21], which is quite comparable to our European results.

Remarkably, in our study, in one center in Netherlands, total cost of RARC averaged 16.635€. In contrast, Michels et al. have evaluated the cost of RARC in 19 Dutch hospitals, and concluded that the mean cost of RARC per patient is 21.266€ (19.163€–23.650€), with a mean cost difference of 4.125€ compared to open radical cystectomy (17.141€ (15.791€–18.720€)) [13]. A possible reason for this difference is that Michels et al. included different parameters in their cost-analysis, which we did not include in ours, such as number of surgeons, additional imaging and recurrences. Also, Bansal et al. showed that mean cost for RARC in a tertiary care center in the UK is 12,449£, which equals approximately to 14,480€ [15]. This cost is quite comparable to UK's results in our study.

Since a significant difference ($p < 0.001$) was found in our study for type of urinary diversion between the different countries, one might think that this could have accounted for the difference of total cost of RARC between included countries. However, this is not completely true according to our results: French centers, which had the highest rate of neobladder reconstruction (49.4%), also had the lowest total cost for RARC (11.920€).

As for subcost analysis, cost of hospital stay varied in the literature between 3.886 and 5.195€ [15–17]. It seems a bit higher in our study (6.203€, ranging between 5.101 and 6.973€). Only the UK's cost of hos-

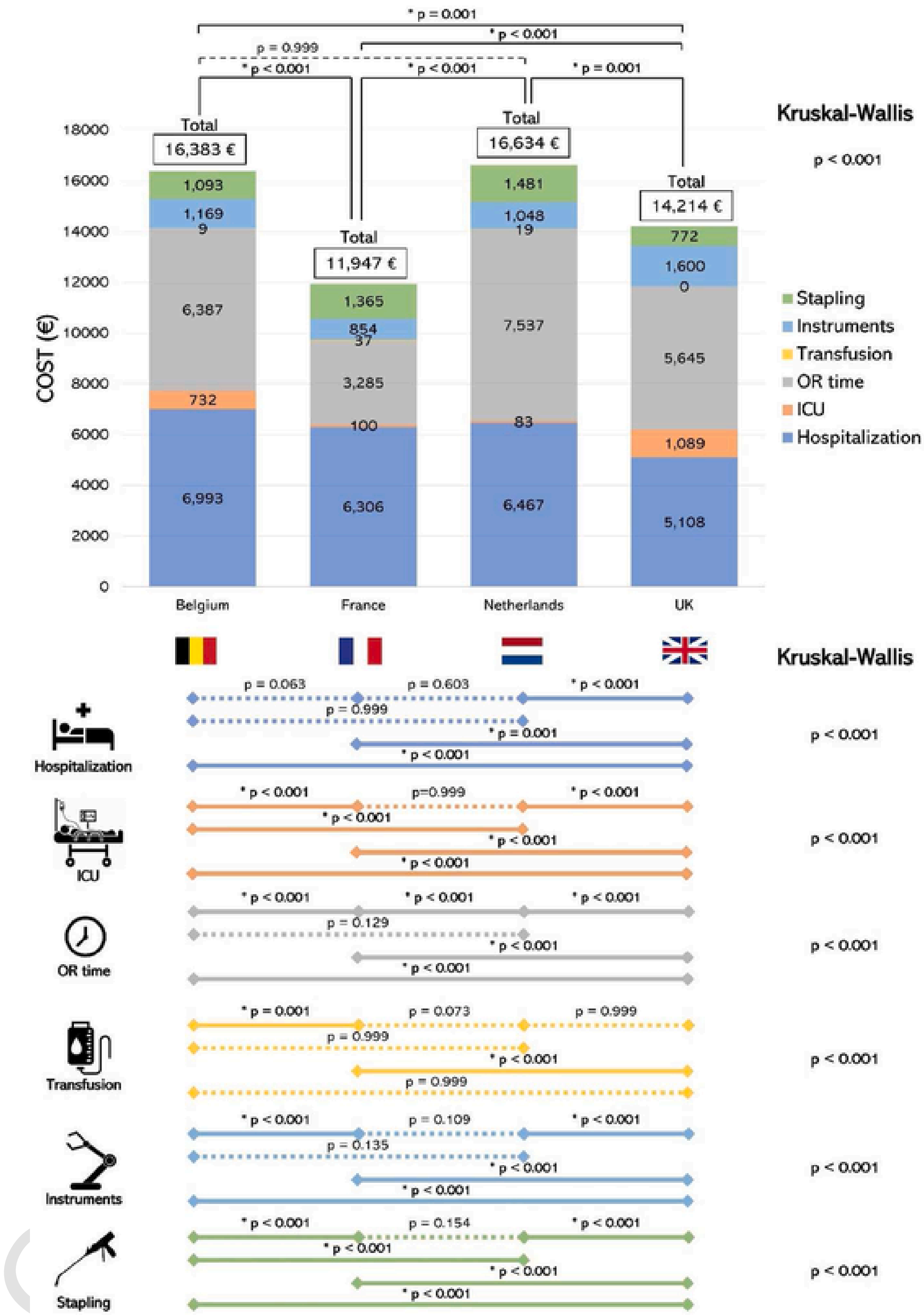

Fig. 2. Comparison of costs and subcosts of robot-assisted-radical cystectomy between included European countries (Belgium, France, Netherlands and UK). Cost data from UK were converted from british currency to euros at the mean exchange rate for 2021 (1£ = 1.1632€). OR = Operative Room. ICU = Intensive Care Unit.

pital stay falls into the literature range (Bansal et al.'s study [15] was done in the UK) while Belgium, France and the Netherlands seem to be higher. The reason behind this may be due to higher length-of-stay in European centers (11 days in our study) compared to some American centers (4.7–5.5 days [16,17]). However, we should note that other American centers have a comparable length-of-stay (7–12 days) [7,11,22,23].

Cost of ICU stay was shown to be different along some of the included countries. This is clearly because (1) some centers admit post-operatively all their patients in the ICU, while others do not, and (2) the cost for an ICU stay differs between the different centers. Except for rare

Table 2
Average cost distribution for robot-assisted radical cystectomy with intracorporeal urinary diversion globally in Europe, and specifically in each country included in the study.

		Belgium	France	Netherlands	UK	Average
Hospitalization	Mean ± SD	6993€ ± 4029€	6306€ ± 4324€	6467€ ± 3358€	5108€ ± 3492€	**6218€** ± 3976€
	95% CI	6370€ - 7620€	5630€ - 6990€	5675€ - 7259€	4520€ - 5850€	5870€ - 6570€
ICU	Mean ± SD	732€ ± 1658€	100€ ± 984€	83€ ± 685€	1089€ ± 333€	**501€** ± 1206€
	95% CI	475€ - 989€	−54€ - 255€	−82€ - 247€	1030€ - 1150€	394€ - 608€
OR time	Mean ± SD	6387€ ± 1550€	3285€ ± 937€	7537€ ± 2224€	5645€ ± 1410€	**5713€** ± 2136€
	95% CI	6150€ - 6630€	3140€ - 3430€	7003€ - 8071€	5380€ - 5910€	5520€ - 5900€
Transfusion	Mean ± SD	9€ ± 53€	37€ ± 111€	19€ ± 93€	0€ ± 0€	**16€** ± 79€
	95% CI	1€ - 17€	19€ - 54€	−3.8€ - 40€	–	9€ - 23€
Robotic instruments	Mean ± SD	1169€ ± 266€	854€ ± 311€	1048€ ± 0€	1600€ ± 242€	**1167€** ± 373€
	95% CI	1130€ - 1210€	805€ - 903€	–	1550€ - 1650€	1130€ - 1200€
Stapling	Mean ± SD	1093€ ± 422€	1365€ ± 463€	1481€ ± 373€	772€ ± 205€	**1177€** ± 464€
	95% CI	1030€ - 1160€	1290€ - 1440€	1391€ - 1570€	733€ - 811€	1140€ - 1220€
TOTAL COST	Mean ± SD	**16383€** ± 4889€	**11947€** ± 5106€	**16635€** ± 4262€	**14214€** ± 3757€	**14794€** ± 5040€
	95% CI	15600€ - 17100€	11100€ - 12800€	15629€ - 17640€	13500€ - 14900€	14300€ - 15200€

cases of extremely comorbid patients or major intraoperative adverse events, most patients undergoing RARC + ICUD should not be admitted to the ICU for standard post-operative surveillance.

This highlights the importance of Enhanced Recovery after Surgery (ERAS) protocols which constitute a safe alternative in order to decrease hospital length of stay and ICU stay after radical cystectomy [24], contributing therefore to the decrease in the cost of RARC.

Cost for operative time varied in the literature between 8.383 and 12.809€ [15–17]. It seems much lower in our study (3.296–7.537€). Operative time may not explain this difference since it is comparable between US and European centers. However, when we see the comparison between the different countries included, whenever there is a significant difference in operative time between two countries, there is also a significant difference in the cost for this operative time (except for France vs. UK).

As for cost of robotic instruments, our study is the first to highlight the difference in the set and types of instruments used, and the impact this has on the difference of cost for robotic instruments. While the set of instruments is dependent on the habits of each center, standardizing instrumentation can reduce cost. For example, the vessel sealer was used in 5/11 included centers in our study. Cost of robotic instruments decreased by half when avoiding to use the vessel sealer (≈1300€ when used vs. ≈670€ when not used(Fig. 1)). Another example is the use of two needle holders rather than one in 5/11 included centers. RARC can be efficiently performed with only four robotic instruments, including one needle holder and no vessel sealer [18]. However, in the present study we report that total cost of robotic instruments is inversely correlated to bleeding, complications and grade of complications. To be precise, the use of a vessel sealer in particular was inversely correlated to surgical outcomes as well. These surgical outcomes have a significant impact on our patients, and on the potential incremental costs due to complications, and as we demonstrated that the robotic instrumentation is responsible for $<10\%$ of total gross cost, it should be clear that patient safety should not be endangered to avoid using an extra robotic instrument or an advanced coagulation device in necessary. All in all, surgeons should keep in mind that the cost of the single robotic instrument outweighs higher costs of the procedure as a whole.

Finally, as for cost of stapling instruments, there was a significant difference between nearly all the included countries. These differences can be explained by: (1) a significant difference between types of urinary diversion between countries translating into a difference in number of staple throws as mentioned previously, and (2) type of stapling, robotic or laparoscopic, the latter being more expensive. Using robotic stapling rather than laparoscopic stapling could therefore also decrease cost of RARC. We might think that bulk purchase of laparoscopic staplers – since they are used also by other specialties such as general and

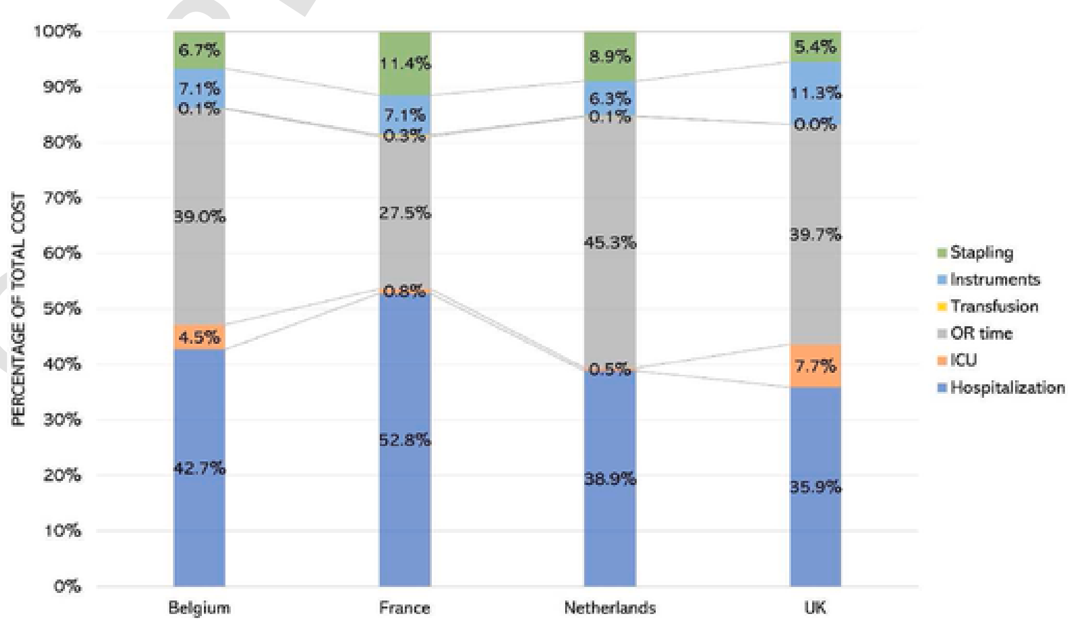

Fig. 3. Comparison of proportions of subcosts of RARC among the four included European countries (Belgium, France, Netherlands and UK).

gastrointestinal surgeons – in a deal with the provider, would reduce the cost of laparoscopic stapling. However, robotic surgery is more and more used by other surgical specialties as well, and the principle of bulk purchase applies also for the robotic instruments, including robotic staplers.

As for proportions of subcosts, hospital stay cost accounted for 26–30.2% in the literature [15–17], operative time costs for 63.1–70.5% [15–17], and robotic instruments for 2.3–8.4% [15,17]. Similar results were found by Martin et al. [25]. The results of our study corroborate these findings and confirm that the cost of RARC is mostly due to hospital stay and operative time rather than robotic instruments.

As a brief sum up, costs of RARC can be reduced in different ways: (1) decreasing hospital length-of-stay (ERAS protocols), (2) avoiding to admit fit patients post-operatively to ICU systematically, (3) decreasing operative time by the means of trained and experienced surgeons, (4) avoiding use of an excessive number of robotic instruments, and (5) using robotic rather than laparoscopic stapling. These measures would eventually make RARC more widely accessible from an economic perspective.

This study is however not devoid of limitations. First, we did not include the total price of purchase cost, amortization cost and annual maintenance cost. These costs are quite similar between the different countries for the same number of operated patients and including these costs while not taking into consideration the volume of each center is a sampling bias. Moreover, we did not include the cost of complications. Leow et al. found that cost of radical cystectomy in general is mostly dependent from postoperative morbidity and patient comorbidities, and that other hospital and surgical-related characteristics, especially robotic assistance, are less likely to contribute to outlier costs [10]. This shows a real interplay between costs and complications. However, we have included this aspect indirectly by counting the prolongation of hospital stay, cost of readmission, and ICU admission for grade≥4 complications. Further studies are underway to assess the utility of the Comprehensive complication index on hospitalization costs [26]. Another limitation is that only one center from the Netherlands was included. This implicates that the Dutch figures represent average costs from a tertiary referral hospital, rather than the average costs of RARC in the Netherlands in general. The cost was the lower in France; however two private centers were included in the analysis with well known lower costs which may have dragged the cost down for the country. However, when excluding these two centers from the analysis, similar results were obtained. Finally, regarding instrument and stapling costs, we are aware that each hospital negotiates with the providers a cost, also based on volume of business; however, we decided to use listing prices for Europe.

5. Conclusion

The cost of RARC + ICUD varies significantly across European countries. Costs of hospital stay and operating theater occupation account for the vast majority of this price. By improving surgical training and standardizing surgical technique and enhancing post-operative management, these variables can be reduced with a consequent reduction in cost, which would make RARC + ICUD a more widely accessible procedure.

Funding

This study did not receive any funding

Data availability statement

Data available upon request from corresponding author.

CRediT authorship contribution statement

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Declaration of competing interest

Guillaume Ploussard: COI with Intuitive®. The rest of co-authors have no conflict-of-interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejso.2022.07.023.

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