



# Introducing robotic surgery into an endometrial cancer service—a prospective evaluation of clinical and economic outcomes in a UK institution

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## Abstract

**Background** We have assessed how the introduction of robotics in a publicly funded endometrial cancer service affects clinical and economic outcomes.

**Methods** The study included 196 women. Costs were divided into those for wards, high dependency, staffing, theatres, pharmacy, blood products, imaging, pathology and rehabilitation. Capital depreciation was included.

**Results** Prior to the introduction of robotics, 78/130 (60.0%) cases were performed open, compared to 17/66 (25.8%) afterwards ( $p < 0.0001$ ). The median operative time increased 37 min (95% CI 17–55 min;  $p = 0.0002$ ); the median blood loss was 55 ml lower (95% CI 0–150 ml;  $p = 0.0181$ ); the stay was 2 days shorter (95% CI 1–3;  $p < 0.0001$ ). Complications reduced from 64/130 (49.2%) to 19/66 (28.8%) ( $p = 0.0045$ ). Costs reduced from £11 476 to £10 274 ( $p = 0.0065$ ). Conversions for 'straight stick' surgery were 18.2% (14/77) compared to 0.0% (0/24) for robotics ( $p = 0.0164$ ).

**Conclusions** Introducing robotics resulted in fewer laparotomies, shorter stays, fewer complications and lower costs. © 2015 The Authors. *The International Journal of Medical Robotics and Computer Assisted Surgery* Published by John Wiley & Sons Ltd.

**Keywords** laparoscopy; endometrial cancer; robotic surgery; complications; economic evaluation

## Introduction

Robotic surgery using the da Vinci<sup>®</sup> robot (Intuitive Surgery Inc., CA, USA) has been advocated for endometrial cancer. However, it is perceived by many as resulting in increased costs compared to surgery without the robot, and offering no clinical benefit when compared directly with laparoscopic surgery using straight instruments ('straight sticks') (1). One study looked at the effect on a whole service rather than a direct comparison of the routes of surgery, and this showed both a financial and clinical advantage to an institution by introducing robotics into their service (2).

To date, no study has assessed the financial and clinical effect of introducing robotics into the UK National Health Service. Furthermore, most studies have

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assessed the effect of introducing robotics into a team of novices at robotic surgery and are biased by a learning curve. We have assessed the economic and clinical outcomes of introducing robotics into our service, using a theatre team that was already experienced in robotic surgery and a surgeon already experienced in robotic surgery at another institution.

## Methods

An independent financial audit was undertaken for endometrial cancer surgery in the period 1 January 2010–31 December 2013, during which robotic surgery was introduced into the service on 28 September 2012. Patients receiving primary surgery for endometrial cancer were identified using a prospectively collected surgical database. Clinical data was collected from this database and cross-reference against the hospital's electronic patient record (EPR), which included clinical and operative notes. The EPR system also contained a preoperative anaesthetic assessment, which included a thorough systematic clinical history, microbiological records, blood transfusion records, histopathology, cytopathology, haematology and biochemistry results. All clinical documentation for patients was reviewed for Clavien–Dindo (3) grade II complications and above for 30 days following surgery.

Costs were assessed independently of the clinicians by the hospital's finance department. These were allocated into one of nine categories. They included costs for ward, high-dependence care, medical staffing, theatres, drugs and pharmacy, blood products, imaging, pathology and rehabilitation therapy. The exact allocation of different costs into each of these categories is detailed in Table S1 (see supporting information). Included in the above cost categories was also an element of overheads. The allocation of overheads into each category is detailed in Table S2 (see supporting information).

The hospital already had a da Vinci robot that was initially purchased for urological surgery and was not being used on one of the days the gynaecological oncology team was operating. Furthermore, it was donated to the hospital by a charity, so the total cost of robotic surgery was only a marginal cost to the hospital. To take this into account, all costs to the hospital are presented twice, once as costs without the robot, and secondly including costs that would have occurred from depreciation of the da Vinci robot. As laparoscopic surgery was performed in an integrated operating theatre (OR1™ Storz, Stuttgart, Germany), a similar capital depreciation was added to straight stick cases. Costs including these depreciations are presented and include an additional £25.80/case for straight stick laparoscopic operations, and £598.02/case for robotic procedures, based

on the total annual depreciation and number of patients in the time period that utilized the capital equipment. Depreciation was calculated over a 10 year period.

The Royal Marsden Hospital is a tertiary referral centre that does not assess patients with postmenopausal bleeding. The service consists of a network of a further eight hospitals in the region and the Channel Isles that refer only patients with high-risk pathology or those with a high-risk co-morbidity. All operations included a hysterectomy and removal of the Fallopian tubes and ovaries. It is policy to perform a limited pelvic lymphadenectomy in patients with more than grade 1 or stage 1a disease, although it is often not performed on an individual basis in patients who are elderly or who have excess co-morbidity. It is not common practice in the institution, nor in the UK, to perform para-aortic lymphadenectomy routinely for women with endometrial cancer. Robotic cases were performed with two rather than three 8 mm operating arms, a 12 mm umbilical port for the camera and a 5 mm portside assistant's port. Lymph nodes and other specimens were retrieved through the vagina. Lymph nodes were normally placed in a bag prior to retrieval. Laparoscopic cases were performed with two 12 mm ports centrally and two 5 mm ports laterally. In the majority of cases, the main specimen was retrieved through the vagina and lymph nodes were placed in bags and retrieved through the suprapubic 12 mm port. The allocation of a patient to an open or minimal access technique was chosen by the lead surgeon and was normally based on surgical factors, such as uterine size, previous laparotomy, the presence of an incisional hernia and body mass index (BMI). When the robot became available, the two surgeons who had robotic training were able to use the equipment to enable a minimal access technique if they felt it would be preferable to straight stick surgery. No specific rules were set within the department but each case was discussed in a multidisciplinary meeting.

Dichotomous data were analysed using Fisher's exact test (FET). Continuous data were assessed for normality using the Shapiro–Wilks test and, as most series were significantly different from a normal distribution, data were presented as medians with a range and comparisons were made using the Mann–Whitney test. The project had ethical approval as a service evaluation project from the Royal Marsden Committee on Clinical Research (SE314).

## Results

A total of 196 procedures were included in the analysis, with 130 performed prior to the introduction of robotics and 66 after. This included 95 open cases, 77 straight stick

cases and 24 robot-assisted laparoscopies. The median age of women in the series was 65.8 (range 38.8–89.7) years. There was no significant difference in age between the routes of surgery and the period before and after the introduction of robotics. Prior to the introduction of robotic surgery, 78/130 (60.0%) of cases were performed by open laparotomy. This reduced to 17/66 (25.8%) of cases after the introduction of the robot surgery [Fisher's exact test (FET):  $p < 0.0001$ ] (Figure 1). The proportion of straight stick cases did not decrease with the introduction of robotics (Figure 1).

The median BMI increased from 30.2 (range 18.3–59.8) before the introduction of robotic surgery to 33.0 (range 18.0–56.6) after the introduction of robotics ( $p = 0.0492$ ; median difference 2.5; 95% CI 0.0–4.8). The median BMI for open cases was 29.5 (range 18.3–52.5), for straight stick cases 31.3 (range 18.7–59.8) and for robotic cases 36.2 (range 18.0–56.6). These data represent a significantly higher BMI for robotic cases compared to open ( $p = 0.0074$ ; median difference 5.7; 95% CI 1.8–10.0).

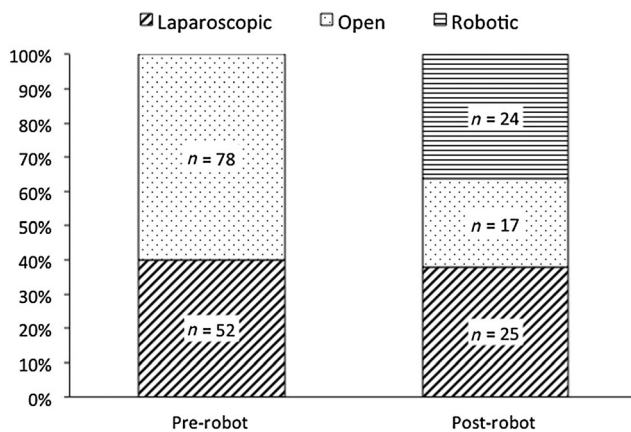


Figure 1. The proportion of women receiving open, straight stick and laparoscopic surgery before and after the introduction of robotics

There was also a significantly higher BMI for straight stick cases compared to open ( $p = 0.0432$ ; median difference, 4.2; 95% CI 0.2–9.1). There was no significant difference between the BMIs of robotic and straight stick cases.

The distribution of surgical and medical co-morbidity between different routes, as well as before and after introduction of the robot, was introduced is detailed in Table S3 (see supporting information). Only 26/196 (13.3%) of cases had either no surgical or medical co-morbidity. The surgical stages and histology between all the groups is presented in Table S4 (see supporting information).

Prior to the introduction of robotics, the median total cost/case was £11 463 (range £3062–34 276). This is compared to £10 048 (range £4192–17 306) after the introduction of robotics (Table 1). The total cost including the calculated depreciation was £11 476 (range £3088–34 276) prior to the introduction of robotics, compared to £10 274 (range £4402–17 306) afterwards (Table 1). Costs were significantly lowered after the introduction of robotics for ward/clinic expenses and for rehabilitation therapy, but not for medical staffing, theatre, drugs, blood products, imaging, pathology and high dependency (Table 1).

Comparing the different routes of surgery, the total costs/procedure were cheapest for robotic cases (median £7883; range £4192–14 813) compared to open (median £12 462; range £5736–34 276) and straight stick (median £9953; range £3062–12 533) (Table 2). Straight stick surgery was also cheaper than open surgery (Table 2). Similar findings existed for the total expenses when including the estimated depreciation costs for the robot and integrated theatre (Table 2).

Clinical outcomes before and after the introduction of the robotics are reported in Table 3. After robotics was introduced, the median operative time increased by 43 min (95% CI 17–55 min;  $p = 0.0002$ ) (Table 3). The median difference in estimated blood loss was 50 ml lower (95% CI 0–150 ml;  $p = 0.0181$ ) and the median stay was 2 days shorter (95% CI 1–3;

Table 1. Cost of primary surgery for endometrial cancer before and after the introduction of robotics

	Pre-robot Median (range)	Post-robot Median (range)	All cases Median (range)	Comparison Mann–Whitney $p$ (median difference: 95% CI)
Ward/clinic costs (£)	3391 (641–14 303)	1585 (380–4410)	2631 (380–14 303)	$p < 0.0001$ (1528: 1070–2021)
Medical staffing costs (£)	2153 (143–7936)	2322 (73–5811)	2182 (73–7936)	NS (11: –304 to 349)
Theatre costs (£)	2325 (917–5264)	2476 (599–4722)	2355 (599–5264)	NS (118: –45 to 279)
Drugs/pharmacy costs (£)	150 (16–5178)	139 (7–579)	147 (7–5178)	NS (18: –12 to 49)
Blood products costs (£)	0 (0–490)	0 (0–588)	0 (0–588)	NS (0: 0–0)
Imaging costs (£)	54 (0–893)	133 (0–602)	71 (0–893)	NS (0: 0–55)
Pathology costs (£)	614 (35–1804)	585 (35–1134)	605 (35–1804)	NS (41: –23 to 105)
Rehabilitation therapy costs (£)	198 (0–3582)	0 (0–8174)	153 (0–8714)	$p < 0.0001$ (84: 41–158)
High-dependency care costs (£)	2830 (0–9639)	2560 (0–5222)	2830 (0–9639)	NS (270: –128 to 270)
Total cost (£)	11 463 (3062–34 276)	10 048 (4192–17 306)	11 115 (3062–34 276)	$p = 0.0021$ (1707: 638–2745)
Cost including depreciation (£)	11 476 (3088–34 276)	10 274 (4402–17 306)	11 124 (3088–34 276)	$p = 0.0065$ (1470: 441–2478)

NS, not significant.

Table 2. Cost of primary surgery for endometrial cancer by route

	Open (Op) Median (range)	Straight sticks (SS) Median (range)	Robot (Ro) Median (range)	Comparison Mann–Whitney <i>p</i> (median difference: 95% CI)
Ward/clinic costs (£)	3739 (816–14 303)	1889 (380–5399)	1428 (662–2843)	Ro vs Op: <i>p</i> < 0.0001 (2289: 1681–2988) Ro vs SS: <i>p</i> = 0.0009 (577: 225–996) SS vs Op: <i>p</i> < 0.0001 (1625: 1169–2094)
Medical staffing costs (£)	2185 (143–7936)	2272 (73–5932)	1998 (119–3483)	Ro vs Op: <i>p</i> = 0.0533 (390: –5 to 1037) Ro vs SS: <i>p</i> = 0.0436 (495: 19–1140) SS vs Op: NS (66: –252 to 404)
Theatre costs (£)	2282 (599–5264)	2565 (599–4722)	2280 (599–3247)	Ro vs Op: NS (48: –204 to 265) Ro vs SS: NS (260: –14 to 495) SS vs Op: <i>p</i> = 0.0042 (213: 66–372)
Drugs/pharmacy costs (£)	201 (28–5178)	101 (10–1845)	119 (7–282)	Ro vs Op: <i>p</i> < 0.0001 (89: 45–136) Ro vs SS: NS (5: –42 to 29) SS vs Op: <i>p</i> < 0.0001 (87: 60–118)
Blood products costs (£)	0 (0–588)	0 (0–246)	0 (0–120)	Ro vs Op: NS (0: 0–0) Ro vs SS: NS (0: 0–0) SS vs Op: <i>p</i> = 0.0002 (0: 0–0)
Imaging costs (£)	102 (0–893)	7 (0–589)	0 (0–133)	Ro vs Op: <i>p</i> = 0.0075 (22: 0–102) Ro vs SS: NS (0: 0–7) SS vs Op: <i>p</i> = 0.002 (16: 0–71)
Pathology costs (£)	692 (80–1804)	544 (35–1383)	141 (35–815)	Ro vs Op: <i>p</i> < 0.0001 (265: 157–434) Ro vs SS: NS (83: –12 to 215) SS vs Op: <i>p</i> < 0.0001 (165: 112–220)
Rehabilitation therapy costs (£)	287 (0–8714)	31 (0–922)	0 (0–287)	Ro vs Op: <i>p</i> < 0.0001 (262: 189–309) Ro vs SS: <i>p</i> = 0.0242 (0: 0–79) SS vs Op: <i>p</i> < 0.0001 (211: 161–264)
High-dependency care costs (£)	2830 (0–8488)	2561 (0–9639)	2213 (0–5222)	Ro vs Op: <i>p</i> = 0.0327 (617: 0–1723) Ro vs SS: NS (270: –178 to 617) SS vs Op: <i>p</i> = 0.0263 (270: 0–617)
Total cost (£)	12 462 (5736–34 276)	9953 (3062–12 533)	7883 (4192–14 813)	Ro vs Op: <i>p</i> < 0.0001 (4668: 3247–5954) Ro vs SS: <i>p</i> = 0.0021 (2099: 768–3360) SS vs Op: <i>p</i> < 0.0001 (2601: 1557–3532)
Cost including depreciation (£)	12 462 (5736–34 276)	9979 (3088–21 215)	8481 (4790–15 411)	Ro vs Op: <i>p</i> < 0.0001 (4070: 2649–5356) Ro vs SS: <i>p</i> = 0.0284 (1527: 196–2788) SS vs Op: <i>p</i> < 0.0001 (2575: 1531–3506)

NS, not significant.

*p* < 0.0001) (Table 3). The overall complication rate prior to the introduction of robotics was 64/130 (49.2%) compared to 19/66 (28.8%) afterwards (FET: *p* = 0.0045) (Table 3). No single complication was less common after the introduction of robotics, other than wound complications, which occurred in 17/30 (13.1%) cases before and 2/66 (3.0%) cases afterwards (FET: *p* = 0.017) (Table 3).

A comparison of clinical outcomes between robotic, straight stick and open surgery is given in Table 4. There was no difference in operative time between robotic and open surgery, although straight stick surgery was a median of 50 min longer compared to open (95% CI 25–65; *p* < 0.0001) (Table 4). Robotic surgery was associated with the shortest stay in hospital, the least high-dependency care usage, the lowest estimated blood loss and the least post-operative drop in haemoglobin (Table 4). Many parameters were statistically better for the robotic approach than for both straight stick and open surgery (Table 4). The conversion rate for straight stick surgery was 18.2% (14/77) compared to 0.0% (0/24) for robotic surgery (FET: *p* = 0.0164)

(Table 4). Specifically, there were more urinary tract infections, wound infections and blood transfusions in open procedures compared to straight stick or robotic ones (Table 4).

## Discussion

These data demonstrate an overall cost saving, shorter hospital stay and lower complications in a UK National Health Service institution when robotic surgery was introduced into the endometrial cancer service. The main area of cost savings occurred in ward expenses, but a significant difference was also demonstrated in rehabilitation services, such as physiotherapy and occupational health. Wound complications were lowered in particular, but it was also noted that robotic surgery resulted in fewer conversions to laparotomy than straight stick laparoscopy. Furthermore, there was a significant shift towards minimal access techniques with the introduction of robotics, resulting in the shorter hospital stays.

Table 3. Outcomes following primary surgery for endometrial cancer before and after the introduction of robotics

	Pre-robot	Post-robot	All cases	Mann-Whitney <i>p</i> (median difference: 95% CI) or Fisher's exact test (FET)
Operative time (min), median (range)	185 (75–430)	228 (120–585)	194 (73–585)	<i>p</i> = 0.0002 (37: 17–55)
High-dependency postop. care, <i>n/N</i> (%)	112/130 (86.1)	57/66 (86.4)	169/196 (86.2)	FET NS
Estimated blood loss (ml), median (range)	250 (50–3700)	200 (0–1200)	250 (0–3700)	<i>p</i> = 0.0181 (55: 0–150)
Drop in Hb (g/l), median (range)	21 (–18 to 58)	19 (–5 to 38)	20 (–18 to 58)	NS (3: –1 to 6)
Number of days stay, median (range)	5 (1–26)	3 (1–8)	4 (1–26)	<i>p</i> < 0.0001 (2: 1–3)
Any complication, <i>n/N</i> (%)	64/130 (49.2)	19/66 (28.8)	83/196 (42.4)	FET <i>p</i> = 0.0045
Urinary tract infection, <i>n/N</i> (%)	31/130 (23.8)	13/66 (19.7)	44/196 (22.4)	FET NS
Wound infection, <i>n/N</i> (%)	17/130 (13.1)	2/66 (3.0)	19/196 (9.7)	FET <i>p</i> = 0.0177
Blood transfusion, <i>n/N</i> (%)	29/130 (22.3)	8/66 (12.1)	37/196 (18.9)	FET NS
Other complications, <i>n/N</i> (%)	24/130 (18.5)	5/66 (7.6)	29/196 (14.8)	FET <i>p</i> = 0.0308
Ileus	5	1	6	
Pyrexia of unknown origin	3	0	3	
<i>Clostridium difficile</i>	2	0	2	
Chest infection	4	0	4	
Arrhythmia	2	1	3	
Severe constipation	1	0	1	
MRSA	1	0	1	
Vascular injury	2	0	2	
Septicaemia	1	0	1	
Urine retention	0	2	2	
Bladder injury	1	0	1	
Vault bleeding	1	0	1	
Acute tubular necrosis	1	0	1	
Bowel serosa tear	0	1	1	

This study is the first to report on the impact of introducing robotics into an endometrial cancer service in a UK tertiary referral cancer centre, although similar results have been reported in Canada (2) and the USA (4). Whereas some studies have compared the eventual routes of surgery (2,4), this study reports on the impact to a whole service and therefore takes into account the differences in the proportion of patients receiving each route of surgery after robotics are introduced, the hypothesis being that a reduction in the proportion of women having open surgery would impact on costs and complications.

As an observational study, the comparisons do not take into account the extrinsic differences before and after the introduction of robotic surgery. For example, five consultants performed open and straight stick surgery, whereas only two used the robot. No correction was made for inflation, as this would have biased the results towards the post-robotic arm of the study.

Cost analyses can take into account many aspects of the expense of health care. This study looked at the institutional costs for a surgical procedure, which were assessed independently by the hospital's finance department. It did not take into account the costs of subsequent treatment for recurrence, as this is unknown. Furthermore, the societal costs are not assessed in this study.

In this study, the costs were reduced secondary to a shorter hospital stay and therefore fewer ward and clinical expenses. This was predominantly secondary to the

reduction in the number of open operations performed as a result of the introduction of robotics.

The data are consistent with one other study that has compared the costs and outcomes of a whole service after introducing robotics, rather than just a straight comparison of the different routes (2). In that study (2), there was also a reduction in complications, costs and hospital stay, in addition to a significantly lower proportion of open cases, once robotics was introduced into their institution. Another more recent study has also demonstrated comparable costs (4).

When comparing specific routes of surgery, other papers have demonstrated a greater cost for robotics compared to straight sticks for endometrial cancer (1,5–9). In our study there was a small saving. Possible causes for these differences may relate to surgical experience, the different surgeons, and use of consumables. In early papers looking at finances, the data were biased by inexperienced surgeons in the robotic arms. In this paper, robotic surgery was introduced by a surgeon experienced in over 100 procedures, with a theatre team experienced in robotic urological surgery. Therefore, the data were not affected by the learning curve. In this study, only two surgeons performed robotic surgery, yet all five performed straight stick and open surgery, and the diversity of surgeons in each arm might have influenced the results. The final reason why robotics was cheaper in this study compared to others is that the cases utilized only two operating arms of the robot. This is likely to be cheaper

Table 4. Outcomes following primary surgery for endometrial cancer by route

	Open (Op)	Straight sticks (SS)	Robot (Ro)	Mann–Whitney <i>p</i> (median difference: 95% CI) or Fisher's exact test (FET)
Operative time (min), median (range)	180 (75–430)	230 (78–585)	192 (130–306)	Ro vs Op: NS (18: –8 to 45) Ro vs SS: NS (25: –5 to 55) SS vs Op: <i>p</i> < 0.0001 (45: 25–65)
High-dependency postoperative care, <i>n/N</i> (%)	90/95 (94.7)	62/77 (80.5)	17/24 (70.8)	Ro vs Op: FET <i>p</i> = 0.0024 Ro vs SS: FET NS SS vs OP: FET <i>p</i> = 0.0072
Estimated blood loss (ml), median (range)	400 (50–3700)	200 (50–850)	100 (0–250)	Ro vs Op: <i>p</i> < 0.0001 (300: 200–500) Ro vs SS: <i>p</i> = 0.0158 (50: 0–100) SS vs OP: <i>p</i> < 0.0001 (200: 150–350)
Drop in Hb (g/l), median (range)	23 (–8 to 58)	19 (–18 to 41)	17 (0–33)	Ro vs Op: <i>p</i> = 0.0045 (7: 2–12) Ro vs SS: NS (4: 0–8) SS vs OP: NS (3: 0–6)
Number of days stay, median (range)	6 (3–26)	3 (1–11)	2 (1–4)	Ro vs Op: <i>p</i> < 0.0001 (4: 3–5) Ro vs SS: <i>p</i> = 0.0031 (1: 0–2) SS vs OP: <i>p</i> < 0.0001 (3: 3–4)
Conversion to laparotomy, <i>n/N</i> (%)	NA	14/77 (18.2)	0/24 (0.0)	Ro vs SS: FET <i>p</i> = 0.0164
Any complication, <i>n/N</i> (%)	59/95 (62.1)	23/77 (29.9)	1/24 (4.2)	Ro vs Op: FET <i>p</i> < 0.0001 Ro vs SS: FET <i>p</i> = 0.0061 SS vs OP: FET <i>p</i> < 0.0001
Urinary tract infection, <i>n/N</i> (%)	30/95 (31.6)	14/77 (18.2)	0/24 (0.0)	Ro vs Op: FET <i>p</i> = 0.0004 Ro vs SS: FET <i>p</i> = 0.0164 SS vs OP: FET <i>p</i> < 0.033
Wound infection, <i>n/N</i> (%)	15/95 (15.8)	4/77 (5.2)	0/24 (0.0)	Ro vs Op: FET <i>p</i> = 0.0267 Ro vs SS: FET NS SS vs OP: FET <i>p</i> = 0.0227
Blood transfusion, <i>n/N</i> (%)	36/95 (37.9)	0/77 (0.0)	1/24 (4.2)	Ro vs Op: FET <i>p</i> = 0.0006 Ro vs SS: FET NS SS vs OP: FET <i>p</i> < 0.0001
Other complications, <i>n/N</i> (%)	18/95 (18.9)	11/77 (14.3)	0/24 (0.0)	Ro vs Op: FET <i>p</i> = 0.012 Ro vs SS: FET <i>p</i> = 0.042 SS vs OP: NS
Ileus	5	1	0	
Pyrexia of unknown origin	3	0	0	
<i>Clostridium difficile</i>	2	0	0	
Chest infection	2	2	0	
Arrhythmia	1	2	0	
Severe constipation	1	0	0	
MRSA	1	0	0	
Vascular injury	1	1	0	
Septicaemia	1	0	0	
Urine retention	1	1	0	
Bladder injury	0	1	0	
Vault bleeding	0	1	0	
Acute tubular necrosis	0	1	0	
Bowel serosa tear	0	1	0	

in terms of consumables compared to other reports, in which four arms were used.

These data assessed the specific costs of surgery and did not look at societal costs, such as time off work. These have been reported in two studies (5,6). One found robotic surgery to be cheaper than open surgery (6) and another more expensive, but with narrowing of cost differences once societal expenses were included (5).

Comparisons between each individual route, although valuable, distract from the cost evaluation of how finances change with the introduction of robotics, which is what institutions experience. This is the reason why selection of cases into open or laparoscopic arms (straight stick or robot) is not understood. This study and one other (2) have demonstrated a lower utilization of open surgery

with the introduction of robotics. Many randomized studies have demonstrated that a minimal access approach to endometrial cancer compared to open is associated with fewer complications and a shorter hospital stay (10). Therefore, if robotics reduces the proportion of women having open surgery, then there is a benefit. In this study, the proportion of women having straight stick surgery was the same before and after the introduction of robotics, and therefore the conversion to robotics was from patients who would otherwise have had open surgery.

One notable difference between robotic and straight stick surgery in this study was the difference in conversion rate to open laparotomy. The rate of 18% is high compared to many reports for straight stick surgery and endometrial cancer (11) but lower than that reported in

the large GOG-Lap2 study (12). As the centre was only referred patients with high-stage disease or high medical or surgical co-morbidity, it is not unexpected that the conversion rate for straight stick surgery is at the higher end of the distribution in the reported literature. A significantly lower conversion rate for robotic compared to straight stick surgery in this study is consistent with that reported by others (13–15).

## Conclusion

Our data show that the introduction of robotics into the endometrial cancer service in our institution was associated with a shorter hospital stay and fewer costs and complications. There was a significant reduction in resource to open surgery with use of the robot, either by elective laparotomy or by converting an intended minimal access case.

## Author contributions

T.I. conceived the project, wrote the first draft of the protocol, collected clinical data, performed surgical procedures, analysed the data and wrote the first draft of the article. C.M. collected financial data, devised the method for financial data collection, contributed to the analysis of results and helped in the revision of the manuscript. M.H. helped device the protocol, was the anaesthetist for the project and helped in the revision of the protocol. L.B. contributed to development of the project, the writing of the protocol and the final manuscript. D.B. contributed to the surgical procedures, collection of data and revision of the manuscript. J.B. contributed to the surgical procedures, collection of data and revision of the manuscript. J.S. contributed to the development of the project, surgical procedures, collection of data and revision of the manuscript. M.N. contributed to development of the project, writing of the protocol, submission through ethics, performing surgical procedures, collection of the data and revision of manuscript.

## Conflict of interest

In 2007, Thomas Ind and John Shepherd received 2 days of practical training in robotic surgery. This included premium economy class travel to the USA and accommodation costs paid for, and organized by, Intuitive Surgical Inc. (CA, USA). Intuitive Surgical also sponsored a day's preceptorship for Marielle Nobbenhuis and Thomas Ind at the Royal Marsden Hospital in

2013. In May 2014, both Marielle Nobbenhuis and Thomas Ind received a day of training in Germany (including travel and accommodation) sponsored by Intuitive Surgical; neither robotic surgeon has worked for Intuitive Surgical as a proctor. Thomas Ind is an officer of both the British and Irish Association of Robotic Gynaecological Surgeons (BIARGS) and the British Society of Gynaecological Endoscopy (BSGE).

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## Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Table S1. Methodology for costing

Table S2. Overhead allocation methodology

Table S3. Co-morbidity for endometrial cancer surgery patients by route and before and after the introduction of robotics

Table S4. Histology and stage for endometrial cancer surgery patients by route and before and after the introduction of robotics