Post robotic investment: Cost consequences and impact on length of stay for obese women with endometrial cancer

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Abstract

Introduction: The aim of the study was to investigate whether robotic-assisted surgery is associated with lower incremental resource use among obese patients relative to non-obese patients after a Danish nationwide adoption of robotic-assisted surgery in women with early-stage endometrial cancer. This is a population-based cohort study based on registers and clinical data.

Material and methods: All women who underwent surgery (robotic, laparoscopic and laparotomy) from 2008 to 2015 were included and divided according to body mass index (<30 and ≥30). Robotic-assisted surgery was gradually introduced in Denmark (2008–2013). We compared resource use post-surgery in obese vs non-obese women who underwent surgery before and after a nationwide adoption of robotic-assisted surgery. The key exposure variable was exposure to robotic-assisted surgery. Clinical and sociodemographic data were linked with national register data to determine costs and bed days 12 months before and after surgery applying difference-in-difference analyses.

Results: In total, 3934 women were included. The adoption of robotic-assisted surgery did not demonstrate statistically significant implications for total costs among obese women (€3,417; 95% confidence interval [CI] −€854 to €7,688, \( p = 0.117 \)). Further, for obese women, a statistically significant reduction in bed days related to the index hospitalization was demonstrated (−1.9 bed days; 95% CI −3.6 to −0.2, \( p = 0.025 \)). However, for non-obese women, the adoption of robotic-assisted surgery was associated with statistically significant total costs increments of €9,333 (95% CI €3,729–€1,4936, \( p = 0.001 \)) and no reduction in bed days related to the index hospitalization was observed (+0.9 bed days; 95% CI −0.6 to 2.3, \( p = 0.242 \)).

Conclusions: The national investment in robotic-assisted surgery for endometrial cancer seems to have more modest cost implications post-surgery for obese women. This may be partly driven by a significant reduction in bed days related to the index hospitalization among obese women, as well as reductions in subsequent hospitalizations.
1 | INTRODUCTION

Obese patients benefit from minimally invasive surgery in terms of shorter hospital stay, reduced postoperative pain and scarring, lower risk of abdominal wound infections, and faster recovery compared with laparotomy. However, conventional laparoscopy in obese patients is associated with technical constraints due to limited intraoperative flexibility and difficult peritoneal-cavity access, which may hinder full clinical adoption. In the randomized controlled Gynecologic Oncology Group trial (GOG LAP2) comparing laparoscopy with laparotomy in women with early-stage endometrial cancer, 26% of the laparoscopic procedures were converted to laparotomy mainly due to obesity. Obese women have high prevalence of comorbidities such as diabetes, hypertension and cardiovascular disease, with concomitant increased risk of complications per- and postoperatively. It is therefore important to offer the least harmful surgical intervention to obese women to prevent short- and long-term morbidity related to the surgical treatment of disease. Robotic-assisted surgery (RAS) allows the surgeon to perform more complicated procedures even in obese patients and with a lower conversion rate to laparotomy compared to laparoscopy.

Robotic-assisted surgery is increasingly used in gynecologic cancer surgery. There are concerns about cost implications related to the adoption of this surgical modality. Previous studies have shown significant benefits applying minimally invasive surgery in women with endometrial cancer, and obese women in particular, benefit from decreased risk of post-surgical complications as compared to laparotomy. However, few institutions have succeeded in a broad adoption of conventional laparoscopy for endometrial cancer, probably due to the well-known technical constraints. RAS was introduced nationally in Denmark for the treatment of early-stage endometrial cancer without prior cost assessment. There is currently limited knowledge concerning the long-term resource implications of the adoption of RAS for obese women with endometrial cancer.

The hypothesis was that obese women experience a better postoperative patient course when undergoing RAS, and that this will have a positive impact on the incremental costs associated with RAS post-surgery for the obese relative to the non-obese. The aim of the study was thus to investigate whether RAS is associated with lower incremental resource use among obese women relative to non-obese women after a Danish nationwide adoption of RAS in women with early-stage endometrial cancer. The study did not include the purchase, depreciation or service agreement costs of the robotic platform, as we do not assume that these differ across our two patient populations.

Key message

The national investment in robotic-assisted surgery for endometrial cancer has more modest cost implications for obese than for non-obese women.

2 | MATERIAL AND METHODS

2.1 | Study design

Robotic-assisted surgery was gradually introduced in all highly specialized gynecologic cancer centers in Denmark over a 5-year period from 2008 to 2013. This provides a unique opportunity to evaluate the cost consequences of the national adoption of robotic surgery by comparing patient pathways post-surgery of women treated before and after the adoption of RAS.

The study population consists of 3934 women diagnosed with early-stage endometrial cancer (the International Federation of Gynecology and Obstetrics [FIGO] stage I-II). All women who underwent surgery in Denmark for early-stage endometrial cancer from 1 January 2008 to 30 June 2015 were included, starting the year the first robotic operation was performed in Denmark. Denmark is divided into five administrative regions which provide healthcare to a total population of 5.7 million people. These regions do not reflect any fundamental sociodemographic or health differences. Our study applies a quasi-experimental design, which exploits the gradual nationwide adoption of RAS and allows assessment of exposed and non-exposed individuals simultaneously. Our analytical strategy is to assess costs as a function of the rate of women undergoing RAS over time and across regions. We operate with exposure to RAS (the rate of patients undergoing RAS) as our treatment variable, and not whether women actually underwent RAS, in order to overcome issues of selection bias and possible confounding of unobservable characteristics.

The two cohorts (obese and non-obese) of early-stage endometrial cancer patients were evaluated independently. Body mass index (BMI) was categorized according to the World Health Organization definition. Women with BMI ≥ 30 are considered obese and normal or overweight women with BMI >18.5 and <30 are defined as non-obese. For the two subgroups of the patient sample, women who underwent surgery before the date of the first RAS performed in their respective region were allocated to the non-exposed group and women who underwent surgery after the date of the first RAS performed in their region were allocated to the group exposed to...
RAS. Non-exposed and exposed women were compared in the obese group as well as in the non-obese group.

In the exposed group the level of exposure was measured by the proportion of patients being treated with RAS out of the total number of patients treated in a given region per year.

2.2 | Data sources

All women undergoing surgery for early stage endometrial cancer were identified from the Danish Gynecological Cancer Database (DGCD). Data from the DGCD covers all women with gynecologic cancer and includes clinical, treatment, and sociodemographic information. From the DGCD we extracted information on the surgical procedure, region of surgery, BMI, tumor histology and grade, FIGO stage, and whether lymphadenectomy was performed. Histopathologic risk groups were based on histology and sub-stage and were defined as follows: low-risk encompassed endometrioid adenocarcinoma, FIGO stage IA + IB grade I–II; high-risk encompassed endometrioid adenocarcinoma, FIGO stage IA + IB grade III, endometrioid adenocarcinoma stage II, non-endometrioid adenocarcinoma FIGO stage I–II.

The unique personal identification number (CPR number) assigned to all permanent residents in Denmark was used to link individual-level register data from DGCD and national registers. Data was pseudo-anonymized and linked in Statistics Denmark.

Cost data and data on bed days were extracted from five different national registers:

1. The Diagnosis Related Grouping (DRG) system, includes the average costs related to all public hospitalizations and re-operations. The tariffs do not include the depreciation, or the service agreement costs of the robotic platform. The DRG tariffs includes activities related to a time period from the day of admission until discharge after surgery. This includes preparation, operation and mobilization after surgery. Further, the running costs (disposable equipment costs), staff salaries and fixed overhead costs are included in the DRG tariffs.

2. The Danish Ambulatory Grouping System (DAGS), includes costs of outpatient treatments of the hospitals, which are reimbursed separately for ambulatory patients.

The Danish DRG tariffs and DAGS are recalculated each year as the tariffs do not include the depreciation, or the service agreement costs of the robotic platform. To account for potential selection in the use of RAS in the cohort of women with the gradual adoption of RAS over a 5-year period, we used the proportion of robotic-assisted surgeries in each region and each year as an exposure variable. The exposure variable was measured by the proportion $p_{RMS}$ of patients being treated with RAS out of the total number of patients treated in a given region and calendar year. Linear regression analysis was applied to adjust for potential differences in baseline characteristics. We controlled for potential time trends by including a fixed effect for calendar year, and for possible regional effects by including fixed effects for each region. This resulted in the fully adjusted model, where our coefficient of interest, $\beta$ was estimated for obese and non-obese patients, respectively:

$$\Delta C_i = C_{i1} - C_{i0} = c + \beta p_{RMS} + \sum_k \beta_k X_{ik} + \epsilon_i,$$

where $\Delta C_i$ indicated the difference in costs per patient the year after surgery ($C_{i1}$) relative to the year prior to surgery ($C_{i0}$), $c$ denoted the model intercept, $\beta$ was the key result denoting the association between the outcome variable $\Delta C_i$ and our exposure variable $p_{RMS}$. $X_{ik}$ represented covariates (region-of-surgery and year-of-surgery, age, Charlson Comorbidity Index, American Society of Anesthesiologists score, histopathological risk group, lymphadenectomy performed, education level, socioeconomic status) and $\epsilon_i$ denoted the residuals.
of the linear regression. Due to the skewed nature of costs, results were reported as mean differences with 95% confidence intervals (CI) based on bootstrapping with 5000 replicates. The DiD mean estimates for costs and number of bed days 1 year postoperatively were reported in an "unadjusted model". A "model I" adjusted for patient characteristics (year-of-surgery, age, Charlson Comorbidity Index, American Society of Anesthesiologists score, histopathological risk group, lymphadenectomy performed, education level, socioeconomic status) and the region of surgery, and a "model II" that was further adjusted for surgical year. Costs were reported per year.

### 2.4 | Clarifications of terms

- **All hospitalization**: includes the index hospitalization and all hospitalized bed days (all specialties).
- **Bed days**: relates to the number of hospitalized bed days and to the index hospitalization.
- **Index hospitalization**: hospitalization related to the index surgery stay only in the gynecologic field.
- **Length of stay**: the number of bed days related to the index hospitalization only.
- **Subsequent hospitalization**: includes all hospitalized bed days the year after the index hospitalization. Hospitalized bed days are from all specialties.

Costs and number of bed days were analyzed with and without the index surgery stay to investigate whether potential differences in costs and bed days were related to the index surgery stay or to re-admissions during the first-year post-surgery.

We estimated differences in costs and bed days with respect to exposure, separately for obese and non-obese patients. Afterwards we determined the difference with 95% CI between obese and non-obese by bootstrapping with 5000 replicates.

Patient characteristics were compared between groups by chi-square test for categorical characteristics and t-test for age. A two-sided statistical significance level of 5% was used and all analyses were performed using STATA 15.1 (Stata/IC).

### 2.5 | Ethical approval

The study was approved by the Danish Data protection Agency (18/43728) on 21 April 2020. Registry-based research does not require a scientific ethical approval in Denmark.

### 3 | RESULTS

We identified 3934 women diagnosed with early-stage endometrial cancer who underwent surgery in Denmark over a 7.5-year period. Of those women, 1499 (38.1%) were obese (BMI ≥30) (949 women exposed to RAS and 550 non-exposed) and 2435 (61.9%) were non-obese (BMI <30) (1448 women exposed to RAS and 987 non-exposed) (Figure 1). The adoption of RAS decreased the use of laparotomy in the obese group from 95% to 5% (2008–2015) (Figure 2). Laparoscopy accounted for 4% in 2008, which increased to 21% in 2015. Among obese women, 74% underwent RAS in 2015 (Figure 2). In the non-obese group, the adoption of RAS led to a decrease in the use of laparotomy from 96% to 6% (2008–2015) (Figure 2). In 2008, 4% underwent laparoscopy, which increased to 30% in 2015. With the adoption of RAS, 64% of the women underwent RAS in the non-obese group (Figure 2).

Sociodemographic and clinical characteristics for the four groups are provided in Table 1. Minor differences were observed regarding the proportion of women who underwent pelvic lymph node dissection and who presented with high-risk histology in the obese group compared with the non-obese group (Table 1).

### 3.1 | Costs related to the adoption of RAS

In Table 2 a detailed cost overview of the post-robotic investment is outlined consisting of cost from index hospitalization or and subsequent hospitalizations, outpatient and primary sector visits, cost of medication and the total cost.

For the obese patients, the cost of the index hospitalization increased by €3,018 (95% CI 1045–4991, \( p = 0.003 \)) for patients undergoing RAS. In the non-obese group, the cost of the index hospitalization increased by €4,604 (95% CI 3345–5864; \( p < 0.001 \)). The difference between the obese and non-obese group was not significant (\( p = 0.192 \)).

However, in the obese group, the long-term total costs did not demonstrate statistically significant implications (€3,417; 95% CI −854 to 7688, \( p = 0.040 \)) (Table 2) as opposed to the non-obese group, where significantly higher total costs were demonstrated (€9,333; 95% CI 3729–14936, \( p = 0.001 \)). The difference between the obese and non-obese group was significant at the 0.1 level (\( p = 0.093 \)).

In the non-obese group, we observed high costs related to subsequent hospitalizations (Table 2). In depth analyses revealed that these higher costs were influenced by extraordinary high costs related to several readmissions among a small number of women.

Costs of primary sector services differed across obese and non-obese patients; the obese women did not incur any statistically significant cost implications (€−96, 95% CI −264 to 72, \( p = 0.264 \)) whereas the non-obese women did (€134, 95% CI 6–262, \( p = 0.040 \)). The difference between the obese and non-obese group was significant (\( p = 0.033 \)). No cost differences were observed regarding outpatient visits or medications in the exposed and non-exposed groups and across obesity groups (Table 2).

### 3.2 | Bed days related to the adoption of RAS

In Table 3, a detailed overview is outlined of the number of bed days related to index hospitalization, subsequent hospitalizations and all hospitalizations following the post-robotic investment.
The adoption of RAS led to a significant reduction in bed days of 1.9 in the obese group (CI: -3.6 to -0.2, \( p = 0.025 \)) related to index hospitalization. No difference in bed day was observed in the non-obese group (0.9; CI: -0.6 to 2.3, \( p = 0.242 \)) (Table 3). The difference in bed days between the obese and non-obese group was statistically significant (\( p = 0.014 \)) (Table 3).
TABLE 1  Demographic characteristics of included women divided in non-obese vs obese

|                        | Non-obese | Obese | p-value | Non-obese | Obese | p-value |
|------------------------|-----------|-------|---------|-----------|-------|---------|
|                        | Non-exposed group (n = 987) | Exposed group (n = 1448) | p-value | Non-exposed group (n = 550) | Exposed group (n = 949) | p-value |
| Age                    | 0.022     | 0.763 |         |           |       |         |
| Mean (SD)              | 67.8 (10.6) | 68.8 (10.5) |         | 65.4 (9.6) | 65.2 (9.8) |         |
| Median (range)         | 68 (44–90) | 69 (46–91) |         | 65 (38–88) | 66 (40–87) |         |
| Age group              | 0.181     | 0.233 |         |           |       |         |
| ≤59 years              | 224 (22.7) | 300 (20.7) |         | 138 (25.1) | 250 (26.3) |         |
| 60–66 years            | 241 (24.4) | 319 (22.0) |         | 178 (32.3) | 267 (28.1) |         |
| 67–74 years            | 246 (24.9) | 377 (26.0) |         | 139 (25.3) | 276 (29.1) |         |
| ≥75 years              | 276 (28.0) | 452 (31.3) |         | 95 (17.3) | 156 (16.5) |         |
| CCIa                   | 0.658     | 0.089 |         |           |       |         |
| 0                      | 684 (69.3) | 985 (68.0) |         | 326 (59.3) | 574 (60.5) |         |
| 1                      | 153 (15.5) | 223 (15.4) |         | 101 (18.3) | 203 (21.4) |         |
| >2                     | 150 (15.2) | 240 (16.6) |         | 123 (22.4) | 172 (18.1) |         |
| ASA scoreb             | 0.006     | 0.053 |         |           |       |         |
| I                      | 432 (44.0) | 548 (37.9) |         | 145 (26.4) | 198 (20.9) |         |
| II                     | 482 (49.0) | 764 (52.9) |         | 326 (59.3) | 604 (63.8) |         |
| >III                   | 69 (7.0) | 133 (9.2) |         | 79 (14.3) | 145 (15.3) |         |
| Unknown                | <5 | <5 |         | 0 | <5 |         |
| Histopathologic riskc  | 0.912     | 0.820 |         |           |       |         |
| Low-risk               | 688 (71.1) | 1013 (70.9) |         | 425 (78.6) | 729 (78.0) |         |
| High-risk              | 279 (28.9) | 415 (29.1) |         | 116 (21.4) | 205 (22.0) |         |
| Unknown                | 20 | 20 |         | 9 | 15 |         |
| Lymphadenectomy        | 0.071     | 0.594 |         |           |       |         |
| No                     | 641 (65.1) | 875 (61.5) |         | 386 (70.7) | 648 (69.4) |         |
| Yes                    | 343 (34.9) | 547 (38.5) |         | 160 (29.3) | 286 (30.6) |         |
| Unknown                | <5 | 26 |         | <5 | 15 |         |
| Educationd             | 0.001     | 0.002 |         |           |       |         |
| Grade school           | 408 (42.5) | 507 (35.6) |         | 271 (50.4) | 409 (44.0) |         |
| Short education        | 347 (36.1) | 534 (37.6) |         | 202 (37.5) | 346 (37.3) |         |
| Medium-further education | 206 (21.4) | 381 (26.8) |         | 65 (12.1) | 174 (18.7) |         |
| Unknown                | 26 | 26 |         | 12 | 20 |         |
| Socioeconomice         | 0.014     | 0.002 |         |           |       |         |
| I                      | 142 (14.4) | 249 (17.2) |         | 45 (8.2) | 113 (11.9) |         |
| II                     | 372 (37.7) | 589 (40.7) |         | 189 (34.4) | 375 (39.6) |         |
| III                    | 472 (47.9) | 609 (42.1) |         | 316 (57.4) | 460 (48.5) |         |
| Unknown                | <5 | <5 |         | 0 | <5 |         |
| Region                 | <0.001    | <0.001 |         |           |       |         |
| North Denmark          | 33 (3.3) | 264 (18.2) |         | 21 (3.8) | 170 (17.9) |         |
| Capital                | 189 (19.2) | 648 (44.8) |         | 85 (15.5) | 350 (36.9) |         |
| Central Jutland        | 214 (21.7) | 253 (17.5) |         | 134 (24.4) | 213 (22.4) |         |
| Southern Denmark       | 311 (31.5) | 212 (14.6) |         | 169 (30.7) | 158 (16.7) |         |
| Zealand                | 240 (24.3) | 71 (4.9) |         | 141 (25.6) | 58 (6.1) |         |

aCCI, Charlson Comorbidity Index: 10 years before surgery. All diagnosis codes except for referral diagnosis.

bASA, American Society of Anesthesiologists physical status classification system.

cHistopathologic risk groups: low-risk, EAC Stage IA + IB Grade I–II; high-risk, EAC Stage IA + IB grade III/EAC Stage II/non-EAC.

dEducation: highest completed education.

eSocioeconomic status is based on the highest educational level and disposable income the year before surgery.
TABLE 2 Costs associated with the adoption of robotic-assisted surgery for women (body mass index, <30 BMI vs ≥30 BMI) with early-stage endometrial cancer. The difference-in-difference mean estimates for costs 1 year postoperatively are reported in three models separately for obese and non-obese women. The difference between obese and non-obese women were estimated with 95% CI

| Costs                                | Unadjusted model | Adjusted model I Patient characteristics | Adjusted model II Patient characteristics and surgery date |
|--------------------------------------|------------------|-----------------------------------------|----------------------------------------------------------|
|                                      | Costs per patient (Euros) [95% CI] | p-value | Costs per patient (Euros) [95% CI] | p-value | Costs per patient (Euros) [95% CI] | p-value | p-value |
| Index hospitalization*               |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | 5347 (4766–5928) | <0.001   | 5929 (5295–6562)                | <0.001   | 4604 (3345–5864)                 | <0.001   | 0.192   |
| BMI ≥ 30                             | 4754 (3859–5648) | <0.001   | 5782 (4635–6930)                | <0.001   | 3018 (1045–4991)                 | 0.003    |         |
| Subsequent hospitalizations*         |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | 1725 (−633 to 4083) | 0.152  | 1739 (−717 to 4195)            | 0.165    | 4501 (−185 to 9187)              | 0.060    | 0.089   |
| BMI ≥ 30                             | 438 (−717 to 1593) | 0.457  | 226 (−1193 to 1645)           | 0.755    | −197 (−2654 to 2260)             | 0.875    |         |
| All hospitalizations†                |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | 7129 (4614–9643) | <0.001   | 7754 (5140–10368)            | <0.001   | 9331 (4247–14414)               | <0.001   | 0.045   |
| BMI ≥ 30                             | 5200 (3609–6790) | <0.001   | 6053 (4083–8024)            | <0.001   | 3025 (−328 to 6377)             | 0.077    |         |
| Outpatient visits                    |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | −1515 (−2275 to −755) | <0.001  | −1639 (−2595 to −684)         | 0.001    | −43 (−2173 to 2087)              | 0.969    | 0.762   |
| BMI ≥ 30                             | −472 (−1319 to 375) | 0.275  | −783 (−1770 to 205)           | 0.120    | 404 (−1605 to 2414)             | 0.693    |         |
| Primary sector                       |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | 81 (26–135)      | 0.004    | 138 (73 to 202)               | <0.001   | 134 (6–262)                     | 0.040    | 0.033   |
| BMI ≥ 30                             | −19 (−84 to 47)  | 0.574    | 36 (−45 to 117)               | 0.385    | −96 (−264 to 72)                | 0.264    |         |
| Medications                          |                  |          |                                  |          |                                  |          |         |
| BMI < 30                             | −4 (−59 to 52)   | 0.898    | −7 (−76 to 62)                | 0.835    | −89 (−213 to 34)                | 0.155    | 0.114   |
| BMI ≥ 30                             | −2 (−84 to 81)   | 0.968    | 34 (−74 to 142)               | 0.534    | 84 (−97 to 265)                 | 0.364    |         |
| Total costs without the index surgery stay* |          |          |                                  |          |                                  |          |         |
| BMI < 30                             | 287 (−2306 to 2881) | 0.828  | 230 (−2520 to 2981)          | 0.870    | 4503 (−619 to 9625)             | 0.085    | 0.178   |
| BMI ≥ 30                             | −54 (−1640 to 1531) | 0.946  | −486 (2361–1388)             | 0.611    | 195 (−3206 to 3596)             | 0.910    |         |
| Total costs including the index surgery stay† |          |          |                                  |          |                                  |          |         |
| BMI < 30                             | 5691 (3014–8367) | <0.001   | 6245 (3395–9095)            | <0.001   | 9333 (3729–14936)              | 0.001    | 0.093   |
| BMI ≥ 30                             | 4707 (2786–6629) | <0.001   | 5341 (2961–7721)            | <0.001   | 3417 (−854 to 7688)             | 0.117    |         |

Note: Reported estimates are the coefficient (β) for the association between proportion exposed (pRMIS) and difference in cost per patient (ΔC).

BMI < 30: Non-exposed group (n = 987); Exposed group (n = 1448).
BMI ≥ 30: Non-exposed group (n = 550); Exposed group (n = 949).
Costs are per patient using 2015 price index (Euros).

*Costs of robotic-assisted surgery compared with the non-robotic group.

b p-value in relation to costs.

c p-value for the statistical difference in costs.

6 Costs from the index hospitalization stay.

7 Costs from hospitalized bed days without the index surgery stay.

8 Costs from hospitalized bed days including the index surgery stay.

4 DISCUSSION

The present study investigated whether RAS is associated with lower incremental resource use among obese patients relative to non-obese women after a Danish nationwide adoption of RAS in women with early-stage endometrial cancer. The focus of the article was to assess the costs associated with the postoperative patient course when undergoing RAS vs other surgical modalities, and to assess whether these costs differ across obese and the non-obese women. We did not observe higher total costs due to hospitalization, primary sector visits, outpatient visits or prescription medication following adoption of RAS 1-year after surgery in the obese group in contrast to the non-obese group, where significantly higher total costs were observed. Our results suggest that the resource consumption patterns related to the adoption of RAS is affected differently by obese and non-obese patients. This may be partly driven by a reduction in...
the number of bed days related to the index hospitalization of almost 2 days for obese patients compared with no difference for the non-obese patients.

A higher proportion of women (38.4%) underwent lymphadenectomy as part of their treatment in the non-obese group compared with the obese group (30.6%). Evidence has suggested that non-obese women are more often diagnosed with type II histology (serous or clear cell adenocarcinoma or carcinosarcoma) with a worse prognosis and more aggressive clinical course than women with type I histology (endometrioid adenocarcinoma).27,28 In a recent Danish population-based study, it was observed that the rate of lymphadenectomy increased from 10% to 35% in women who underwent surgery for early-stage endometrial cancer during 2005–2015.29 The trend towards more aggressive surgical treatment over time with presumably higher risk of complications and potential higher costs related to re-admissions may, in general, introduce bias in studies with long observation time. In the present study this was handled by time trend adjustment.

The healthcare system is being exposed to a rising incidence of obese patients with endometrial cancer, and surgical approaches such as RAS seem to have clinical benefits for these patients. In recent population-based studies we showed that a nationwide Danish adoption of RAS completely transitioned the surgical approach to minimally invasive surgery and was, in general, associated with a reduced risk of severe complications and improved survival; primarily for two-thirds of the patients who were defined as frail.29,30 In the present study, more than two-thirds of the patients underwent RAS at the end of the observation period and this incurred, in general, increased costs.31 The present study suggests that this is not the case for obese women. Our analysis indicates that obese women experience less resource-intensive patient pathways post-RAS relative to non-obese patients, which suggests that obese patients may benefit more from RAS than non-obese women. The policy implication is that RAS should perhaps be prioritized for certain sub-groups of women with endometrial cancer, ie frail or obese women.

There is limited evidence concerning long-term morbidity in women who have undergone treatment for early-stage endometrial cancer. However, as mentioned, offering these women minimally invasive surgery is likely to decrease their risk of severe complications. This includes venous thromboembolism, surgical scar complications and acute renal failures, all of which are more common in obese women than non-obese women.29 The Danish national investment and the adoption of RAS in this patient group increased the proportion of women who are offered minimally invasive surgery from 2008 to 2015. The present study provides additional evidence of the long-term post-surgery benefits “in the real world”, results which imply that the adoption of robotic surgery in obese women will prove to be associated with a decrease in long-term morbidity.

| TABLE 3 | Bed days associated with the adoption of robotic-assisted surgery for women (body mass index, <30 BMI vs ≥30 BMI) with early-stage endometrial cancer. The difference-in-difference mean estimates for bed days 1 year postoperatively are reported in three models separately for obese and non-obese women. The differences between obese and non-obese women were estimated with 95% CI |
|---------------------------------------------------------------|
| **No. of bed days** | **Unadjusted model** | **Adjusted model I** | **Adjusted model II** |
| | Number per patient [95% CI] | p-value | Number per patient [95% CI] | p-value | Number per patient [95% CI] | p-value | p-value |
| Bed days (index hospitalization) | | | | | | | |
| BMI < 30 | -2.5 (-3.2 to -1.8) | <0.001 | -3.6 (-4.4 to -2.8) | <0.001 | 0.9 (-0.6 to 2.3) | 0.242 | 0.014 |
| BMI ≥ 30 | -3.0 (-3.8 to -2.2) | <0.001 | -3.5 (-4.5 to -2.5) | <0.001 | -1.9 (-3.6 to -0.2) | 0.025 | |
| Bed days (subsequent hospitalizations) | | | | | | | |
| BMI < 30 | -0.0 (-1.6 to 1.5) | 0.954 | -0.2 (-1.9 to 1.5) | 0.821 | -0.1 (-3.2 to 3.1) | 0.966 | 0.909 |
| BMI ≥ 30 | -0.2 (-1.4 to 1.1) | 0.808 | -0.2 (-2.0 to 1.3) | 0.686 | -0.3 (-3.0 to 2.4) | 0.820 | |
| Bed days (all hospitalizations) | | | | | | | |
| BMI < 30 | -2.6 (-4.3 to -0.8) | 0.004 | -3.7 (-5.7 to -1.8) | <0.001 | 0.8 (-2.9 to 4.6) | 0.657 | 0.256 |
| BMI ≥ 30 | -3.1 (-4.7 to -1.6) | <0.001 | -3.8 (-5.8 to -1.8) | <0.001 | -2.1 (-5.4 to 1.2) | 0.220 | |

Note: Reported estimates are the coefficient (β) for the association between proportion exposed (p_exposed) and difference in cost per patient (ΔC_i).

BMI < 30: Non-exposed group (n = 987); Exposed group (n = 1448).

BMI ≥ 30: Non-exposed group (n = 550); Exposed group (n = 949).

No. of bed days are per patient.

1Additional number of bed days related to robotic-assisted surgery compared with the non-robotic group.

2The p-value in relation to additional bed days.

3The p-value for the difference in bed days.

4Number of bed days with the index hospitalization stay.

5Number of bed days without the index surgery stay.

6Number of bed days including the index surgery stay.
Our study demonstrated that the adoption of RAS decreased the number of bed days related to the index hospitalization by almost 2 days for obese patients, whereas no difference was found for non-obese patients. Examining the number of bed days across the obese and non-obese groups provided information on how adjusting for time trends impacted on our results. For the non-obese women who underwent laparotomy or laparoscopy and who were not exposed to RAS, a reduction in bed days from index hospitalization was observed from 2008 to 2013. This is most likely due to the introduction of fast-track principles in Denmark of early mobilization and faster recovery at home. We did not observe the same time-trend in length of stay for the obese patients who underwent laparotomy or laparoscopy. However, we observed that the obese women benefited from the adoption of RAS by a shorter length of stay related to the index hospitalization. Hence, costs for obese women would have been greater, had RAS not been introduced.

A strength of this study is the use of population-based data with clinical information on the individual level in combination with high-quality register data covering the patient’s pathway in the healthcare system and society. In addition, the gradual implementation of RAS in Denmark simulates a quasi-experimental design, thus minimizing patient selection bias. Our large population and the use of the DiD design is particularly powerful for evaluating cost patterns and number of bed days 1 year before vs 1 year after surgery to account for example to co-morbidity.

The major limitation of our study is the use of retrospective data and a comparatively long time period with potential time trends. Our analyses are based on DRG tariffs and these tariffs have varied during our inclusion period. The costs associated with RAS may decrease in the years to come due to expiration of patents and increased surgeon experience with reduction in procedure- and operating room time. Cost-saving procedures such as same-day discharge and the fast-track principle are now established in Denmark but may expand further in the future.

The surgeon experience is not routinely recorded, and it was not possible to estimate the learning curve of RAS in our data. A study by Seamon et al. found that 20 procedures were needed to get through the steepest portion of the learning curve for RAS with pelvic and para-aortic lymphadenectomy for women with endometrial cancer. Another study by Lin et al. reported the learning curve to include 20-30 cases of RAS for newly trained minimally invasive gynecologic surgeons. Even though RAS was introduced during our inclusion period, the severity of complications did not lead to any increase in readmissions when comparing the exposed group with the non-exposed group.

Another limitation was that the number of women with BMI >35 was comparatively low, which precluded analyses based on further subdivision of BMI groups.

The focus of the article was not to perform a full economic evaluation but to assess the resource consequences associated with the introduction of RAS. Information is needed which can be used to inform future full economic evaluations, and which emphasizes the importance of conducting economic evaluations for sub-groups of patients, as cost-effectiveness may vary. Future research should focus on establishing the health-related quality of life gains associated with RAS to establish the cost-effectiveness of RAS for patients with endometrial cancer. Our results suggest different long-term cost effects of RAS across obese and non-obese women; in future economic evaluations, it may be important to analyze obese and non-obese patients separately.

5 CONCLUSION

The national investment in RAS for endometrial cancer seems to have more modest cost implications for obese women than non-obese women. This may be partly driven by a significant reduction in bed days related to the index hospitalization among obese women, as well as reductions in subsequent hospitalizations.

CONFLICT OF INTEREST

None.

AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design, processing of data, statistical analysis and interpretation of data, drafting of the article, critical revision and final approval. MK, DG-H, SM and PTJ additionally contributed with the statistical analysis of the data.

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REFERENCES

1. Bogani G, Multinu F, Dowdy SC, et al. Incorporating robotic-assisted surgery for endometrial cancer staging: analysis of morbidity and costs. Gynecol Oncol. 2016;141:218-224.
2. Shemshedini T, Pradhan TS, Pua TL, Tedjarati SS. The roles and limitations of robotic surgery for obese endometrial cancer patients: a common challenge in gynecologic oncology. J Robot Surg. 2015;9:109-116.
3. Bouwman F, Smits A, Lopes A, et al. The impact of BMI on surgical complications and outcomes in endometrial cancer surgery—an institutional study and systematic review of the literature. Gynecol Oncol. 2015;139:369-376.
4. Cusimano MC, Simpson AN, Dossa F, et al. Laparoscopic and robotic hysterectomy in endometrial cancer patients with obesity: a systematic review and meta-analysis of conversions and complications. Am J Obstet Gynecol. 2019;221:410-428.e19.
5. Walker JL, Piedmonte MR, Spirito NM, et al. Laparoscopy compared with laparotomy for comprehensive surgical staging of uterine cancer: Gynecologic Oncology Group Study LAP2. J Clin Oncol. 2009;27:5331-5336.
6. O’Malley DM, Smith B, Fowler JM. The role of robotic surgery in endometrial cancer. J Surg Oncol. 2015;112:761-768.
7. Kannisto P, Harter P, Heitz F, Traut A, du Bois A, Kurzeder C. Implementation of robot-assisted gynecologic surgery for patients with low and high BMI in a German gynecological cancer center. Arch Gynecol Obstet. 2014;290:143-148.
8. Korsholm M, Sorensen J, Mogensen O, Wu C, Karlsen K, Jensen PT. A systematic review about costing methodology in robotic surgery:
evidence for low quality in most of the studies. Health Econ Rev. 2018;2:11.
9. Barbash GI, Glied SA. New technology and health care costs—the case of robot-assisted surgery. N Engl J Med. 2010;363:701-704.
10. Sofer A, Magnezi R, Eitan R, et al. Robotic vs. open surgery in obese women with low-grade endometrial cancer: comparison of costs and quality of life measures. Isr J Health Policy Res. 2020;9:60.
11. Lindfors A, Heshar H, Adok C, Sundfeldt K, Dahm-Kähler P. Long-term survival in obese patients after robotic or open surgery for endometrial cancer. Gynecol Oncol. 2020;158:673-680.
12. World Health Organization Obesity: Prevention and Managing the Global Epidemic. Geneva: World Health Organization: WHO Europe; 2000. https://www.who.int/news-room/factsheets/detail/obesity-and-overweight. Accessed January 22, 2020.
13. Sorensen SM, Bjorn SF, Jochumsen KM, et al. Danish gynecological cancer database. Clin Epidemiol. 2016;8:485-490.
14. Colombo N, Creutzberg C, Amant F, et al. ESMO-ESGO-ESTRO Consensus Conference on Endometrial Cancer: diagnosis, treatment and follow-up. Ann Oncol. 2016;27:16-41.
15. Pedersen CB. The Danish Civil Registration System. Scand J Public Health. 2011;39(7 Suppl):22-25.
16. Ankjaer-Jensen A, Rosling P, Bilde L. Variable prospective financing in the Danish hospital sector and the development of a Danish case-mix system. Health Care Manag Sci. 2006;9:259-268.
17. Olejaz M, Juul Nielsen A, Rudkjøbing A, Okkels Birk H, Krasnik A, Hernández-Quevedo C. Denmark health system review. Scand J Syst Transl. 2012;14:i-xxii, 1-192.
18. Thygesen LC, Daasnes C, Thaulow I, Brennum-Hansen H. Introduction to Danish (nationwide) registers on health and social issues: structure, access, legislation, and archiving. Scand J Public Health. 2011;39:12-16.
19. Andersen JS, Olivarius Nde F, Krasnik A. The Danish National Health Service Register. Scand J Public Health. 2011;39:34-37.
20. Pottegard A, Schmidt SAJ, Wallach-Kildemoes H, Sorensen HT, Hallas J, Schmidt M. Data resource profile: the Danish National Prescription Registry. Int J Epidemiol. 2017;46:798-84.
21. Lynge E, Sandegaard JL, Rebolj M. The Danish National Patient Register. Scand J Public Health. 2011;39:30-33.
22. Statistics Denmark Consumer Price Index Statistics Denmark 2018. Available from: www.dst.dk/en/Statistik/emner/priser-og-forbrug/forbrugerpriser/forbrugerprisindeks. Accessed January 1, 2018.
23. Jensen VM, Rasmussen AW. Danish Education Registers. Scand J Public Health. 2011;39:91-94.
24. Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health. 2011;39:103-105.
25. Abadie A. Semiparametric difference-in-difference estimators. Rev Econ Stud. 2005;72:1-19.
26. O’Neill S, Kreif N, Grieve R, Sutton M, Sekhon JS. Estimating causal effects: considering three alternatives to difference-in-differences estimation. Health Serv Outcomes Res Methodol. 2016;16:1-21.
27. Doll A, Abal M, Rigau M, et al. Novel molecular profiles of endometrial cancer—new light through old windows. J Steroid Biochem Mol Biol. 2008;108:221-229.
28. Faber MT, Frederiksen K, Jensen A, Aarslev PB, Kjaer SK. Time trends in the incidence of hysterectomy-corrected overall, type 1 and type 2 endometrial cancer in Denmark 1978–2014. Gynecol Oncol. 2017;146:359-367.
29. Jørgensen SL, Mogensen O, Wu C, et al. Nationwide introduction of minimally invasive robotic surgery for early-stage endometrial cancer and its association with severe complications. JAMA Surg. 2019;154:530-538.
30. Jørgensen SL, Mogensen O, Wu CS, Korsholm M, Lund K, Jensen PT. Survival after a nationwide introduction of robotic surgery in women with early-stage endometrial cancer: a population-based prospective cohort study. Eur J Cancer. 2019;109:1-11.
31. Korsholm M, Gyrd-Hansen D, Mogensen O, et al. Long term resource consequences of a nationwide introduction of robotic surgery for women with early stage endometrial cancer. Gynecol Oncol. 2019;154:411-419.
32. Seamon LG, Fowler JM, Richardson DL, et al. A detailed analysis of the learning curve: robotic hysterectomy and pelvic-aortic lymphadenectomy for endometrial cancer. Gynecol Oncol. 2009;114:162-167.
33. Lin JF, Frey M, Huang JQ. Learning curve analysis of the first 100 robotic-assisted laparoscopic hysterectomies performed by a single surgeon. Int J Gynaecol Obstet. 2014;124:88-91.

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