Original Research

Postpartum Opportunistic Salpingectomy Compared With Bilateral Tubal Ligation After Vaginal Delivery for Ovarian Cancer Risk Reduction

A Cost-Effectiveness Analysis

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OBJECTIVE: To compare the cost effectiveness of opportunistic salpingectomy and bilateral tubal ligation for sterilization immediately after vaginal delivery.

METHODS: A cost-effectiveness analytic decision model was used to compare opportunistic salpingectomy with bilateral tubal ligation during vaginal delivery admission. Probability and cost inputs were derived from local data and available literature. Salpingectomy was assumed to be performed with a handheld bipolar energy device. The primary outcome was the incremental cost-effectiveness ratio (ICER) in 2019 U.S. dollars per quality-adjusted life-year (QALY) at a cost-effectiveness threshold of $100,000/QALY. Sensitivity analyses were performed to determine the proportion of simulations in which salpingectomy would be cost effective.

RESULTS: Opportunistic salpingectomy was more cost effective than bilateral tubal ligation with an ICER of $26,150/QALY. In 10,000 patients desiring sterilization after vaginal delivery, opportunistic salpingectomy would result in 25 fewer ovarian cancer cases, 19 fewer ovarian cancer deaths, and 116 fewer unintended pregnancies than bilateral tubal ligation. In sensitivity analysis, salpingectomy was cost effective in 89.8% of simulations and cost saving in 13% of simulations.

CONCLUSION: In patients undergoing sterilization immediately after vaginal deliveries, opportunistic salpingectomy is more cost effective and may be more cost saving than bilateral tubal ligation for reducing ovarian cancer risk.

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Ovarian carcinoma is the most lethal gynecologic malignancy, with nearly 13,000 deaths annually in the United States.[1] About 1 in 80 women will develop ovarian cancer within their lifetime.[2] Because of a lack of effective screening strategies, patients typically present with advanced-stage disease and have an overall poor survival rate (49.7%) at 5 years.[1–3] Consequently, focus has shifted to primary prevention as a means of reducing ovarian cancer mortality.[4–6]

One strategy recommended by the American College of Obstetricians and Gynecologists and the Society of Gynecologic Oncology to reduce ovarian cancer risk in patients desiring sterilization is to remove the fallopian tubes at the time of benign abdominopelvic surgery for another indication.[5,6] This "opportunistic salpingectomy" approach is based on evidence that suggests that the fallopian tube is the

site of origin for up to 70% of high-grade serous ovarian cancers.[7–10] The discovery of dysplastic serous tubal intraepithelial carcinomas lesions identified in the distal fallopian tube of patients with *BRCA* mutations further increased support for risk-reducing salpingectomy.[7] After these endorsements, this procedure was widely implemented into routine practice.[11–14] Opportunistic salpingectomy has been repeatedly demonstrated to be a safe alternative to a variety of standard tubal ligation methods across various surgical settings, including at the time of benign gynecologic surgery, during cesarean delivery, and in the immediate postpartum period, with similar surgical, reproductive, and hormonal outcomes.[14–18] Thus, the use of tubal ligation at vaginal delivery is decreasing in recent years in the United States.[19]

Although opportunistic salpingectomy appears to be as safe as bilateral tubal ligation, which also reduces the risk of ovarian cancer,[4–7] it is not commonly used in the postpartum period in patients who have delivered vaginally.[13] In the United States, more than 2.4 million vaginal births occur annually, and postpartum sterilization occurs during the delivery admission in about 2% of all in-hospital deliveries.[19] Whether opportunistic salpingectomy after vaginal delivery is a cost-effective strategy to prevent ovarian cancer is largely unknown. Our objective was to compare the cost effectiveness of opportunistic salpingectomy with that of bilateral tubal ligation immediately after vaginal delivery as a means of reducing ovarian cancer risk.

METHODS

We designed a decision analytic model to compare the cost and effects of opportunistic salpingectomy and standard bilateral tubal ligation immediately after vaginal delivery, focusing specifically on serous ovarian cancer and unintended pregnancy. The study population included a theoretical cohort of 10,000 women (per treatment option) desiring permanent contraception immediately after vaginal delivery. The time horizon for this cost-effectiveness analysis was over the lifetime of the patient from the time of sterilization until death. The average age of patients seeking sterilization was based on prior literature[16,17] and assumed to be 33 years. The age at death for patients who did not develop ovarian cancer was assumed to be 78 years, the average life expectancy in the United States in 2019.[20] The assumed background risk of ovarian cancer development was 1.26%.[2] The model did not account for patients at high risk of ovarian cancer, including those with *BRCA 1/2* germline mutations or with a family history of hereditary breast and ovarian cancer syndromes. Instead, we assumed that patients at both low and high risk were present in our model, as is the case within the general population, without specifically aiming to identify patients at high risk who may benefit from other risk-reducing strategies.

The model (Fig. 1) was created with Stata and used Monte Carlo simulations assuming binomial probability density functions with success probabilities determined from parameters drawn from the literature. This resulted in a decision tree framework in which model outcomes were the result of simulated joint probabilities given specific parameterization. Estimates were derived from 1,000 simulations of each set of parameters. All model parameters were derived from either the literature or estimates from available data. These parameters, along with their values, extrema, and sources, are outlined in Table 1.

Procedural costs attributed to salpingectomy were estimated from charge data at the University of Wisconsin and its affiliated obstetric hospital, Unity Point Health-Meriter. Average sterilization costs were $4,110.58 across all women, $4,358.09 for those receiving salpingectomy, and $3,753.07 for those receiving bilateral tubal ligation. The reason for the difference in charges was that a bipolar electrocautery device (Ligasure) was used during postpartum salpingectomy procedures.[16] Multivariable regression analysis suggests that standard procedures, common to both forms of sterilization, were the largest significant determinants of cost, such as length of stay, length of procedure, and preoperative antibiotic prophylaxis. On average, length of stay, length of procedure, and proportion receiving antibiotic prophylaxis were 3.5 ± 1.2 days, 34.2 ± 12.1 minutes, and $1 \pm 0.1\%$ for all patients; 3.5 ± 1.6 days, 32.3 ± 11.7 minutes, and $1 \pm 0.1\%$ for patients undergoing salpingectomy; and 3.5 ± 1.1 days, 35.2 ± 12.2 minutes, and $0.5 \pm 0.1\%$ for patients undergoing bilateral tubal ligation. Costs of unintended pregnancy (including ectopic pregnancy) and ovarian cancer treatment, survival, and death were derived from the literature. Costs were adjusted to 2019 dollars by using the health care component of the U.S. personal consumption expenditure chain-type price index.

The primary outcome was the incremental cost-effectiveness ratio (ICER), estimated as the difference in incremental cost between salpingectomy and bilateral tubal ligation divided by the incremental effectiveness, which was measured in quality-adjusted life-years (QALYs). An ICER willingness-to-pay threshold of $100,000/QALY was defined a priori for determining cost effectiveness. We performed a

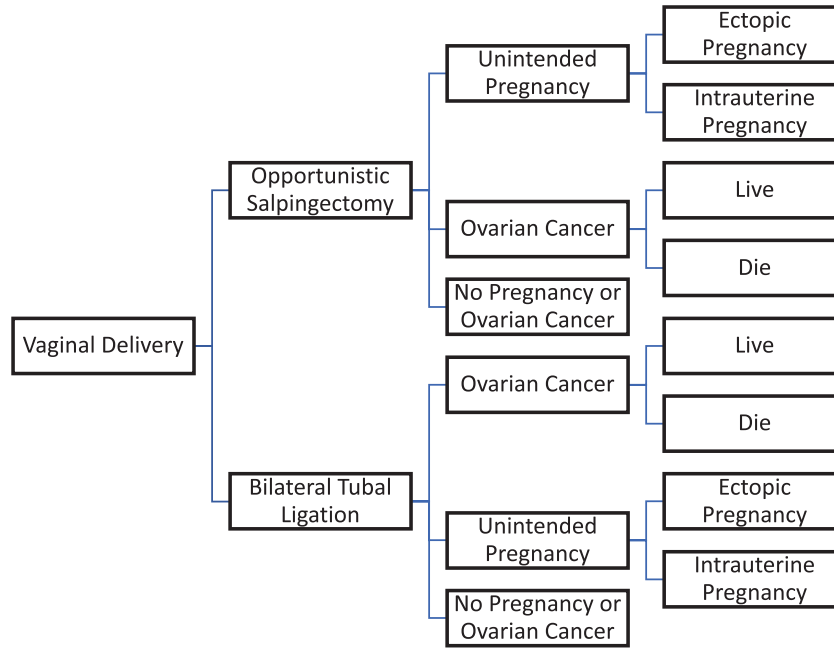

Fig. 1. Decision analytic model schema for opportunistic salpingectomy vs bilateral tubal ligation, created with Stata.
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cost–benefit analysis by using the methods described previously for a simulated population of 10,000 women undergoing treatment. Future costs and utilities were discounted at a rate of 3%/y.

We performed a sensitivity analysis with model parameters outlined in the literature[15] and parameterized to strictly match similar previous studies. Subramaniam et al[21] performed similar analyses comparing salpingectomy and bilateral tubal ligation for patients undergoing cesarean delivery with costs derived from an alternative population of patients. They observed a procedural success rate of 67.5%. We refer to this parametrization as case 1 and compare it with our base-case (case 0) assumptions. When salpingectomy was not successful, bilateral tubal ligation was performed. The analysis was then conducted according to the initial treatment group, and cost was accrued according to the initially assigned procedure. We also performed extreme sensitivity analyses to test the limits of the model relative to salpingectomy compared with bilateral tubal ligation outcomes. These models assumed either the most optimistic or the most conservative results for salpingectomy. The parametrization of these two cases is outlined in Table 1. This study was approved by the Unity Point Health-Meriter IRB (IRB No. 2019-019).

RESULTS

The results of the base-case (case 0 in Table 1) analysis are shown in Table 2. Salpingectomy after vaginal delivery was cost effective, with an average ICER of $26,149.60/QALY. In a population of 10,000 patients undergoing sterilization immediately after vaginal delivery, salpingectomy resulted in 25 fewer ovarian cancer cases, 19 fewer ovarian cancer deaths, and 116 fewer unintended pregnancies than bilateral tubal ligation. The mean total incremental cost for pursuing salpingectomy was $1,665,069, which was derived from the incremental procedure costs of salpingectomy ($6,050,200) less cost savings attributable to reduced cancer cases and deaths ($3,299,331) and reduced incidence of unintended pregnancy ($1,085,800). Detailed incremental base-case cost data are shown in Table 3.

Varying model inputs to reflect the parameterization of Subramaniam et al[21] (case 1) did not change the base-case (case 0) conclusion that opportunistic salpingectomy is more cost effective than bilateral tubal ligation immediately after vaginal delivery. The average ICER under case 1 decreased to $4,195.78 (Table 2). However, mean incremental costs increased to $3,627,433, and mean QALY gains declined to 99.6 relative to case 0 (Table 3). Furthermore, salpingectomy resulted in only 23, 17, and 12 fewer unintended pregnancies, ovarian cancer cases, and ovarian cancer deaths on average, respectively (Table 4). Thus, more simulations under case 1 than under case 0 yielded a negative ICER (incremental costs are positive and incremental QALYs are negative), indicating that salpingectomy was not more cost effective than bilateral tubal ligation in these simulations.

Figures 2 and 3 compare the distributional results of cases 0 and 1. Figure 2 shows that the ICER distribution

Table 1. Model Parameterization

Category	Base Case 0 Estimate	Case 1 Estimate[21]	Extreme Optimistic Case	Extreme Conservative Case	Source
Cost ($)					
SPG	4,358.09				UW data
Standard BTL	3,753.07				UW data
Unintended pregnancy	12,447.52				20, 28, 29
Ectopic pregnancy	8,530.84				20, 30–33
Initial ovarian cancer	90,026.77				20, 34, 35
Yearly ovarian cancer	8,852.09				20, 35
Final-year ovarian cancer	106,400.62				20, 35
Probabilities (%)					
SPG success	95.0	67.5	95.0	50.0	20, 36, UW data
BTL success	95.0	95.0	80.0	99.0	20, 36, UW data
2nd-attempt BTL success	84.5	84.5	99.0	50.0	20, 36, UW data
Ovarian cancer					
No sterilization	1.3	1.3	1.4	1.2	2, 37–41
SPG	0.6*	0.6*	0.2†	0.9‡	2, 37–41
BTL	0.8§	0.8§	1.3‖	0.3¶	2, 37–41
Death resulting from ovarian cancer	75.4	75.4	78.1	54.0	2
Unintended pregnancy					
No sterilization	20.0	20.0	20.0	20.0	42
SPG	0.4	0.4	0.2	0.6	43
BTL	0.8	0.8	1.4	0.4	43
Ectopic pregnancy					
No sterilization	2	2	2	2	22
SPG	10	32.9	10	32.9	22
BTL	20	32.9	32.9	20	22
Utilities					
Cancer in treatment	0.6				20
Cancer in remission	0.8				20
Unintended pregnancy	0.9				20
Ectopic pregnancy#	0.8				20
Death	0				

SPG, salpingectomy; UW, University of Wisconsin; BTL, bilateral tubal ligation.
* Risk reduction: 54%.
† Risk reduction: 83%.
‡ Risk reduction: 27%.
§ Risk reduction: 34%.
‖ Risk reduction: 10%.
¶ Risk reduction: 58%.
# Unintended pregnancy that results in ectopic pregnancy.

of case 0 assumptions was much less variable than the ICER distribution of case 1 distributions, with fewer extreme simulations and more simulations indicating the cost effectiveness of salpingectomy. After application of an ICER threshold of $100,000, 89.8% of case 0 simulations and 71.2% of case 1 simulations indicated that salpingectomy was cost effective. Figure 3 shows the incremental costs and QALYs for each simulation for cases 0 and 1. Contributions to variation in costs for both cases are shown in Figure 4. More simulations under case 0 assumptions than under case 1 assumptions fell within the cost-effective range, with higher incremental QALYs and lower incremental costs across simulations. In 95% of case 0 simulations, incremental costs associated with salpingectomy compared with bilateral tubal ligation were between −$1.3 million and $4.7 million. In case 1 simulations, this range was $0.6–6.7 million. However, both case 0 and case 1 simulations indicated that salpingectomy was more cost effective than bilateral tubal ligation.

We performed two additional extreme cases (optimistic or conservative) to place bounds on the

Table 2. Summary of Incremental Effectiveness and Costs for Simulations*

	Incremental QALY	Incremental Cost ($)	ICER ($)
Base case			
Mean	150.1	1,665,069	26,150
SD	86.5	1,791,683	181,752
5th percentile	6.9	−1,307,072	−7,818
25th percentile	91.0	479,052	1,021
50th percentile	153.3	1,586,320	8,994
75th percentile	209.4	2,857,682	24,904
95th percentile	291.3	4,651,296	111,583
Case 1			
Mean	99.6	3,627,433	4,196
SD	88.8	1,869,791	995,680
5th percentile	−43.0	586,104	−257,602
25th percentile	39.2	2,278,374	6,928
50th percentile	99.2	3,692,926	22,940
75th percentile	160.6	4,845,072	58,925
95th percentile	246.8	6,652,190	260,271

QALY, quality-adjusted life-year; ICER, incremental cost-effectiveness ratio.
* Incremental QALYs, total costs, and resulting ICER are summarized for 1,000 simulations, which assigns a population of 10,000 either bilateral tubal ligation or salpingectomy. Incremental values reflect the difference resulting from pursuing salpingectomy over bilateral tubal ligation. Salpingectomy success rate of 95% is assumed for base case and 67.5% for case 1.

cost-effectiveness estimates (Table 1). With optimistic assumptions, 100% of simulations indicated that salpingectomy was cost saving (and therefore cost effective). Under conservative assumptions, 100% of simulations indicated that salpingectomy was not cost effective.

DISCUSSION

In the majority of simulated cases, our model demonstrated that salpingectomy was more cost effective for reducing ovarian cancer risk than bilateral tubal ligation after vaginal delivery. Standardization of opportunistic salpingectomy for immediate postpartum sterilization in patients who have completed childbearing would decrease the number of ovarian cancer cases, associated morbidity, and deaths and reduce the rate of unintended pregnancy. Despite the cost attributed to the use of bipolar energy devices, opportunistic salpingectomy was cost effective in

Table 3. Summary Statistics for Incremental Costs by Cost Type*

	Incremental Cost ($)		
	Total	Pregnancy	Cancer
Base case			
Mean	1,665,069	−1,085,800	−3,299,331
SD	1,791,683	145,466	1,783,578
5th percentile	−1,307,072	−1,323,619	−6,286,133
25th percentile	479,052	−1,183,899	−4,514,859
50th percentile	1,586,320	−1,086,209	−3,369,728
75th percentile	2,857,682	−981,723	−2,093,696
95th percentile	4,651,296	−853,129	−344,302
Case 1			
Mean	3,627,433	−202,512	−2,220,254
SD	1,869,791	156,997	1,851,435
5th percentile	586,104	−445,942	−5,225,073
25th percentile	2,278,374	−309,008	−3,538,995
50th percentile	3,692,926	−204,083	−2,171,167
75th percentile	4,845,072	−92,721	−980,546
95th percentile	6,652,190	48,520	755,336

The mean procedure cost is $6,050,200 across all percentiles for the base case and case 1; the standard deviation (SD) for cost is 0.
* Incremental costs are summarized for 1,000 simulations. Incremental values reflect the difference resulting from pursuing salpingectomy over bilateral tubal ligation. Salpingectomy success rate of 95% is assumed for base case and 67.5% for case 1.

Table 4. Avoided Unintended Pregnancies, Ovarian Cancer Cases, and Cancer Deaths*

	Unintended Pregnancies	Ovarian Cancer Cases	Ovarian Cancer Deaths
Base case			
Mean	170 (−116)	85 (−25)	63 (−19)
SD	13 (15)	9 (12)	8 (10)
5th percentile	150 (−141)	70 (−45)	51 (−36)
25th percentile	161 (−126)	78 (−33)	58 (−26)
50th percentile	170 (−115)	84 (−25)	63 (−19)
75th percentile	181 (−105)	91 (−17)	69 (−12)
95th percentile	192 (−91)	100 (−4)	77 (−2)
Case 1			
Mean	171 (−23)	85 (−17)	63 (−12)
SD	12 (17)	9 (12)	8 (11)
5th percentile	151 (−51)	70 (−37)	51 (−30)
25th percentile	162 (−35)	79 (−25)	58 (−19)
50th percentile	170 (−23)	85 (−16)	63 (−12)
75th percentile	180 (−12)	91 (−9)	69 (−5)
95th percentile	191 (4)	100 (3)	77 (4)

Data are n (change).

* Estimated avoided pregnancies, ovarian cancer cases, and deaths are summarized for 1,000 simulations. Incremental values reflect the difference resulting from pursuing salpingectomy over bilateral tubal ligation. Salpingectomy success rate of 95% is assumed for base case and 67.5% for case 1.

89.8% of simulations, with an average ICER of $26,149.60, which is well below the cost-effectiveness threshold of $100,000. Furthermore, simulations indicated that opportunistic salpingectomy was cost saving in 13% of cases.

Our findings are consistent with research evaluating the cost effectiveness of salpingectomy in the peripartum period[21] and bring new evidence to this practice after vaginal delivery. Subramaniam et al[21] evaluated the cost effectiveness of opportunistic salpingectomy at the time of cesarean delivery, reporting that salpingectomy was the more cost-effective strategy and was cost saving in multiple scenarios. They calculated an average ICER of $26,616/QALY,[21] which was similar to the ICER we calculated here. Dilley et al[22] evaluated the cost effectiveness of salpingectomy at the time of benign hysterectomy by using a population-based model deriving inputs from the Surveillance, Epidemiology and End Results program. They reported that incorporation of salpingectomy into laparoscopic hysterectomy would save $23.9 million in health care costs annually, with an ICER of $31,432/QALY.[22] The cost effectiveness of opportunistic salpingectomy during benign abdominal surgery has also been examined. Matsuo et al[12] constructed a decision model examining a cohort of women undergoing laparoscopic cholecystectomy with or without opportunistic salpingectomy, demonstrating the cost effectiveness of this method with an ICER between $11,162 and $26,463 across various age ranges. Our model indicates that the cost effectiveness of opportunistic salpingectomy immediately after vaginal delivery is similar to that of opportunistic salpingectomy in other clinical settings.

Several studies have reported procedural risks of opportunistic salpingectomy immediately after

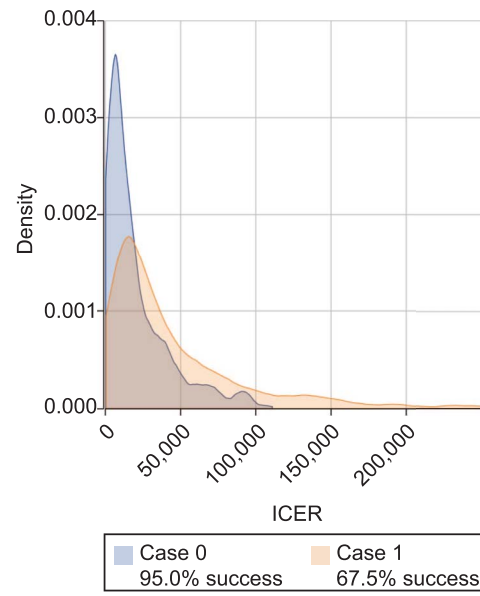

Fig. 2. Distribution of incremental cost-effectiveness ratio (ICER) for the base case (case 0) and the case with a lower success rate for salpingectomy (case 1). Limited to 830 simulations under case 0 and 853 simulations under case 1, where ICER is positive.

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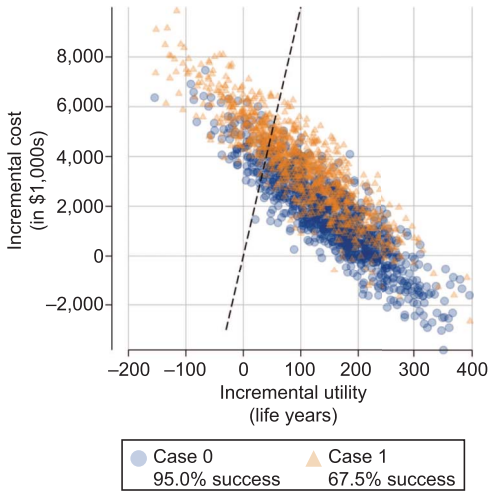

Fig. 3. Distribution of incremental costs for the base case (case 0) and the case with a lower success rate for salpingectomy (case 1). The incremental costs and quality-adjusted life-years (QALYs) are plotted for each of 1,000 simulations under two alternate cases. The *dashed line* represents the incremental cost-effectiveness ratio threshold of $100,000/QALY. Points to the right and below the line are cost effective.

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vaginal delivery.[11,16,18,23] Opportunistic salpingectomy requires similar operative time, results in similar blood loss, and has similar rates of short-term postoperative complications compared with bilateral tubal ligation.[11,16,18] When energy devices are used, salpingectomy can be completed in shorter operative times relative to traditional methods of suture ligation, with improved surgeon satisfaction.[16,23] Venkatesh et al[24] recently reported results of a cost-effectiveness model evaluating opportunistic salpingectomy compared with tubal ligation at the time of cesarean delivery over a wide range of cancer risk reduction and perioperative complication probabilities. Their model suggested that salpingectomy was cost effective with an ICER of $23,189/QALY. However, salpingectomy was not cost effective if the risk of perioperative complication was more than 2% higher for salpingectomy or if the cancer risk reduction potential of salpingectomy was less than 52%, highlighting the uncertainty in data surrounding these inputs.

A few investigators have examined other effects of salpingectomy. For example, data from population-based cohorts revealed that opportunistic salpingectomy was not associated with decreased ovarian reserve or an earlier age of menopause.[15,25] Little is known about the relative effects of salpingectomy and bilateral tubal ligation on cardiovascular risk, osteoporotic risk, or development of other cancers. It is important to note that all of the studies comparing safety and operative metrics for salpingectomy with bilateral tubal ligation in the immediate postpartum period were retrospective.[16,18] As salpingectomy becomes more widely used,[13,14] differences in operative outcomes and costs will become more evident. In addition, prospective trials evaluating salpingectomy as a means of ovarian cancer risk reduction in women with *BRCA* mutations are underway and will provide important information on this strategy for women at high risk of ovarian cancer.[26,27] Given that current evidence does not suggest differences in risks between opportunistic salpingectomy and bilateral tubal ligation strategies, we did not include these risks in our current model.

We note several limitations of our study. First, we used our own institutional charge data to calculate the cost difference between salpingectomy and bilateral

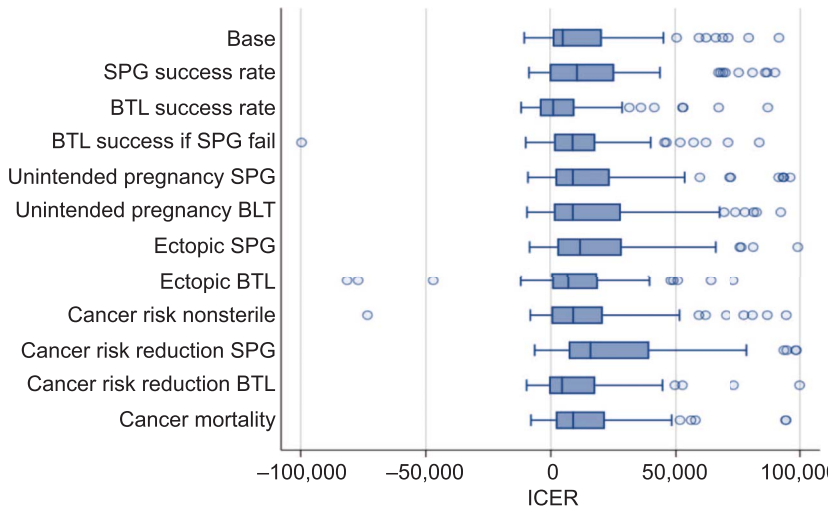

Fig. 4. Range of incremental cost-effectiveness ratios (ICER) for base case (case 0) and by alternate probability assumptions. Each *box* represents the 25th–75th percentile, with the *center line* denoting the median. Each *dot* represents an outlier. Assumed probabilities were decreased by 5% sequentially while all other probabilities were held constant. SPG, salpingectomy; BTL, bilateral tubal ligation.

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tubal ligation. Salpingectomy cost $605.02 more than bilateral tubal ligation because of the use of bipolar energy devices. Future research could directly compare cost and procedural outcomes for patients undergoing peripartum opportunistic salpingectomy with and without bipolar energy devices.

Second, our decision model was inherently limited by the assumed inputs. Most important, we did not account for patients with family history or genetic profile indicating an elevated risk of ovarian cancer, so our results may not be applicable to a patient population at high risk. Furthermore, the National Comprehensive Cancer Network does not currently recommend salpingectomy to reduce ovarian cancer risk in populations at high risk, such as *BRCA1/2* mutation carriers.[28] Although prospective randomized trials are currently evaluating salpingectomy alone compared with bilateral salpingo-oophorectomy to reduce ovarian cancer risk in patients at high risk,[26,27] evidence for salpingectomy as a method of primary prevention in these patients is currently lacking. Thus, our current model should not be applied to this patient population. Similarly, our decision model assumed the development of high-grade serous carcinoma and did not account for rarer histologic subtypes that may present at different stages of life or with varying degrees of morbidity, affecting health care utilization and cost. Third, we did not account for patients undergoing procedures to restore fertility after undergoing permanent sterilization. An estimated 8.2% of patients between the ages of 31 and 35 years regret undergoing permanent sterilization.[29] Such patients can undergo tubal reanastomosis or in vitro fertilization. However, the risk of regret after either salpingectomy or bilateral tubal ligation is likely similar. Finally, we did not account for the fact that some patients undergoing tubal ligation may in the future undergo hysterectomy with completion salpingectomy. This could overestimate the effectiveness of salpingectomy compared with bilateral tubal ligation in our model.

In summary, our cost-effectiveness analysis provides evidence that, immediately after vaginal delivery, salpingectomy is more cost effective than bilateral tubal ligation. Future research should prospectively assess the relative risks of salpingectomy and bilateral tubal ligation in the postpartum period and should focus on the long-term potential of these two approaches for reducing ovarian cancer risk. Furthermore, despite guideline-based recommendations supporting opportunistic salpingectomy, various racial and ethnic groups inequitably receive opportunistic salpingectomy.[30] Routine institutional policy supporting opportunistic salpingectomy in the postpartum period could mitigate these disparities and ensure equitable delivery of surgical prophylaxis.[13] Our analysis supports opportunistic salpingectomy as a cost-effective method of postpartum sterilization immediately after vaginal delivery.

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