REVIEW ARTICLE

Risk-Reducing Appendectomy and the Elimination of *BRCA1*-Associated Intraperitoneal Cancer

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Risk-reducing bilateral salpingo-oophorectomy (RRBSO) and risk-reducing mastectomy are widely used for *BRCA1* and *BRCA2* mutation carriers to reduce the risk of ovarian and breast cancer. To our knowledge, no risk-reduction therapy has addressed the *BCRA1/2* carrier lifetime risk of intra-abdominal peritoneal carcinoma from an appendix source. We identified a *BRCA1* carrier in a hereditary breast and ovarian cancer kindred who developed a low-grade malignant appendiceal mucocele 2 years after risk-reducing salpingo-oophorectomy. Our retrospective meta-analysis assessed the risk of intraperitoneal appendiceal cancer in *BRCA1/2* carriers after RRBSO to determine whether elective risk-reduction appendectomy could reduce the incidence of intraperitoneal cancer. Data sources included the case report and 12 reports of *BRCA1* and *BRCA2* carriers after RRBSO with ovarian, fallopian tube, breast, and peritoneal cancer published from January 1, 1985, through April 30, 2012. Main outcome measures were nonovarian, non–fallopian tube, nonbreast, positive intra-abdominal peritoneal carcinoma in previously cancer-free *BRCA1/2* carriers after RRBSO. The source of intraperitoneal cancer in *BRCA1/2* carriers after risk-reducing salpingo-oophorectomy is highly likely the appendix. Use of risk-reduction appendectomy with RRBSO in younger *BRCA1/2* carriers may reduce lifetime risk of malignant tumor and eliminate intraperitoneal cancer.

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The well-documented penetrance of ovarian cancer (OC) in *BRCA1* (OMIM 113705) mutation carriers is 11% to 54%, and the OC penetrance in *BRCA2* (OMIM 600185) carriers is 11% to 23%.[1-5] Clinical therapy for OC prevention has progressed to routine use of risk-reducing bilateral salpingo-oophorectomy (RRBSO) in women with hereditary breast cancer and OC (HBOC) kindred.[3,4] Risk-reduction operative ablative procedures have been reported in more than 8000 women resulting in reduction of risk of OC in HBOC kindreds by 80%.[6] Multiple studies have noted that *BRCA1/2* carriers after BSO retain a lifetime risk of intraperitoneal cancer from 1% to 10%.[7,8] The peritoneal cancer occurrence in *BRCA1/2* cohorts presents an unknown, unanswered mortality question related to the pathologic origin site of the intraperitoneal tumor: ovarian or fallopian tube or gastrointestinal (GI) intra-abdominal primary sites remain the most common suggested sources.

See Invited Critique at end of article

An element of diagnostic difficulty is using only histologic examination in determining the primary organ source of malignant tumor intraperitoneal carcinomatosis. On the basis of the histology of intraperitoneal cancers, the primary site has been reported to be an ovary, a fallopian tube, or the appendix and other possible GI sources, such as the colon, stom-

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ach, bile duct, or pancreas.[9] All the peritoneal cancers from GI sources have been documented to produce histologically quite similar serous intraepithelial mucoid cells. The appendiceal source of low-grade mucoid tumor follows a clinical course of origin and growth within the appendix progressing to appendiceal rupture and peritoneal surface dissemination with carcinomatosis, which has been called pseudomyxoma peritonei (PMP) for decades.[10-16] Many published reports[17-20] of intraperitoneal cancer occurrence in *BRCA1/2* cohorts suggest that after RRBSO a pathology laboratory analysis error has occurred.

The multiple primary cancer sites associated with *BRCA1/2* carriers result in lifetime cancer risk for HBOC kindred of 85% compared with 38% in the general population.[21,22]

The current case report of *BRCA1* HBOC kindred developing a low-grade malignant appendiceal mucocele 2 years after RRBSO is notable. The clinical presentation reveals an unsuspected malignant appendiceal mucocele before rupture without intraperitoneal dissemination. This case is an example of a potential major cause of intraperitoneal cancer in *BRCA1* mutation carriers in which rupture of the appendix results in PMP. This clinical case prompted a retrospective meta-analysis literature review to assess the relationship of *BRCA1/2* mutation carriers after RRBSO and risk-reducing bilateral mastectomy (RRBM) who develop intraperitoneal cancer and to determine whether elective risk-reduction appendectomy would reduce the residual intraperitoneal cancer risk in female *BRCA1/2* carriers.

To estimate the risk of nonovarian, non–fallopian tube, primary appendix origin of intraperitoneal cancer in *BRCA1/2* mutation carriers, a review of published studies of *BRCA1/2* cohorts was conducted. The review yielded 12 nonoverlapping studies reporting the incidence of intraperitoneal cancer. These studies[23-34] included *BRCA1/2* carriers after RRBSO and RRBM with no history of breast, ovarian, fallopian tube, or uterine cancer. These studies form the basis of a meta-analysis estimate of intraperitoneal cancer risk from a suspected primary appendiceal source in *BRCA1/2* carriers who were documented to be free of all other primary cancer sites.

METHODS

The Indiana University institutional review board provided expedited approval of the study (full review of case studies and meta-analyses is not required by this board). Methods and case report clinical data were obtained, de-identified from hospital records of the *BRCA1* patient and her HBOC kindred.

META-ANALYSIS CRITERIA

Intraperitoneal cancer primary site of origin is a diagnosis of exclusion reached by a process of elimination, which is the method used to identify the intraperitoneal cancer source of the highest probability. The method of elimination is iterative. The possible primary site of origin of intraperitoneal cancer in every patient considered for enrollment in this meta-analysis was identified. Every case enrolled from published cohorts into the present meta-analysis had established resections of several primary sites (breast, ovary, fallopian tube, and uterus), thus eliminating these as primary site possibilities. This left only 4 intra-abdominal sites of intraperitoneal cancer: appendix, colon, GI tract, or pancreas. The latter GI sources (colon, GI tract, and pancreas) cannot be accepted as probable primary sites with no primary organ mass and no symptoms, which leads to greater than 99.99% diagnosis before classification as intraperitoneal cancer. Any *BRCA1/2* mutation carrier reported to have colon, gastric, or pancreatic cancer was excluded from the analysis.

META-ANALYSIS DATA ACCRUAL

Meta-analysis patient-specific clinical data were extracted from the case report, and 12 reports published from January 1, 1985, through April 30, 2012, were obtained from a PubMed search[23-34] of *BRCA1/2* mutation carriers followed up after RRBSO and/or RRBM who developed peritoneal cancer.

Cohort studies and prospective studies with retrospective elements were reviewed, and the case familial series report was included. The basic design of the 12 published studies used to extract data was that of a prospective cohort study of *BRCA1* and *BRCA2* female carriers. The case report qualified as a familial cohort series. Randomized control trials were excluded. The major effect of pathologic determination within any reported cohort series was derived from specific data on individual patient cancer site identification, and there was no overlap with prior reports.

Length of follow-up by definition was more than 5 years after RRBSO and/or RRBM in order to have a patient develop intraperitoneal cancer with no risk of peritoneal metastatic cancer from these common sources. This study used process of elimination to lead to a conclusion. All other consensus primary-origin sites of intraperitoneal cancer (of the breast, uterus, fallopian tube, ovary, pancreas, colon, and stomach) were methodically excluded from any patient included in this meta-analysis.

DATA EXTRACTION METHOD

The method used an extensive limitation of inclusion criteria. The "extraction criteria" eliminated all other consensus-accepted primary pathologic sources of reported intraperitoneal cancers in female patients. This method assumes that breast, ovarian, fallopian tube, uterine, pancreatic, colon, or stomach primary cancer had been identified and reported in the manuscripts used in the meta-analysis. For the published studies to be accepted in this meta-analysis, all cancer sources in all patients had to be reported. In publications accepted into the meta-analysis, all breast, ovarian, and fallopian tube cancers found in resected tissues in the patients were reported, and these specific patients were excluded from the analysis. Only previously cancer-free patients and those with intraperitoneal cancer with no other primary-site cancer identified were extracted from series for inclusion in this study. All reports of any other cancer site or mortality from all other causes resulted in exclusion of the patient from the current meta-analysis.

RISK ANALYSIS

A meta-analysis estimate of risk and mortality reduction was stratified by *BRCA1* and *BRCA2* mutation status, intraperitoneal carcinoma incidence, sex, OC status, breast cancer status, other cancer site status, and age to evaluate the risk and benefit of a novel intraperitoneal cancer risk-reduction strategy: elective appendectomy. The analysis cohort was restricted to women, and all cases of OC or breast cancer of any stage identified before or after RRBSO were excluded. Also, all patients with any other cancer present before or at the time of RRBSO and/or RRBM were excluded. Therefore, all patients with extraperitoneal cancer or with intraperitoneal cancer that could represent OC or breast cancer or fallopian tube cancer progression were excluded.

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Table 1. Meta-analysis: Intraperitoneal Cancer in Otherwise Cancer-Free *BRCA1/2* Patients After RRBSO

		No. of Patients					Peritoneal Cancer, No. of Patients			Risk, %		
Rank	Source	*BRCA1*	*BRCA2*	*BRCA1/2*	Mean Age, y	RRBSO	*BRCA1*	*BRCA2*	*BRCA1/2*	*BRCA1*	*BRCA2*	All (*BRCA1/2*)
0	Case report	3	1	4	45	4	1	0	1	0.333	0.000	0.333
1	Finch et al[23]	374	113	487	51	487	6	1	7	0.016	<0.009	0.016
2	Scheuer et al[24]	77	40	117	48	117	1	0	1	<0.013	0.000	<0.009
3	Olivier et al[25]	26	12	38	48	38	3	0	3	0.115	0.000	<0.079
4	Kauff et al[26]	56	42	98	48	98	1	0	1	<0.018	0.000	0.010
5	Rebbeck et al[27]	114	22	136	52	136	2	0	2	<0.018	0.000	<0.015
6	Powell et al[28]	55	46	101	63	101	6	0	6	0.109	0.000	0.059
7	Maehle et al[29]	48	1	49	56	49	5	0	5	0.104	0.000	0.102
8	Domchek et al[30]	342	123	465	46	465	6	0	6	<0.018	0.000	<0.013
9	Rutter et al[31]	7	0	7	48	7	5	0	5	0.714	0.000	0.714
10	Kauff et al[32]	325	184	509	47	509	3	0	3	0.009	0.000	<0.006
11	Casey et al[33]	65	13	78	56	78	5	0	5	<0.077	0.000	0.064
12	Rhiem et al[34]	91	83	174	47	174	1	0	1	<0.011	0.000	<0.006
Totals		**1583**	**680**	**2263**	59.4[a]	**2263**	**45**	**1**	**46**	11.644[a]	0.885[a]	10.970[a]

Abbreviation: RRBSO, risk-reducing bilateral salpingo-oophorectomy.
[a] Indicates a mean value.

STATISTICAL MODELING

Statistical modeling used data censoring and Cox proportional analysis and has been widely used in *BRCA* studies.[35] Data censoring was performed to remove variables and narrowed to a specific variable (intraperitoneal cancer) assessment over time variable before applying Cox proportional risk assessment.[36]

HAZARD RATIO ANALYSIS

Hazard ratio estimates were identified directly from data extracted from the original articles. Pooled results were computed from nonconcurrent studies by fixed-effects meta-analysis.[37] Intraperitoneal cancer incidence was calculated directly from extracted data by age, mutation-type cohort, and other-site "cancer-free" status. The hazard ratio analysis using Cox proportional hazard risk was performed comparing risk of intraperitoneal cancer occurrence in each specific group: all *BRCA1* carriers and all *BRCA2* carriers, and all female *BRCA1* plus *BRCA2* carriers. Also, hazard ratio analysis of censored longitudinal data of intraperitoneal cancer in patients with *BRCA1*, *BRCA2*, and *BRCA1/2* was determined by unpaired *t* test.[38]

RESULTS

CASE REPORT

A 44-year-old woman presented with a 40-day history of increasing right lower quadrant abdominal pain. Her medical history was significant for RRBSO and risk-reducing mastectomy as a carrier of *BRCA1* mutation 2 years before this presentation. Both her mother and sister were kindred *BRCA1/2* carriers who had developed OC. The patient did well after RRBSO. Subsequently, evaluation of the new abdominal pain included a computed tomographic scan that demonstrated a large appendiceal mass. At exploratory laparotomy, she was found to have an appendiceal mass, which was resected with appendectomy and partial cecectomy. This was malignant. Pathologic evaluation revealed a nonperforated, low-grade, mucinous appendiceal neoplasm with negative colonic margins and no nodal involvement in the 5 lymph nodes evaluated. The patient was discharged 24 hours after the operation and has done well in 1 year of follow-up. The case reveals the clinical presentation of an unsuspected appendiceal mucocele before progression to intraperitoneal cancer in a *BRCA1* mutation carrier from a well-documented HBOC kindred.

META-ANALYSIS ESTIMATE

The meta-analysis estimates of risk of primary peritoneal cancers for HBOC kindred women with no breast, no ovarian, and no fallopian tube cancers after RRBSO, by age and mutation type, are presented in **Table 1**. The risk of peritoneal cancer following RRBSO was significantly higher for *BRCA1* mutation carriers than for *BRCA2* mutation carriers (11.6% vs 0.9%; $P < .01$) (Table 1). Also notable is that intraperitoneal cancer incidence increased with age. There was 0% risk before age 40 years. No case of intraperitoneal cancer in *BRCA1/2* cohorts younger than 40 years was reported.

The annualized *BRCA1* carrier intraperitoneal cancer hazard risk of 0.06% rose from the youngest reported case (age 42 years) in a cumulative fashion, which summed to 5% per decade after the fifth decade of life (40-49 years of age). The cumulative hazard rate reached 11.6% penetrance after the seventh decade (**Figure**). This represents 30 years of exposure after age 40. This steady increase in intraperitoneal cancer correlation with age may relate to increased occurrence due to timeline exposure or due to years' delay in clinical presentation. Hazard risk analysis revealed 6.8% annualized risk in *BRCA1* carriers older than 40 years and 0.5% risk in *BRCA2* carriers older than 40 years. Total *BRCA1/2* carriers have 6.7% annual hazard risk of intraperitoneal cancer (**Table 2**).

Statistical modeling predicts that widespread use of elective risk-reduction appendectomy in HBOC kindred *BCRA1* mutation carriers combined with early RRBSO would result in 99% reduction of the lifetime risk

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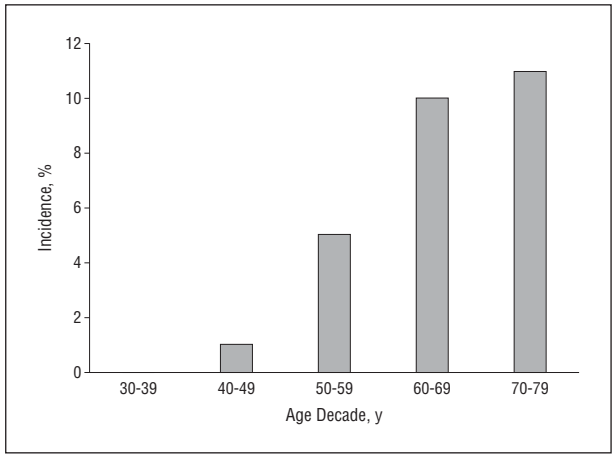

Figure. Intraperitoneal cancer cumulative incidence in *BRCA1* carriers.

Table 2. Hazard Risk of Intraperitoneal Cancer in *BRCA1/2* Carriers After Risk-Reducing Bilateral Salpingo-oophorectomy

Variable	*BRCA1*	*BRCA2*	*BRCA1/2*
Hazard risk assessment	2.721518987	0.147058824	2.032699956
Annual risk	0.068037975	0.004901961	0.067756665
Annual risk, %	6.803797468	0.490196078	6.775666519

for intraperitoneal cancer. Risk-reduction appendectomy would not reduce peritoneal cancer if the source were gastric, biliary, pancreatic, or other colonic sites as typically found in other familial cancer cohorts, such as familial adenomatous polyposis. Risk-reduction appendectomy, when combined with RRBSO and risk-reducing mastectomy, may also complete a "trifecta" resulting in an 80% reduction of total lifetime cancer risk.

The *BRCA1/2* mutation carries a 1000-fold increased risk of peritoneal cancer compared with the risk in the general population. Also, *BCRA1* mutation carries a specific 11.6% lifetime risk of intra-abdominal peritoneal cancer. Aging increases the risk of peritoneal cancer in *BRCA1/2* mutation carriers. This study indicates that age greater than 40 years carries a 1000-fold increased risk of mucinous peritoneal cancer in HBOC kindred women. In *BRCA1* carriers, aging steadily increased the risk of intraperitoneal cancer by 0.5% per year after the age of 40 years was reached (Figure). The cohort of women with *BRCA1* mutations who are older than 40 years have a significantly increased incidence of intraperitoneal cancer compared with the general population.

COMMENT

Women who carry the *BRCA1* and/or *BRCA2* genetic mutations have a well-documented increased risk of breast, ovarian, and fallopian tube cancers. Individual lifetime OC risk is estimated to range from 36% to 63% but is elevated to 95% if both maternal and sibling *BRCA1* carriers have already developed OC.[39] Additional cancer risk has also been reported to include an increased association of intra-abdominal peritoneal malignant tumors with OC.[40] Some highly selective *BRCA1/2* cohort studies based on primary therapy RRBSO in young patients and brief follow-up with or without chemotherapy report a low incidence of intraperitoneal cancer.[41] Other larger, longer-term studies have identified peritoneal carcinomatosis in 2% to 3% of *BRCA1/2* HBOC kindred cohorts after RRBSO with no prior OC diagnosis.[23-34]

Multiple studies have observed that female carriers of *BRCA1* or *BRCA2* germline mutations are at an increased risk of developing breast, ovarian, salpingo-fallopian tube, and/or peritoneal malignant tumors. Management strategies for genetically susceptible women include genetic counseling, chemoprevention, radiologic and tumor-marker surveillance, and risk-reducing surgery, such as mastectomy and bilateral salpingo-oophorectomy.[42]

Identification of the source organ in intraperitoneal cancer is frequently inaccurate because the pathology nomenclature classification includes primary papillary serous carcinoma of the peritoneum with no identification of the primary organ site. Papillary serous carcinoma of the peritoneum is considered a rare tumor found predominantly in elderly and postmenopausal women. Papillary serous carcinoma of the peritoneum has histologic characteristics similar to serous ovarian papillary carcinoma, serous fallopian tube cancer, and PMP arising from the appendix.[43-45] These histologic similarities render an extracorporeal pathologic identification of organ origin site quite difficult, with primary site investigation limited to radiologic imaging and histologic analysis without pathologic examination of the primary organ site following excision or resection. Although the pathogenesis of papillary serous carcinoma of the peritoneum remains unclear, documentation or exclusion of GI sources has not been complete. Several published familial studies[46,47] have included peritoneal carcinoma in the HBOC syndrome, which also includes breast, ovarian, and fallopian tube neoplasms.

Many published reports[16-19] of intraperitoneal cancer in *BRCA1/2* cohorts suggest that occurrence after RRBSO indicates that a pathology laboratory analysis error has occurred. The possible errors include that OC or fallopian tube cancer was not found or that cancer was missed owing to a sampling error or poor pathology processing. The diffuse peritoneal cancer primary source of origin has commonly been suggested to be an ovary, a fallopian tube, or the appendix (PMP) or to be a pancreatic intraductal papillary mucinous neoplasm, or a low-grade colonic mucoid epithelial tumor.[48] The total cancer risk for a *BRCA* HBOC kindred is increased for gastric cancer, gallbladder and biliary tract cancer, and melanoma.

Multiple other primary sites of metastatic intraperitoneal mucoid epithelial serous cancers may originate from GI sources. Low-grade, mucinous, adenomatous, intraperitoneal colon cancer syndromes include Lynch syndrome, familial adenomatous polyposis, attenuated familial adenomatous polyposis, *MYH*-associated polyposis, familial colon rectal cancer, Peutz-Jeghers syndrome, juvenile polyposis syndrome, hereditary mixed polyposis syndrome, and hyperplastic polyposis syndrome.[49-57] The *BRCA1/2* gene mutations have never been linked to any of these syndromes nor has *BRCA1/2* been directly linked to colon cancer except in 1 case report.[58] Also, no ovar-

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ian, breast, or fallopian tube cancers have been reported in any of the colon cancer syndrome cohorts.

Many studies have identified multiple variable genetic expressions in histologically similar or identical tumors in appendiceal and ovarian tumors. The incidence of appendiceal cancer is rare, occurring in less than 0.5% of all general population GI tumors.[59] Appendiceal mucocele incidence is reported to occur rarely, in less than 0.3% of all appendectomies, and occurs in less than 0.0001% of the general population based on data about lifetime risk from the Surveillance, Epidemiology, and End Results program of the National Cancer Institute.[60,61] These tumors may represent appendiceal tumors, which progress to locoregional peritoneal carcinomatosis, which is characteristic of PMP. Most intra-abdominal tumors in OC patients are reported as low-grade, mucinous, intraperitoneal cancers.

A mucocele is characterized by the accumulation of mucoid material in the appendiceal lumen. The designation of *mucocele* has been proposed for a neoplasm that is pathologically benign, premalignant, or malignant. Epithelial appendiceal tumor histology has been classed as 4 types: (1) a simple appendiceal mucocele, (2) a mucocele with epithelial hyperplasia, (3) a cystadenoma, and (4) a cystadenocarcinoma.[62,63] The latter 2 are more aggressive neoplasms. Dissemination of neoplastic cells producing mucoid material in the abdominal cavity typically occurs following appendiceal perforation, which results in PMP. This has been reported in 10% to 15% of appendiceal epithelial tumors. Metastatic dissemination of appendiceal low-grade epithelial tumors by vascular or lymphatic invasion has not been reported. These appendiceal benign or malignant proliferative pathologic features either can remain asymptomatic for a lifetime or present clinically with abdominal pain associated with intraperitoneal volume space reduction due to increasing tumor volume. The most common initial clinical manifestation is pain in the right iliac fossa. The appendiceal epithelial proliferative pathology diagnosis is most frequently based on intraoperative observation without histologic evaluation.

To our knowledge, this report presents the first case of a documented HBOC kindred *BRCA1* carrier presenting with an appendiceal mucocele tumor 2 years after RRBSO before developing PMP. This analysis provides strong clinical evidence that *BRCA1* mutation carriers older than 40 years carry an additional 11% lifetime risk of appendiceal mucinous neoplasm, which is the most likely source of reported intraperitoneal cancer in *BRCA1* and *BRCA2* carriers. The data also strongly suggest that appendiceal tumors are the predominant source of intraperitoneal cancer in *BRCA1/2* mutation carriers who have undergone RRBSO and have no fallopian tube cancer or OC.

Treatment of appendiceal tumor is excision appendectomy. Appendectomy is curative for a simple appendiceal mucocele, for an appendiceal mucocele with epithelial hyperplasia, and for cystadenoma with an intact appendiceal base; cecal resection is indicated for cystadenoma with appendiceal base involvement or invasion.[64] Right hemicolectomy remains the elective oncologic staging and treatment for appendiceal cyst adenocarcinoma. Elective appendectomy carries no risk of functional loss and total operative risk of less than 0.01%.[62,65] Elective appendectomy performed during RRBSO would not result in significant complications specifically related to appendectomy.[66]

These facts, the strong statistical correlation of appendiceal mucinous peritoneal malignant tumor with OC, and the increased risk of intra-abdominal carcinomatosis in *BRCA1* carriers support the proposed clinical treatment mandate of risk-reduction surgery to include prophylactic elective appendectomy with RRBSO in all *BRCA1* carriers older than 40 years.

CONCLUSIONS

This meta-analysis confirms that *BRCA1/2* mutation carrier cohorts older than 40 years have significantly increased incidence and risk of intraperitoneal cancer compared with the general population. The *BRCA1* mutation carrier has a 6.8% annualized cumulative hazard risk of intraperitoneal cancer compared with a 1% risk in *BRCA2* carriers. The *BRCA1* risk of 11.6% is increased 1000-fold above that of PMP or other intraperitoneal cancer risk in the general population, whose risk is 1 in 100 000 (0.001%). Based on the hazard risk assessment, the addition of risk-reduction appendectomy to RRBSO and RRBM in the cohort of women older than 40 years with *BRCA1* or *BRCA2* mutations is predicted to reduce the annual 6.7% risk of intraperitoneal cancer. This may also contribute a 12% total reduction in lifetime malignant tumor risk after eliminating the breast, fallopian tube, ovary, and appendix as intraperitoneal cancer primary source risks. The statistical model predicts that widespread use of risk-reduction appendectomy with RRBSO and risk-reducing mastectomy in HBOC kindred *BCRA1* mutation carriers would result in a 99% reduction of the lifetime risk for peritoneal cancer and also lower total lifetime cancer risk from 95% to 20%.

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INVITED CRITIQUE

The Appendix

A Culprit for BRCA1*-Associated Intraperitoneal Cancer?*

Women with inherited *BRCA1/2* mutations have substantially elevated risks of breast and ovarian cancer, with 60% to 85% cumulative lifetime risk of invasive breast cancer and 10% to 63% risk of ovarian cancer.[1-3] Prophylactic mastectomy and risk-reducing bilateral salpingo-oophorectomy (RRBSO) reduce the risk of both cancers and of cancer-specific and all-cause mortality in these patients.[1]

Women with *BRCA1* mutations also have an increased risk of intra-abdominal carcinomatosis, which is reduced but not abrogated following RRBSO. The estimated risk for intra-abdominal carcinomatosis following RRBSO is less than 5%.[4,5] The origins of intra-abdominal carcinomatosis after RRBSO remain unclear; dissemination of occult ovarian, fallopian tube, and possibly endometrial neoplasms has been suggested.

Here, Sitzmann and Wiebke[6] review 12 studies examining outcomes among female *BRCA1/2* mutation carriers. They report a 2% incidence (46 of 2262 patients) of intraperitoneal cancer following RRBSO; most cases occurred in *BRCA1* mutation carriers. The authors raise the interesting possibility that the appendix may be the source of intraperitoneal cancer following RRBSO.

Although this hypothesis is intriguing, the data are far from convincing. The authors make the assumption that all cases of intraperitoneal cancer after RRBSO must be secondary to an appendiceal source because other potential sources were previously resected (ovaries and fallopian tubes) or "should" present with a primary lesion (colon, stomach, or pancreas). However, in the case of at least 1 patient included in this study, occult borderline serous papillary tumor was found in 1 ovary removed during RRBSO.[4] It is also unknown how many of the patients with intraperitoneal cancer after RRBSO in this study had an appendix in situ because appendectomy is among the most commonly performed surgeries in the United States with an estimated 250 000 to 300 000 cases in 2010. The title "Risk-Reducing Appendectomy and the Elimination of *BRCA1*-Associated Intraperitoneal Cancer" is misleading because no patients included in this study underwent prophylactic appendectomy.

It therefore remains to be seen whether the appendix is a significant contributor to intra-abdominal cancer following RRBSO or whether occult gynecologic sources (ovaries, fallopian tubes, or endometrium) are the major players. If the authors' theory can be verified, a question that still must be addressed before widespread adoption of appendectomy at the time of RRBSO is whether the intraperitoneal cancer risk-reduction benefit of prophylactic appendectomy justifies its attendant surgical risks.

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