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Reducing Unnecessary Oophorectomies for Benign Ovarian Neoplasms in Pediatric Patients

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Supplemental content

IMPORTANCE Although most ovarian masses in children and adolescents are benign, many are managed with oophorectomy, which may be unnecessary and can have lifelong negative effects on health.

OBJECTIVE To evaluate the ability of a consensus-based preoperative risk stratification algorithm to discriminate between benign and malignant ovarian pathology and decrease unnecessary oophorectomies.

DESIGN, SETTING, AND PARTICIPANTS Pre/post interventional study of a risk stratification algorithm in patients aged 6 to 21 years undergoing surgery for an ovarian mass in an inpatient setting in 11 children's hospitals in the United States between August 2018 and January 2021, with 1-year follow-up.

INTERVENTION Implementation of a consensus-based, preoperative risk stratification algorithm with 6 months of preintervention assessment, 6 months of intervention adoption, and 18 months of intervention. The intervention adoption cohort was excluded from statistical comparisons.

MAIN OUTCOMES AND MEASURES Unnecessary oophorectomies, defined as oophorectomy for a benign ovarian neoplasm based on final pathology or mass resolution.

RESULTS A total of 519 patients with a median age of 15.1 (IQR, 13.0-16.8) years were included in 3 phases: 96 in the preintervention phase (median age, 15.4 [IQR, 13.4-17.2] years; 11.5% non-Hispanic Black; 68.8% non-Hispanic White); 105 in the adoption phase; and 318 in the intervention phase (median age, 15.0 [IQR, 12.9-16.6)] years; 13.8% non-Hispanic Black; 53.5% non-Hispanic White). Benign disease was present in 93 (96.9%) in the preintervention cohort and 298 (93.7%) in the intervention cohort. The percentage of unnecessary oophorectomies decreased from 16.1% (15/93) preintervention to 8.4% (25/298) during the intervention (absolute reduction, 7.7% [95% CI, 0.4%-15.9%]; P = .03). Algorithm test performance for identifying benign lesions in the intervention cohort resulted in a sensitivity of 91.6% (95% CI, 88.5%-94.8%), a specificity of 90.0% (95% CI, 76.9%-100%), a positive predictive value of 99.3% (95% CI, 98.3%-100%), and a negative predictive value of 41.9% (95% CI, 27.1%-56.6%). The proportion of misclassification in the intervention phase (malignant disease treated with ovary-sparing surgery) was 0.7%. Algorithm adherence during the intervention phase was 95.0%, with fidelity of 81.8%.

CONCLUSIONS AND RELEVANCE Unnecessary oophorectomies decreased with use of a preoperative risk stratification algorithm to identify lesions with a high likelihood of benign pathology that are appropriate for ovary-sparing surgery. Adoption of this algorithm might prevent unnecessary oophorectomy during adolescence and its lifelong consequences. Further studies are needed to determine barriers to algorithm adherence.

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Approximately 20 000 patients are diagnosed with a benign ovarian neoplasm annually in the United States, with 90% undergoing surgical resection. Ovary-sparing surgery (OSS), the standard approach for benign lesions in adults with removal of the tumor only, leaves the normal ovarian tissue in place. Ovary-sparing surgery for benign neoplasms in children ranges from 18% to 77%.[1] This suggests that many children are undergoing unnecessary oophorectomies. Oophorectomy can lead to premature ovarian failure, early menopause, and associated increased risks of cognitive impairment, osteopenia, impaired sexual health, and cardiovascular disease.[2-11] Furthermore, patients with benign ovarian neoplasms are at increased risk of developing a contralateral second neoplasm.[4,12-14] This may result in unintentional castration due to potential contralateral torsion or surgical castration if oophorectomy is ultimately required for malignant disease.

Preoperative risk stratification through a comprehensive evaluation including history and physical examination, imaging studies, and serum tumor markers is critical to help identify lesions that are likely to be benign and appropriate for OSS. Implementation of a preoperative risk stratification algorithm at a single institution reduced unnecessary oophorectomies from 72% to 4.6% with no missed malignancies and no tumor upstaging.[15] We implemented a consensus-based risk stratification algorithm in 11 children's hospitals and evaluated its ability to discriminate between benign and malignant ovarian pathology, hypothesizing that adherence to the algorithm would safely decrease unnecessary oophorectomies for benign neoplasms.

Key Points

Question Can a consensus-based, preoperative risk stratification algorithm reduce unnecessary oophorectomies in pediatric and adolescent patients with benign ovarian disease?

Findings In this multi-institutional, pre/post interventional study that included 519 patients aged 21 years or younger with ovarian masses, the percentage of oophorectomies performed for benign disease decreased from 16.1% to 8.4% after implementation of a consensus-based preoperative risk stratification algorithm.

Meaning Managing pediatric and adolescent patients with ovarian masses using a consensus-based preoperative risk stratification algorithm can prevent unnecessary oophorectomies for benign disease.

Methods

Study Overview

We performed a prospective, multi-institutional, pre/post interventional cohort study of a consensus-based risk stratification algorithm (eFigure 1 in Supplement 1). Patients aged 6 to 21 years treated at 11 children's hospitals participating in the Midwest Pediatric Surgery Consortium were included from August 2018 to January 2021 with an initial 6 months of preintervention assessment (August 1, 2018, to January 31, 2019), 6 months of intervention adoption (February 1, 2019, to July 31, 2019), and 18 months of intervention use (August 1, 2019, to January 31, 2021). Based on preoperative risk of malignancy, patients underwent oophorectomy or OSS. This study was approved with a waiver of consent by the institutional review board (IRB) of the central site (Nationwide Children's Hospital), and all other sites either relied on the central IRB or obtained institutional IRB approval.

Risk Stratification Algorithm Development and Implementation

A multidisciplinary team of pediatric surgeons, pediatric and adolescent gynecologists, radiologists, and medical oncologists collaborated to develop the study's risk stratification algorithm based on clinical experience, practical considerations, and evidence.[16-19] After development, we reviewed outcomes in a cohort of 673 patients from the participating institutions to assess the algorithm's potential to misclassify malignant lesions as benign. Among 55 patients with malignant disease, all had at least 1 concerning feature detailed in the algorithm that would triage them to multidisciplinary team discussion prior to intervention, with none being guided directly to OSS, offering provisional reassurance that the algorithm would not lead to withholding of a curative procedure in children with malignancy. The final version of the algorithm was reviewed and adopted by clinicians at all 11 participating institutions as the standard of care.

Algorithm implementation sought to standardize the workup and management of ovarian masses across clinicians and institutions. Implementation included standardized education on the value of OSS and algorithm use via faculty meetings, feedback to nonadherent surgeons, and development of a local multidisciplinary team. Participants on the multidisciplinary team varied by site based on available specialties and included 2 or more of the following specialties: pediatric surgery, pediatric and adolescent gynecology, adult gynecology, adult gynecologic oncology, radiology, surgical oncology, medical oncology, and pathology. The role of local multidisciplinary teams was to assess the details of cases and use their collaborative clinical judgment to recommend either OSS or oophorectomy based on whether they were concerned for malignancy or thought a lesion was more likely to be benign.

Participants

Patients aged 6 through 21 years diagnosed with an ovarian mass were included. During the intervention phase, each patient was supposed to be evaluated with the study's standardized algorithm. Data on race and ethnicity, as specified by patients or caregivers using fixed categories (**Table 1**), were collected to assess their association with outcomes.

Cases were identified within each institution's electronic medical record using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*), *ICD-10-CM*, and *Current Procedural Terminology* procedure codes listed in the eAppendix in Supplement 1. Study data were collected via

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Table 1. Baseline Participant Characteristics

Characteristics	Preintervention (n = 96)	Adoption (n = 105)	Intervention (n = 318)
Age, median (IQR), y	15.4 (13.4-17.2)	15.0 (13.5-17.1)	15.0 (12.9-16.6)
No. (%)			
<8	2 (2.1)	2 (1.9)	5 (1.6)
8-13	19 (19.8)	21 (20.0)	82 (25.8)
>13	75 (78.1)	82 (78.1)	231 (72.6)
Postmenarche, No./total (%)	81/92 (88.0)	90/101 (89.1)	260/302 (86.1)
Race and ethnicity, No./total (%)[a]	n = 88	n = 93	n = 269
Alaska Native or American Indian	1 (1.1)	1 (1.1)	1 (0.4)
Asian	2 (2.3)	3 (3.2)	7 (2.6)
Black, non-Hispanic	11 (12.5)	17 (18.3)	44 (16.4)
Hispanic, non-White	1 (1.1)	4 (4.3)	11 (4.1)
Hispanic, White	5 (5.7)	7 (7.5)	27 (10.0)
Multiracial	2 (2.3)	4 (4.3)	9 (3.3)
White, non-Hispanic	66 (75.0)	57 (61.3)	170 (63.2)
Preoperative suspicion for torsion, No. (%)	48 (50.0)	48 (45.7)	160 (50.3)
Preoperative abdominal pain, No. (%)	66 (68.8)	80 (76.2)	231 (72.6)
Operative urgency, No. (%)[b]	n = 96	n = 103	n = 313
Urgent	41 (42.7)	31 (30.1)	127 (40.6)
Elective	40 (41.7)	42 (40.8)	112 (35.8)
Emergent	15 (15.6)	30 (29.1)	74 (23.6)
Clinician specialty, No. (%)			
Pediatric surgery	59 (61.5)	61 (58.1)	183 (57.5)
Pediatric and adolescent gynecology	28 (29.2)	34 (32.8)	116 (36.5)
Adult gynecology	7 (7.3)	10 (9.5)	17 (5.4)
Gynecologic oncology	2 (2.1)	0	2 (0.6)

[a] Race and ethnicity were identified by patients or their caregivers from a list that also included "other" with the option of an open-ended response.

[b] Operative urgency was determined by urgency level indicated in the surgical case scheduling.

chart review on a rolling basis including patient demographics, admission characteristics, laboratory results, preoperative imaging, operative details, pathology reports, and postoperative follow-up and imaging. All patients had at least 1 year of follow-up at the time of analysis. Algorithm implementation and adherence monitoring were performed by the principal investigator at each site, monthly enrollment logs submitted to the lead site, and bimonthly study conference calls held to monitor and report algorithm adherence.

Study Outcomes

The primary outcome was the percentage of unnecessary oophorectomies, defined as oophorectomy for a benign ovarian neoplasm. This outcome was evaluated using medical record review with specimen pathology used for confirmation in all cases, including those with torsion, except in 2 cases of torsion that underwent detorsion alone with interval imaging confirmation of simple cyst resolution.

Considering the algorithm as a diagnostic tool to guide patients toward OSS vs oophorectomy based on preoperative assessment of the likelihood of benign vs malignant disease with pathologic confirmation as a reference standard, secondary outcomes included test performance characteristics (sensitivity, specificity, positive and negative predictive values, likelihood ratios, and accuracy) of the algorithm, and the proportion of harmful misclassification of the algorithm (ie, patients with malignant disease undergoing OSS). Ovary-sparing surgery for benign disease was considered a true positive (algorithm guiding to OSS because of high likelihood of benign disease and pathology confirms benign disease), oophorectomy for malignant disease a true negative (algorithm guiding to oophorectomy because of high likelihood for malignancy and pathology confirms malignant disease), OSS for malignant disease a false positive (algorithm guiding to OSS but pathology demonstrates malignant disease), and oophorectomy for benign disease a false negative (algorithm guiding to oophorectomy but pathology demonstrates benign disease). Consensus prespecified thresholds needed to promote algorithm adoption were a positive predictive value greater than 98% and misclassification (guiding patients with malignant disease to OSS) less than 5%.

We calculated these estimates for the overall population and in subgroups by patient age (<8 years, 8-13 years, >13 years), menarche status, operative urgency (emergent, urgent, elective), torsion status (preoperative suspicion, no preoperative suspicion), and surgeon specialty (pediatric surgery, pediatric and adolescent gynecology, adult gynecology, gynecologic oncology).

We also assessed algorithm adherence and fidelity, with adherence assessment based on monthly site enrollment logs and reflecting local team self-assessment of adherence to the algorithm, and fidelity based on central site study staff review

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of final data input as a measure of how well the algorithm was actually adhered to.

Sample Size and Power Calculations

Based on an annual volume of 156 patients with complex ovarian masses, we expected to have 78 patients in the preintervention cohort and 156 patients in the intervention cohort. Assuming 9% of cases being malignant with 27% of preintervention oophorectomies being unnecessary based on historical data from participating sites and 10% of postintervention oophorectomies being unnecessary, this study had 85% power to detect the proposed difference at a 2-sided α = .05 using a Cochran-Mantel-Haenszel test of 2 proportions, stratified by site.[20]

Patients were enrolled for 6 months prior to implementation of the algorithm (preintervention cohort), during a 6-month adoption phase (adoption cohort), and for 18 months after algorithm adoption (intervention cohort). The intervention phase was expected to last 1 year; however, the COVID-19 pandemic changed referral patterns and decreased the number of patients with complex masses treated. Consequently, the intervention phase was extended until 156 patients with complex masses were enrolled based on monthly enrollment logs.

Statistical Analysis

Patient characteristics are described with medians and interquartile ranges and proportions. The proportions of unnecessary oophorectomies in the preintervention and intervention cohorts were compared overall using a Cochran-Mantel-Haenszel test and based on clinician type using Fisher exact tests with significance considered at $P < .05$. Patients from the intervention adoption cohort were excluded from statistical comparisons. Adherence to the algorithm was determined based on monthly enrollment logs completed by each site. Algorithm fidelity was assessed by the lead site as strict adherence to all components of the algorithm. Statistical analysis was performed using SAS Enterprise Guide version 8.1 (SAS Institute Inc).

Results

Demographics and Clinical Characteristics

Of 519 included patients, 96 were in the preintervention phase (August 2018 to January 2019), 105 in the adoption phase (February 2019 to July 2019), and 318 in the intervention phase (August 2019 to February 2021) (Table 1; see eTable 1 in Supplement 1 for site-specific enrollment). Baseline demographic and clinical characteristics of the groups are shown in Table 1. There was no clinically important difference in patient age, race and ethnicity, or operative urgency between the preintervention and intervention groups. The median age of patients who underwent urgent/emergent vs elective operations was similar in the preintervention and intervention groups (15.1 years in both). Site-specific standardized mean differences of patient characteristics comparing preintervention and intervention cohorts are shown in eTable 2 in Supplement 1. Clinical characteristics by study phase for the 4 highest-enrolling sites are shown in eTable 3, A-D, in Supplement 1.

Patient Flow and Outcomes

Patient flow through the algorithm for each phase is detailed in the **Figure**. Among the 318 patients in the intervention group, 174 presented with suspected torsion, 1 of whom was pregnant at presentation and underwent urgent detorsion with OSS, and 2 (1.1%) of whom underwent detorsion alone, both cases of radiographically simple cysts that resolved on interval imaging. Pathology was confirmed in the other 171 cases with 6 malignancies (3.5%), 5 of which were managed with oophorectomy and 1 with OSS in which the lesion was resected in its entirety. Among the remaining 165 with benign tumors, unnecessary oophorectomies were performed in 9 (5.2%), with pathology revealing mature teratoma (5), mucinous tumor (2), and cyst (2).

Among the remaining 144 patients without suspected torsion, 54 had radiographically simple or hemorrhagic cysts and 90 had complex masses. Of patients with complex masses, 85 had concerning features, no patients had negative tumor markers and no concerning features, and 5 patients could not be further classified because tumor markers were not evaluated.

All patients underwent an operation, with 273 OSSs, 43 oophorectomies, and 2 detorsions without additional intervention. Benign disease was confirmed in most (n = 93 [96.9%] in the preintervention cohort; n = 298 [93.7%] in the intervention cohort).

Primary Outcome

The percentage of oophorectomies for benign disease was 16.1% (15/93) preimplementation and 8.4% (25/298) after implementation of the algorithm (absolute risk reduction, 7.7% [95% CI, 0.4%-15.9%]; $P = .03$).

Diagnostic Test Performance

Diagnostic test characteristics of the algorithm for distinguishing benign from malignant disease are detailed in **Table 2**. Test performance for identifying benign lesions among all patients in the preintervention cohort included a sensitivity of 83.9% (95% CI, 76.4%-91.4)%, specificity of 100% (1-tailed 97.5% CI, 29.2%-100%), positive predictive value of 100% (1-tailed 97.5% CI, 95.4%-100%), and negative predictive value of 16.7% (95% CI, 0.0%-33.9%). Performance in the intervention cohort included a sensitivity of 91.6% (95% CI, 88.5%-94.8%), specificity of 90.0% (95% CI, 76.9%-100%), positive predictive value of 99.3% (95% CI, 98.3%-100%), and negative predictive value 41.9% (95% CI, 27.1%-56.6%). These test performance measures were comparable across age, menarche status, operative urgency, torsion status, and surgeon specialty categories (eTables 4-7 in Supplement 1).

Misclassification of patients with malignant disease as eligible for OSS was low, involving 0 of 78 preintervention patients and 2 of 275 intervention patients (0.7%), both of whom had immature teratomas that were completely excised without oophorectomy and without subsequent symptoms, ipsilateral or contralateral recurrence, or need for additional operations.

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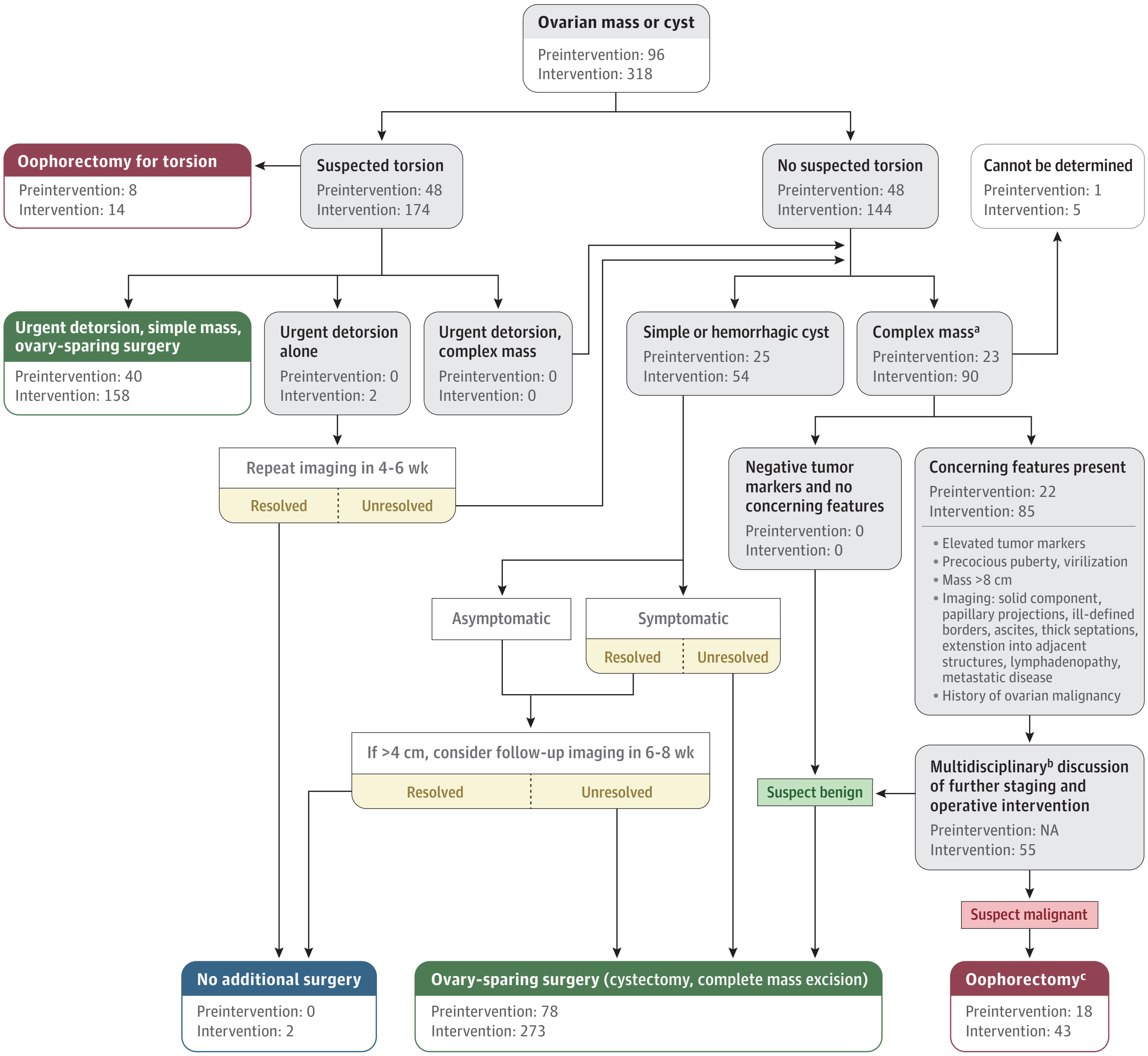
Figure. Algorithm for Management of Ovarian Masses in Pediatric Patients, Including Number of Patients Treated During the Preintervention and Intervention Study Phases



NA indicates not applicable.

[a] Obtain tumor markers, including at least α-fetoprotein, β human chorionic gonadotropin, lactate dehydrogenase, cancer antigen 125, and inhibin A.

[b] Multidisciplinary team varied by site based on available specialties and included 2 or more of the following specialties: pediatric surgery, pediatric and adolescent gynecology, adult gynecology, adult gynecologic oncology, radiology, surgical oncology, medical oncology, and pathology.

[c] Consider peritoneal washings; inspection and/or biopsy of the peritoneum, omentum, contralateral ovary, and retroperitoneal and pelvic lymph nodes; salpingo-oophorectomy if unable to obtain negative margins with oophorectomy alone.

Surgeon Specialty

Most patients were treated by pediatric surgeons or pediatric and adolescent gynecologists (Table 1). There were no differences in the age of patients treated by the 2 specialties, but the few patients treated by adult gynecologic specialty clinicians were slightly older (eTable 8 in Supplement 1). A higher proportion of patients who underwent elective procedures were operated on by pediatric surgeons (62/112 [55.4%]) than by pediatric and adolescent gynecologists (42/112 [37.5%]).

Implementation of the algorithm was associated with a non-statistically significant decline in the proportion of patients operated on by pediatric surgeons (preintervention, 61.5% [59/96], vs intervention, 57.5% [183/318]; absolute difference, 4.0% [95% CI, −15.1% to 7.2%]; *P* = .50) and a non-statistically significant increase in the proportion operated on by pediatric and adolescent gynecologists (29.2% [28/96] vs 36.5% [116/318]; absolute difference, 7.3% [95% CI −3.2% to 17.8%]; *P* = .19); unnecessary oophorectomies decreased

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Table 2. Diagnostic Performance of Algorithm[a]

Performance	Malignancy status			
	Benign		Malignant	
	Ovary-sparing surgery	Oophorectomy	Ovary-sparing surgery	Oophorectomy
Preintervention (n = 96)[b]	78	15	0	3
Sensitivity, % (95% CI)	83.9 (76.4-91.4)			
Specificity, % (97.5% CI)	100 (29.2-100)[c]			
Positive predictive value, % (97.5% CI)	100 (95.4-100)[c]			
Negative predictive value, % (95% CI)	16.7 (0.0-33.9)			
Positive likelihood ratio	NA[d]			
Negative likelihood ratio	0.16 (0.10-0.26)			
Accuracy, % (95% CI)	84.4 (77.1-91.7)[e]			
Intervention (n = 318)[b]	273	25	2	18
Sensitivity, % (95% CI)	91.6(88.5-94.8)			
Specificity, % (95% CI)	90.0 (76.9-100)			
Positive predictive value, % (95% CI)	99.3 (98.3-100)			
Negative predictive value, % (95% CI)	41.9 (27.1-56.6)			
Positive likelihood ratio	9.2 (2.5-34.1)			
Negative likelihood ratio	0.09 (0.06-0.14)			
Accuracy, % (95% CI)	91.5 (88.4-94.6)[e]			

[a] Tissue pathology was the reference standard for distinguishing benign from malignant mass, except for 2 patients with torsion in the intervention group who underwent detorsion alone with interval imaging confirmation of simple cyst resolution. True positive = ovary-sparing surgery for benign disease; false positive = ovary-sparing surgery for malignant disease; false negative = oophorectomy for benign disease; true negative = oophorectomy for malignant disease.

[b] Preintervention = 6 months; intervention = 18 months.

[c] One-tailed 97.5% CI from 100% reported.

[d] Not applicable (NA): value and/or 95% CI is undefined because of 0 events.

[e] Accuracy = (true positives + true negatives)/total patient population.

significantly among pediatric surgeons with algorithm implementation (15.5% [9/58] to 6.0% [10/168]; difference, −9.5% [95% CI, −19.6% to 0.4%]; *P* = .03) with no statistically significant difference among pediatric and adolescent gynecologists (7.1% [2/28] to 9.7% [11/113]; difference, 2.6%, [95% CI, −8.4% to 13.6%]; *P* > .99).

Diagnostic performance of the algorithm was similar to overall estimates for procedures by pediatric surgeons and pediatric and adolescent gynecologists, but sensitivity of the algorithm was slightly lower for procedures by adult gynecologists, who tended to see older patients (eTable 8 in Supplement 1).

Algorithm Adherence and Fidelity

Overall reported adherence was 95.0% (302/318) (eFigure 2A in Supplement 1). Reasons for nonadherence were unfamiliarity with or misunderstanding of the algorithm (n = 5), surgeon preference (n = 1), and not specified (n = 10).

Overall algorithm fidelity was 81.8% (260/318) (eFigure 2B in Supplement 1). The most common reason for deviation was failing to evaluate tumor markers or evaluating an incomplete panel (n = 50 [17.9%]). Among cases for whom tumor markers were indicated, the most common tumor markers not evaluated were inhibin A (56/90 [62.2%]) and lactate dehydrogenase (61/90 [67.8%]). No tumor markers were evaluated in 15.6% of cases (14/90) for whom tumor markers were indicated. Teratoma was the most common pathologic finding when tumor markers were not fully assessed (33/50 [66.0%]) or none were evaluated (9/14 [64.3%]). The remaining deviations (8/318 [2.5%]) were due to not convening a multidisciplinary team review when indicated; the pathologic findings in these cases were teratoma (3), serous cystadenoma (2), granulosa cell tumor (2), and endometrioid tumor (1).

Site-specific adherence, fidelity, sensitivity, specificity, and proportion of unnecessary oophorectomies in the intervention cohort are detailed in eTable 9 in Supplement 1.

Discussion

This multi-institutional, prospective interventional cohort study demonstrated that implementation of a consensus-based preoperative risk stratification algorithm significantly decreased the percentage of unnecessary oophorectomies performed for benign ovarian neoplasms in patients aged 6 to 21 years. Use of the algorithm also minimized OSS for patients with malignant lesions, with a misclassification percentage of less than 1%. Although adherence to the algorithm was high, fidelity was lower, suggesting additional room for improvement in algorithm understanding and adoption. Nevertheless, the estimates met prespecified thresholds for promoting its use (positive predictive value >98%; misclassification <5%).

Unnecessary oophorectomies for benign disease can result in substantial lifelong harm. One study found that unilateral oophorectomy was associated with higher odds of premature ovarian failure.[2] Another study found that women who had undergone unilateral oophorectomy experienced onset of menopause earlier than those who had not undergone unilateral oophorectomy and women who had undergone unilateral oophorectomy had an increased risk of early menopause.[3] Previous studies have found a higher risk of cognitive impairment and dementia among patients who undergo oophorectomy prior to natural menopause, with risk linearly increasing with younger age at oophorectomy.[4] Patients who have undergone oophorectomy experience a higher rate of bone loss during the first several years after menopause and higher rates

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of osteopenia than patients who underwent natural menopause; this effect is exacerbated by estrogen deficiency during development of peak bone mass.[5,6] Patients who have early menopause also have impaired sexual health, with worse body image, lower desire and arousal, and higher rates of dyspareunia, as well as a higher prevalence of cardiovascular disease.[7,8] Additionally, after unilateral oophorectomy, patients have a shorter reproductive life span with a less robust response to in vitro fertilization in terms of number of follicles, concentration of estradiol, number of oocytes retrieved, and requirement for higher doses of gonadotropins.[9] Furthermore, patients with benign ovarian neoplasms have an increased risk for developing a second neoplasm in the contralateral ovary.[10,13,14] The current study demonstrates that this algorithm can be implemented successfully to reduce unnecessary oophorectomies across multiple institutions and multiple clinician types with high adherence, overall improved diagnostic performance, and low misclassification.

Specialty-based differences in operative management of ovarian neoplasms between pediatric surgeons and pediatric and adolescent gynecologists have previously been reported.[21] Retrospective analysis of 819 patients from 10 children's hospitals demonstrated that oophorectomy for benign disease was associated with clinician specialty, with patients treated by pediatric surgeons more likely to undergo an unnecessary oophorectomy than those treated by pediatric and adolescent gynecologists.[22] Gonzalez et al[1] found that physician specialty and treatment in a high-volume pediatric and adolescent gynecologist hospital were significant predictors of likelihood of undergoing OSS compared with oophorectomy for benign disease. Another previous study demonstrated that pediatric surgeons were more likely to perform an unnecessary oophorectomy prior to adding a pediatric and adolescent gynecologist to the surgical staff.[21] These specialty-based differences existed in our preintervention cohort but were minimized after algorithm implementation. These results demonstrate that development and implementation of a consensus algorithm can promote ovarian preservation across clinician specialty.

Accurate preoperative risk stratification is necessary to minimize harm and promote ovarian preservation. Although no widely accepted guidelines exist, several studies report risk stratification strategies for ovarian neoplasms.[16-19] Our algorithm incorporated available evidence on important findings from patient history and physical examination, imaging studies, and tumor markers to allow for preoperative risk stratification that can reduce unnecessary oophorectomies for benign disease and minimize misclassification of patients with malignant disease to undergo OSS. The misclassification percentage in the intervention cohort was low (2/275 [0.7%]), with both patients having immature teratomas, which were completely excised without oophorectomy or need for additional interventions. These results suggest that algorithm implementation decreased unnecessary oophorectomies for benign disease and minimized harm to patients with malignant disease.

The high algorithm adherence (95.0%) demonstrates surgeons' willingness to follow the algorithm. However, the lower algorithm fidelity (81.8%) suggests that barriers to complete implementation were present. Adherent cases with incomplete fidelity with the algorithm were often due to a discrepancy between the initial and final interpretations of imaging. Additionally, many patients had an incomplete panel of tumor marker data available, which may have resulted from clinicians not having certain tumor markers evaluated based on clinical judgment. The lower fidelity deserves further study to identify ways to improve algorithm implementation to benefit a greater number of patients. As an example, 9 of the 25 unnecessary oophorectomies during the intervention phase occurred in patients with suspected torsion. This suggests that better adherence to the algorithm's guidance for detorsion and completion of preoperative risk stratification with subsequent definitive procedure may further reduce unnecessary oophorectomies.

Limitations

There are notable limitations to this study. First, clinical practice at participating sites began to change during the planning of this study and resulted in the percentage of unnecessary oophorectomies decreasing from an expected 27% to 16% in the preintervention cohort. Second, this study was performed at tertiary children's hospitals with pediatric surgical subspecialists, so the results may not be broadly generalizable.

Conclusions

Implementation of a consensus-based preoperative risk stratification algorithm for patients with ovarian masses reduced the percentage of unnecessary oophorectomies without increasing harm. Algorithm use also improved the consistency of care by minimizing differences in unnecessary oophorectomies between surgical specialties. Adoption of this algorithm could prevent significant lifelong harm caused by unnecessary oophorectomy during adolescence. Future studies are needed to determine barriers to algorithm adherence and adoption.

ARTICLE INFORMATION

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Author Contributions: Dr Minneci had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Minneci, Aldrink, Bence, Downard, Fallat, Grabowski, Helmrath, Hirschl, Lal, Leys, Mak, Markel, Saito, St. Peter, Cooper, Deans.
Acquisition, analysis, or interpretation of data: Minneci, Bergus, Lutz, Aldrink, Breech, Dillon, Ehrlich, Fallat, Fraser, Helmrath, Hewitt, Hirschl, Kabre, Lal, Landman, Leys, Mak, Markel, Pressey, Raiji, Rymeski, Cooper, Deans.
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Group Information: The members of the Midwest Pediatric Surgery Consortium are listed in Supplement 2.

Data Sharing Statement: See Supplement 3.

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