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Surgical Management Disparities and Clinical Outcomes of Pediatric Ovarian Malignant Germ Cell Tumors: A Multicenter Comparison Between Pediatric Surgeons and Gynecologists in China

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Abstract

Background

Pediatric ovarian malignant germ cell tumors (POMGCTs) account for the majority of pediatric ovarian malignancies, requiring rigorous surgical oncologic management tailored to pediatric and adolescent populations. In China, due to the lack of dedicated pediatric gynecologic oncology subspecialties, POMGCT patients are treated by either pediatric surgeons or gynecologists, leading to heterogeneous care. However, high-quality multicenter data on cross-specialty surgical disparities and guideline adherence remain scarce. This study aimed to compare surgical management and clinical outcomes between the two specialties and identify determinants of suboptimal guideline adherence.

Methods

This multicenter retrospective cohort study was conducted at two Chinese institutions from January 2010 to December 2024. Eligible patients were aged ≤ 18 years with histopathologically confirmed POMGCTs who underwent primary surgical treatment, with complete medical records and at least 6 months of follow-up. Patients were categorized into Group A (managed by pediatric surgeons) and Group B (managed by gynecologists) according to the operating surgeon's specialty. Primary outcomes included Children's Oncology Group (COG)-concordant comprehensive staging completion rate, recurrence-free survival, and overall survival. Between-group comparisons, Kaplan–Meier survival estimation with log-rank tests, and multivariate logistic regression were performed to identify independent risk factors for incomplete staging.

Results

This 15-year multicenter retrospective study included 82 histologically confirmed POMGCT patients aged ≤ 18 years treated at two Chinese institutions (2010–2024): 60 managed by pediatric surgeons (Group A) and 22 by gynecologists (Group B). Group A had a significantly younger median age (7 vs. 17 years, $P < 0.001$) and higher emergency surgery rates. Group B achieved higher rates of complete preoperative tumor marker testing (86.4% vs. 63.3%, $P = 0.039$) and laparoscopic utilization (45.5% vs. 5.0%, $P < 0.001$). The Children's Oncology Group (COG)-concordant comprehensive staging completion rate was markedly lower in Group A (36.7% vs. 77.3%, $P < 0.001$). Multivariate analysis identified three independent risk factors for incomplete staging: pediatric surgical specialty (OR = 5.23, 95% CI: 1.68–16.27, $P = 0.004$), emergency surgery (OR = 4.01, 95% CI: 1.47–10.93, $P = 0.006$), and incomplete preoperative tumor marker testing (OR = 3.12, 95% CI: 1.15–8.47, $P = 0.026$). Overall survival was comparable between groups, but suboptimal staging increased recurrence risk. Pediatric surgeons achieved steady improvement in staging compliance over the 15-year period, but still lagged far behind gynecologists.

Conclusions

While overall survival is similar between specialties, substantial disparities exist in surgical management and COG guideline adherence. Integrating the complementary strengths of pediatric surgery and gynecologic oncology, standardizing clinical workflows, and establishing multidisciplinary teams are critical to optimizing outcomes for Chinese pediatric and adolescent POMGCT patients.

1. Introduction

- Malignant ovarian tumors constitute a distinct clinical entity in pediatric and adolescent surgical oncology, with the incidence gradually increasing and reaching 20–25 per 100,000 population by 18 years of age [1]. Approximately 27% of pediatric ovarian neoplasms are malignant [2], and pediatric ovarian malignant germ cell tumors (POMGCTs) make up roughly 85% of these malignant lesions [3]. Their clinical and biological characteristics differ substantially from epithelial ovarian carcinoma, the dominant histological subtype in adult patients [4]. The core clinical challenge of POMGCT management lies in delivering adequate oncologic resection while minimizing long-term adverse effects for prepubertal and young reproductive-age patients.
- Owing to the rarity of POMGCTs, emergent surgical demands in selected cases, and fragmented referral pathways, patients are treated by either pediatric surgeons or gynecologists in routine clinical practice, resulting in marked heterogeneity in surgical strategies and perioperative care. Prior studies have highlighted the potential for cross-specialty variations in preoperative evaluation, surgical approaches, and adherence to staging guidelines when pediatric malignant ovarian tumors are managed by different specialists [5]. Evidence-based guidelines issued by the Children's Oncology Group (COG) and the International Society of Pediatric Oncology (SIOP) uniformly recommend comprehensive surgical staging for eligible early-stage patients [6, 7]. Accurate preoperative risk stratification via combined tumor marker detection is essential for surgical planning, as no single marker delivers sufficient diagnostic reliability [4, 13]. Nevertheless, guideline implementation varies widely across specialties and regions worldwide.
- In mainland China, most tertiary pediatric hospitals lack dedicated pediatric gynecologic oncology subspecialties [17]. Young children are primarily managed by pediatric surgeons, whereas adolescents are usually referred to gynecologists in adult general hospitals. To date, high-quality real-world data on surgical practice patterns, long-term temporal trends, and risk factors for poor guideline adherence among Chinese POMGCT patients remain limited, creating an evident evidence gap for clinical standardization [10]. Existing domestic studies are mostly single-center, small-sample retrospective analyses focusing on pathological subtypes and chemotherapy regimens, with minimal data regarding cross-specialty surgical discrepancies.
- To fill this research gap, we conducted a 15-year multicenter retrospective study of Chinese POMGCT patients. We compared preoperative diagnostic workflows, surgical strategies, and clinical outcomes between patients treated by pediatric surgeons and gynecologists, analyzed temporal changes in clinical practice, and identified independent predictors of failure to complete COG-

standard comprehensive staging. Our findings aim to provide evidence for unified diagnostic and therapeutic protocols and quality improvement programs, supporting a pediatric surgery–gynecology collaborative multidisciplinary care model for POMGCTs.

2. Methods

2.1. Study design and setting

- This multicenter retrospective cohort study was carried out at two Chinese medical institutions: Shanghai Children's Medical Center and Guizhou Provincial People's Hospital. The study period covered January 2010 to December 2024, and the research protocol obtained ethical approval from the institutional review board of each participating center.

2.2. Patient selection

- Inclusion criteria were: (1) age ≤ 18 years at the time of initial diagnosis; (2) histopathologically confirmed POMGCT (including immature teratoma, yolk sac tumor, dysgerminoma, and mixed germ cell tumor); (3) primary surgical treatment for POMGCT at one of the participating centers; (4) complete medical records, including preoperative evaluations, detailed surgical reports, pathological findings and at least 6 months of follow-up data.
- Exclusion criteria were: (1) incomplete key clinical, surgical or pathological data; (2) concurrent malignant neoplasms or severe comorbidities precluding guideline-concordant surgery; (3) salvage surgery for recurrent POMGCT or neoadjuvant chemotherapy prior to primary surgery; (4) ovarian tumors of non-germ cell origin (e.g. epithelial ovarian cancer, juvenile granulosa cell tumor); (5) patients with non-ovarian primary germ cell tumors with ovarian metastasis.
- Patients were divided into two groups according to the specialty of the surgeon performing primary surgery: Group A (pediatric surgeons) and Group B (gynecologists), consistent with grouping approaches adopted in international pediatric ovarian malignancy research [5].

2.3. Data collection

- A standardized data extraction form was developed based on core research domains of pediatric ovarian malignant tumors. Two trained researchers independently extracted anonymized data from electronic and paper medical charts. Disagreements were resolved via mutual consensus, and missing or abnormal data were cross-verified against original medical records when available.
- Extracted variables covered the following dimensions: Demographic and clinical features: age at diagnosis, onset time, presenting symptoms, menstrual status, emergency admission, emergency surgery and indications; Preoperative assessments: imaging modalities, chest CT/cranial MRI results, completeness of tumor marker testing, radiological suspicion of malignancy; Surgical parameters: surgeon specialty and professional title, surgical approach, completion of COG-

standard comprehensive staging, specific staging procedures, intraoperative tumor rupture; Pathological characteristics: tumor laterality, histological subtype, COG surgical stage, metastasis status and metastatic sites; Adjuvant therapy and follow-up: chemotherapy/radiotherapy administration, treatment response, tumor recurrence, recurrence-free interval, overall survival, follow-up duration.

2.4. Statistical analysis

- Statistical analyses were performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA) and R 4.0.0 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were expressed as mean ± standard deviation or median (range) and compared using independent-samples t-tests or Mann–Whitney U tests, as appropriate. Categorical variables were summarized as frequencies (percentages) and compared using the chi-square test or Fisher's exact test. Temporal trends were assessed by dividing the study period into three 5-year intervals (2010–2014, 2015–2019, 2020–2024), with linear regression applied where sample size permitted. Recurrence-free survival (RFS) and overall survival (OS) were estimated via Kaplan–Meier method and compared using the log-rank test. Independent risk factors for incomplete comprehensive staging were identified through univariate screening ($P < 0.1$) followed by multivariate logistic regression, with results reported as odds ratios (OR) with 95% confidence intervals (CI). A two-tailed $P < 0.05$ was considered statistically significant.
- Complete comprehensive staging was defined according to COG guidelines as performance of all the following core procedures: contralateral ovarian exploration, omentectomy, peritoneal washing cytology, peritoneal multiple-site biopsy, and retroperitoneal lymph node evaluation.

3. Results

3.1. Baseline demographic and clinical characteristics

- A total of 82 eligible patients with pathologically confirmed POMGCTs were enrolled: 60 patients (73.2%) in Group A and 22 patients (26.8%) in Group B. The median age at diagnosis was 7 years (range: 2 months–14 years) in Group A and 17 years (range: 13–18 years) in Group B, with Group A significantly younger ($P < 0.001$). No patients younger than 13 years were treated by gynecologists across all centers.
- Abdominal pain and distension were the most prevalent presenting symptoms in both groups. Group A exhibited numerically higher rates of emergency admission and emergency surgery, with ovarian torsion, suspected tumor rupture, and peritonitis as the primary emergency indications. Tumor laterality was comparable between groups.

Table 1
Baseline demographic and clinical characteristics

Variable	Group A (Pediatric Surgeons) n = 60	Group B (Gynecologists) n = 22	*P* value
Age at diagnosis, median (range)	7 (2months-14)	17 (13–18)	< 0.001*
Age < 10 years	52 (86.7)	0 (0)	< 0.001*
Postmenarchal	7 (11.7)	22 (100)	< 0.001*
Presenting symptoms			
Abdominal pain/distension	47 (78.3)	18 (81.8)	0.752
Abdominal mass	16 (26.7)	7 (31.8)	0.643
Fever	9 (15.0)	1 (4.5)	0.220
Vaginal bleeding	5 (8.3)	3 (13.6)	0.469
Emergency admission,	19 (31.7)	3 (13.6)	0.098
Emergency surgery	11 (18.3)	2 (9.1)	0.312
Tumor laterality			0.785
Right ovary	32 (53.3)	11 (50.0)	
Left ovary	28 (46.7)	11 (50.0)	
Histological subtype			0.987
Immature teratoma	23 (38.3)	8 (36.4)	
Yolk sac tumor	17 (28.3)	6 (27.3)	
Dysgerminoma	12 (20.0)	5 (22.7)	
Mixed germ cell tumor	6 (10.0)	2 (9.1)	
COG stage			0.976
Stage I	27 (45.0)	10 (45.5)	
Stage□	16 (26.7)	6 (27.3)	
Stage I□	13 (21.7)	5 (22.7)	
Stage IV	4 (6.7)	1 (4.5)	
*It indicates statistical significance			

As shown in Table 1, the two groups differed significantly in age distribution and menstrual status. The median age was markedly younger in Group A than in Group B (7 vs. 17 years, $P < 0.001$), and all patients in Group B were postmenarchal compared with only 11.7% in Group A ($P < 0.001$). No patients younger than 13 years were treated by gynecologists across all centers. In contrast, tumor laterality, histological subtype distribution and COG surgical stage distribution were comparable between the two cohorts (all $P > 0.05$), indicating baseline homogeneity in tumor characteristics. The distribution of histological subtypes by specialty is shown in Fig. 1.

3.2. Preoperative diagnostic workup

- Transabdominal ultrasound was the first-line imaging modality for all patients in both groups. Cross-sectional imaging (CT/MRI) was performed for most patients, and chest CT and cranial MRI were applied for metastatic screening. Preoperative tumor marker testing was conducted in nearly all patients, with elevated AFP as the most common abnormal marker.
- CT/MRI CT Computed Tomography, MRI Magnetic Resonance Imaging, AFP Alpha-fetoprotein, β-HCG Beta-human chorionic gonadotropin, LDH Lactate dehydrogenase, CA125 Cancer antigen 125, CEA Carcinoembryonic antigen

Table 2
Preoperative diagnostic workup comparison

Variable	Group A (Pediatric surgeons) n = 60	Group B (Gynecologists) n = 22	*P* value
Imaging modalities			
Transabdominal ultrasound	60 (100)	22 (100)	1.000
CT/MRI	36 (60.0)	18 (81.8)	0.058
Chest CT	24 (40.0)	12 (54.5)	0.243
Cranial MRI	10 (16.7)	5 (22.7)	0.542
Imaging suggestive of malignancy	56 (93.3)	21 (95.5)	0.672
Any tumor marker tested	58 (96.7)	22 (100)	0.368
Elevated AFP	40 (66.7)	14 (63.6)	0.793
Elevated β-hCG	10 (16.7)	5 (22.7)	0.531
Elevated LDH	47 (78.3)	18 (81.8)	0.733
Complete testing (AFP + β-hCG)	38 (63.3)	19 (86.4)	0.039*
CA125 measured	15 (25.0)	16 (72.7)	< 0.001*
CEA measured	12 (20.0)	13 (59.1)	0.001*

*It indicates statistical significance

- As shown in Table 2, preoperative evaluation patterns differed between the two groups. Group B had a significantly higher completion rate of full-panel tumor marker testing (AFP + β-HCG + LDH) than Group A (86.4% vs. 63.3%, $P = 0.039$). The detection rates of CA125 (72.7% vs. 25.0%, $P < 0.001$) and CEA (59.1% vs. 20.0%, $P = 0.001$) were also significantly higher in Group B. For imaging modalities, the utilization rates of cross-sectional CT/MRI, chest CT and cranial MRI were comparable between cohorts (all $P > 0.05$). Comparisons of preoperative workup and surgical approaches between the two cohorts are shown in Fig. 2.

3.3. Surgical practice patterns

- Open surgery predominated in Group A, while laparoscopic surgery was more frequently applied in Group B. The completion rate of COG-standard comprehensive staging differed substantially between the two groups.

- As shown in Table 3, the primary outcome of COG-concordant comprehensive staging completion rate was significantly lower in Group A than in Group B (36.7% vs. 77.3%, $P < 0.001$). The most frequent staging deficiencies in Group A were insufficient retroperitoneal lymph node evaluation (48.3%), absent peritoneal washing cytology (25.0%), and incomplete peritoneal biopsy (16.7%). Regarding surgical approach, Group A had a predominance of open surgery (93.3% vs. 50.0%, $P < 0.001$) and a markedly lower laparoscopic utilization rate (5.0% vs. 45.5%, $P < 0.001$). Intraoperative tumor rupture rate was numerically higher in Group A, while fertility preservation rate was significantly lower in Group A (63.3% vs. 86.4%, $P = 0.037$).

Table 3
Surgical practice patterns comparison

Variable	Group A (Pediatric surgeons) n = 60	Group B (Gynecologists) n = 22	*P* value
Surgical approach			
Open surgery	56 (93.3)	11 (50.0)	< 0.001*
Laparoscopic surgery	3 (5.0)	10 (45.5)	< 0.001*
Laparoscopic conversion	1 (1.7)	1 (4.5)	0.469
COG comprehensive staging			
Complete staging	22 (36.7)	17 (77.3)	< 0.001*
Ascites/peritoneal washing cytology	45 (75.0)	21 (95.5)	0.028*
Peritoneal biopsy	50 (83.3)	22 (100)	0.057
Retroperitoneal lymph node evaluation	31 (51.7)	20 (90.9)	0.001*
Omentectomy	48 (80.0)	21 (95.5)	0.107
Contralateral ovarian exploration	44 (73.3)	22 (100)	0.003*
Intraoperative outcomes			
Intraoperative tumor rupture	14 (23.3)	2 (9.1)	0.147
Fertility preservation			
Unilateral salpingo-oophorectmy	55 (91.7)	20 (90.9)	0.912
Fertility preservation achievement	38 (63.3)	19 (86.4)	0.037*
*It indicates statistical significance			

3.4. Pathological features

- Immature teratoma (37.8%), yolk sac tumor (28.0%), and dysgerminoma (20.7%) were the three most common histological subtypes, followed by mixed germ cell tumor (13.4%). Histological subtype distribution was identical between groups (*P* = 0.987). According to COG surgical staging, 45.1% of patients had stage I disease, 26.8% stage II, 22.0% stage III, and 6.1% stage IV, with no

intergroup difference in disease stage distribution (*P* = 0.976). Tumor metastasis was identified in 28.0% of all patients, most frequently involving the omentum (47.8%), peritoneal cavity (34.8%), and retroperitoneal lymph nodes (21.7%); metastasis rates were equivalent between groups (28.3% vs. 27.3%, *P* = 0.927).

3.5. Temporal trends in clinical practice

- The 15-year observation period was divided into three consecutive 5-year intervals: 2010–2014, 2015–2019, and 2020–2024. Laparoscopic utilization showed a stepwise increase in Group B across periods, while remaining persistently low in Group A. Comprehensive staging completion rates increased significantly in Group A over time, yet remained lower than those in Group B. Intraoperative tumor rupture rates declined gradually in Group B, while staying relatively high in Group A. Temporal trends of key surgical practice metrics over the study period are shown in Fig. 3.

3.6. Risk factors for incomplete comprehensive staging

- Univariate analysis identified six variables correlated with incomplete staging (P < 0.10): pediatric surgical specialty, emergency surgery, incomplete preoperative tumor marker testing, age < 10 years, premenarcheal status, and open surgical approach.

Table 4 Multivariate logistic regression analysis for incomplete staging

Variable	Odds Ratio	95% Confidence Interval	*P* value
Pediatric surgical specialty	5.23	1.68-16.27	0.004*
Emergency surgery	4.01	1.47-10.93	0.006*
Incomplete preoperative tumor marke testing	3.12	1.15-8.47	0.026*
Age < 10 years	1.87	0.56-6.25	0.312
Premenarcheal status	1.54	0.42-5.65	0.516
Open surgical approach	2.15	0.68-6.79	0.189

*It indicates statistical significance

- As shown in Table 4, multivariate logistic regression analysis identified three independent risk factors for incomplete comprehensive surgical staging. Pediatric surgical specialty was associated with the highest risk of incomplete staging (OR = 5.23, 95% CI: 1.68–16.27, *P* = 0.004), followed by emergency surgery (OR = 4.01, 95% CI: 1.47–10.93, *P* = 0.006) and incomplete preoperative tumor marker testing (OR = 3.12, 95% CI: 1.15–8.47, *P* = 0.026). Age younger than 10 years, premenarcheal status and open surgical approach were not independent predictors of incomplete staging (all *P* >

0.05). Forest plot of odds ratios for risk factors of incomplete staging is shown in Fig. 4. The distribution of specific deficiencies for incomplete staging is shown in Fig. 5.

4. Discussion

- Internationally, COG and SIOP have established standardized POMGCT management protocols centered on complete surgical staging, delivered via mature multidisciplinary collaboration between pediatric surgeons and gynecologic oncologists [7, 14]. Accurate imaging evaluation serves as the foundation for implementing these protocols [12]. However, real-world implementation of these consensus guidelines remains inconsistent globally. Incomplete surgical staging hinders accurate determination of postoperative adjuvant regimens and follow-up schedules, while non-standard intraoperative manipulation may cause tumor spillage or rupture, leading to unanticipated upstaging [16] and intensified chemotherapy that carries long-term toxic risks for pediatric and adolescent patients [20].
- In mainland China, POMGCT care is split across two specialties: young children are managed by pediatric surgeons, while adolescents are treated by gynecologists in general hospitals. The lack of regular cross-disciplinary case conferences and academic exchange drives substantial heterogeneity in perioperative management and surgical decision-making. This multicenter retrospective study characterizes real-world clinical practice, quantifies inter-specialty gaps in guideline adherence and outcomes, and provides evidence for standardized multidisciplinary care pathways for Chinese pediatric and adolescent POMGCT patients.
- The core finding of this study is the pronounced inter-specialty disparity in COG-compliant complete staging rates: only 36.7% of patients in the pediatric surgery group received full guideline-concordant staging, compared with 77.3% in the gynecology group. Incomplete staging in the pediatric surgery cohort was mainly attributed to insufficient retroperitoneal lymph node sampling, omitted peritoneal cytology, and inadequate peritoneal biopsy, whereas gynecologists completed nearly all recommended staging procedures. Complete surgical staging is the cornerstone of accurate disease stratification, individualized adjuvant therapy, and reduced recurrence risk, yet it is difficult to achieve under emergency operative conditions. While incomplete staging simplifies intraoperative procedures, it leads to disease stage misclassification and inappropriate adjuvant treatment, ultimately elevating recurrence risk. Rates of incomplete staging and intraoperative tumor rupture, which are recognized risk factors for disease recurrence, were relatively elevated among patients managed by pediatric surgeons. Nevertheless, comparable overall survival was observed between the two groups, which is likely related to the satisfactory efficacy of standardized salvage chemotherapy administered for recurrent disease [11]. Platinum-based regimens, particularly bleomycin, etoposide, and cisplatin (BEP), have drastically improved survival for pediatric germ cell tumors, with high cure rates even for recurrent lesions [17, 19].
- Beyond staging compliance, intergroup differences were also observed in surgical modalities and intraoperative management. Gynecologic surgeons demonstrated more standardized intraoperative oncologic protocols, while pediatric surgeons more frequently encountered intraoperative ovarian

injury, which may partly stem from differences in standardized gynecologic oncology training systems [3]. Linear regression further verified that pediatric surgeons achieved steady improvement in standardized comprehensive staging over the 15 years, yet their overall staging compliance still lagged far behind gynecologists. Gynecologists maintained consistently high staging completion rates without significant temporal changes, indicating mature standardized gynecologic oncologic staging workflows. The 15-year temporal analysis revealed progressively widening practice gaps between the two specialties. From 2010–2014, discrepancies mainly lay in standardized staging, with both groups still in the early stage of minimally invasive surgery (MIS) adoption. From 2015–2019, laparoscopic utilization rose substantially in the gynecology group alongside sustained high staging compliance, while the pediatric surgery group showed no meaningful improvement in either staging adherence or minimally invasive technique adoption. By 2020–2024, the minimally invasive gap expanded further, with no inflection point for improved staging compliance in the pediatric surgery cohort. These findings indicate that current guideline dissemination and gynecologic oncology surgical skills training for pediatric surgeons are inadequate, failing to keep pace with global advances in POMGCT care.

- Notably, pediatric surgeons tend to reserve minimally invasive techniques for routine benign pediatric conditions such as gastrointestinal malformations and abdominal wall hernias; for malignant ovarian pelvic masses, they generally favor open laparotomy out of conservative concerns over limited intra-abdominal working space in young children and the risk of intraoperative tumor spillage leading to disease upstaging, which further explains their persistently low laparoscopic uptake. The higher laparoscopic utilization in the gynecology group aligns with existing evidence supporting the safety and favorable short-term outcomes of laparoscopy for selected pediatric ovarian tumors [8]. Nonetheless, the role of minimally invasive surgery for malignant ovarian germ cell tumors remains controversial due to tumor spillage and upstaging risks [9, 20]. Open surgery remains the standard for confirmed or highly suspected malignant lesions; laparoscopy should only be considered for strictly selected early-stage patients operated on by experienced surgeons. Overall, the two specialties have complementary strengths and limitations: pediatric surgeons excel in navigating pediatric anatomy and managing acute emergencies in young children but lack formal training in gynecologic oncologic staging, while gynecologists master standardized oncologic resection but have limited experience with pediatric physiology and emergency care [15].
- Based on our findings and international consensus guidelines [7], multi-dimensional interventions are required to optimize POMGCT care across China. First, targeted training for pediatric surgeons should prioritize standardized staging protocols, retroperitoneal lymph node sampling techniques, and standardized oncologic resection to address critical skill gaps. Second, hospital-wide standardized preoperative pathways mandating full-panel tumor marker testing should be implemented, as combined marker assessment is essential for preoperative risk stratification of pediatric adnexal masses [13]. Preoperative evaluation should be maximized even for emergency admissions within safety constraints. Third, formal multidisciplinary teams integrating pediatric surgery, gynecologic oncology, pediatric oncology, radiology, and pathology should be established to

unify perioperative care workflows [7, 18]. Finally, regular clinical quality control should be implemented to strengthen staging guideline compliance, reduce intraoperative tumor rupture via standardized operative techniques, and standardize oncologic surgical principles for all eligible patients, with a sustainable monitoring system to drive continuous quality improvement.

- This study has limitations inherent to its retrospective design. First, the sample size of the gynecology cohort is relatively small, with higher loss-to-follow-up rates among gynecology-managed patients. Second, significant age imbalance exists between the two groups: pediatric surgeons exclusively manage younger children, while gynecologists treat only adolescents. Age is strongly associated with surgical field exposure, staging technical difficulty and clinical decision-making, which may act as a confounding factor and partially overestimate the inter-specialty difference. Third, the minimum follow-up period of 6 months is relatively short, which may limit the reliability of long-term RFS and OS outcomes. Fourth, stratified temporal data are incomplete due to limited subgroup sample sizes. Despite these drawbacks, our findings clearly demonstrate cross-specialty practice disparities in Chinese POMGCT care and confirm that multidisciplinary collaboration, standardized specialty training, and unified clinical pathways are essential to improve oncologic safety for pediatric and adolescent patients.

5. Conclusion

- Overall survival was comparable between pediatric surgeons and gynecologists treating POMGCTs, yet substantial inter-specialty disparities persist in surgical practice and COG guideline adherence. Pediatric surgeons achieved steady improvement in staging compliance over the 15-year study period, but their overall guideline adherence still lagged far behind gynecologists. Integrating the complementary strengths of both specialties, standardizing clinical workflows, and establishing multidisciplinary teams are critical to optimize oncologic safety and surgical outcomes. Large-scale prospective multicenter trials are warranted to validate unified care protocols and quantify the long-term benefits of cross-specialty collaborative care.

Abbreviations

POMGCTs	Pediatric ovarian malignant germ cell tumors
COG	Children’s Oncology Group
SIOP	International Society of Pediatric Oncology
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
AFP	α-fetoprotein
β-HCG	β-human chorionic gonadotropin
LDH	Lactate dehydrogenase
CA125	Cancer antigen 125
CEA	Carcinoembryonic antigen
RFS	Recurrence-free survival
OS	Overall survival
OR	Odds ratio
CI	Confidence interval

MIS	Minimally invasive surgery
BEP	Bleomycin, etoposide, and cisplatin

Declarations

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Not applicable.

Authors' contributions

Dapeng Jiang and Yali Han conceived and designed the study. Chencheng Xu collected clinical data from Shanghai Children's Medical Center. Lindong Tang collected clinical data from Guizhou Provincial People’s Hospital. Yiting Chen and Ningjie He performed statistical analysis. Mei Hong drafted the manuscript. Dapeng Jiang revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are not publicly available due to patient privacy and ethical restrictions, but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This multicenter retrospective cohort study was approved by the Institutional Review Board of Shanghai Children's Medical Center Affiliated to Shanghai Jiao Tong University School of Medicine (approval number: SCMCIRB-K2026184-1) and the institutional review boards of all other participating centers. Given the retrospective nature of the study, the requirement for written informed consent from participants or their legal guardians was waived by all involved institutional review boards. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

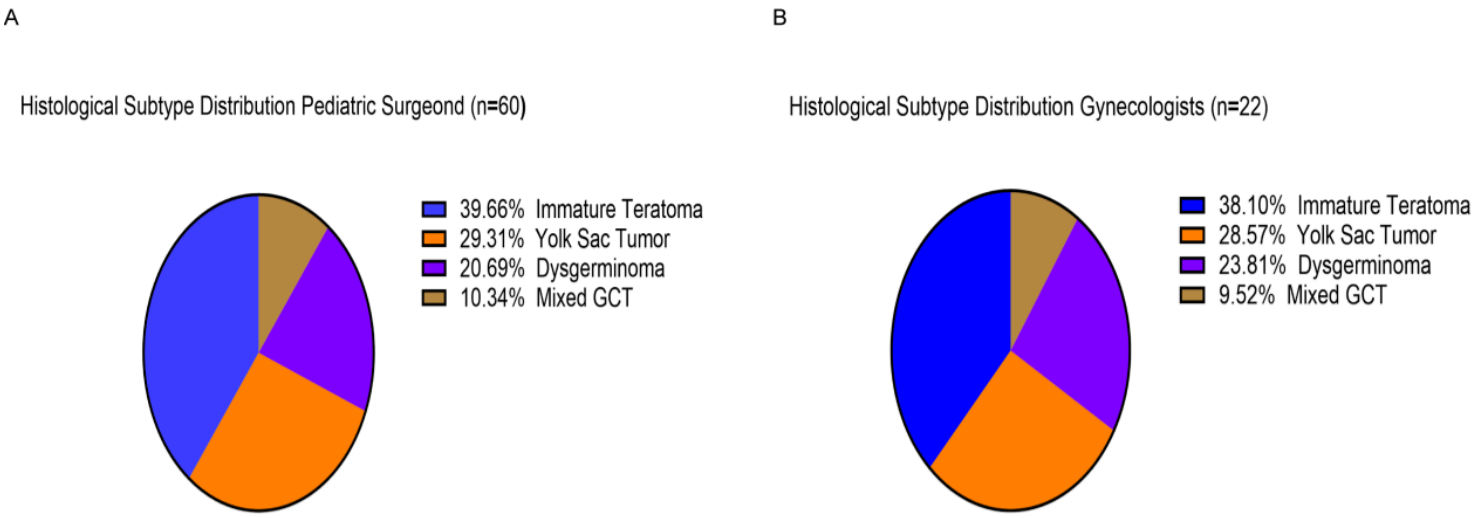


Figure 1

Histological subtype distribution of pediatric ovarian malignant germ cell tumors. **A** Cases managed by pediatric surgeons (n = 60). **B** Cases managed by gynecologists (n = 22). The histological subtypes include immature teratoma, yolk sac tumor, dysgerminoma, mixed germ cell tumor (GCT).

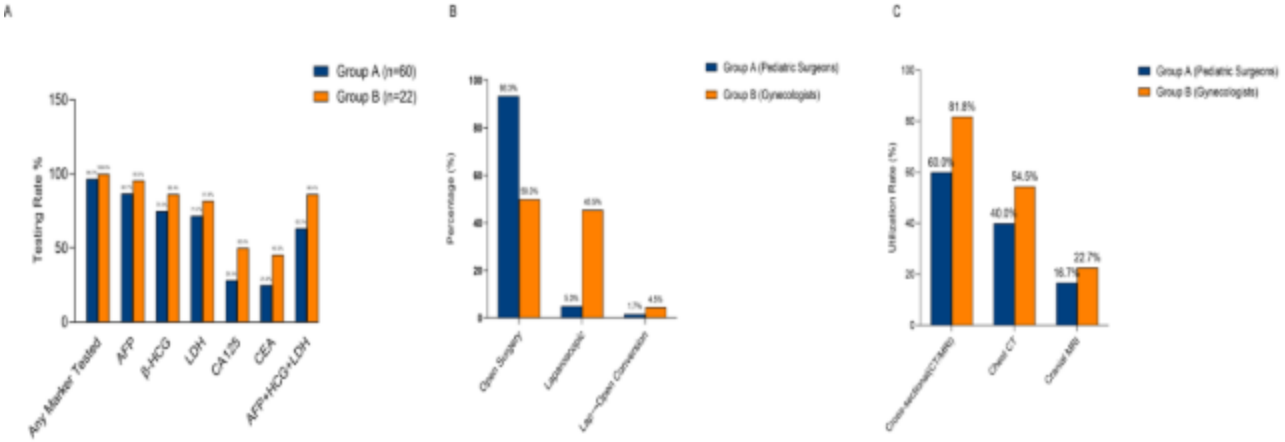


Figure 2

Comparison of preoperative workup and surgical approaches between the pediatric surgeon cohort (Group A, n = 60) and the gynecologist cohort (Group B, n = 22). **A**Testing rates of serum tumor markers (AFP, β-HCG, LDH, CA125, CEA) and the combined panel of AFP + β-HCG + LDH. **B** Proportions of open surgery, laparoscopic surgery, and laparoscopy-to-open conversion. **C** Utilization rates of cross-sectional imaging (CT/MRI), chest CT, and cranial MRI.

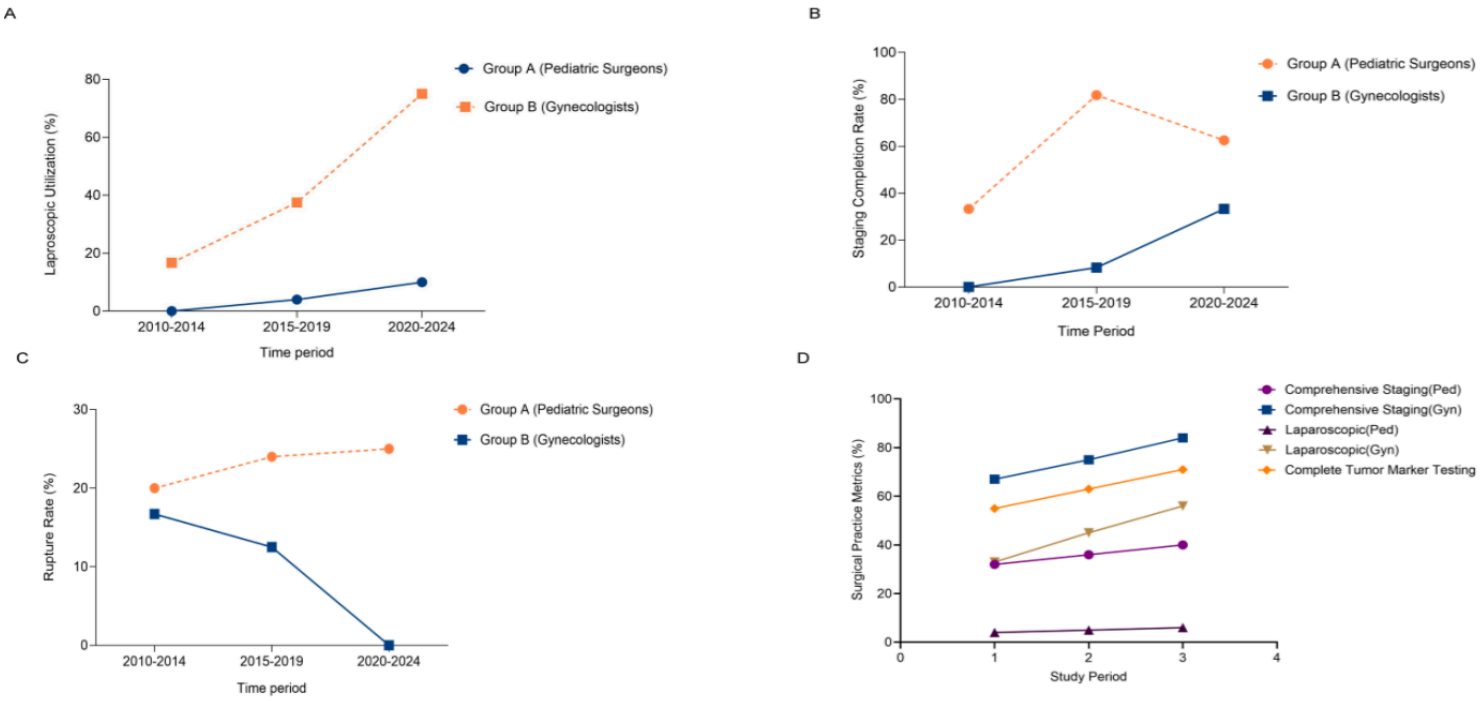


Figure 3

Temporal trends in surgical practice patterns across three time periods (2010–2014, 2015–2019, 2020–2024). **A** Laparoscopic utilization rate. **B** Surgical staging completion rate. **C** Intraoperative tumor rupture rate. **D** Evolution of multiple surgical quality metrics over study periods, including comprehensive staging (pediatric and gynecologic cohorts), laparoscopic approach (pediatric and gynecologic cohorts), and complete preoperative tumor marker testing.

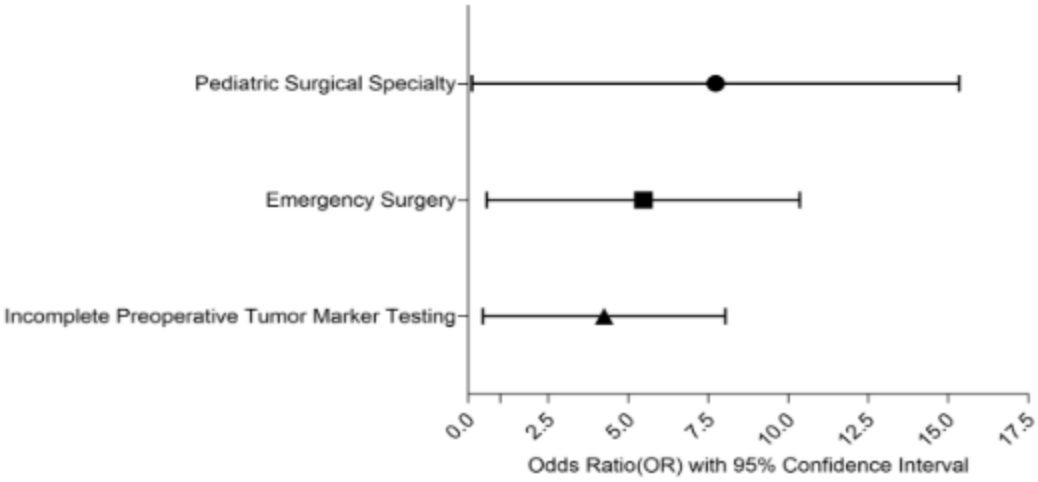


Figure 4

Forest plot illustrating odds ratios (OR) with 95% confidence intervals for risk factors associated with incomplete surgical staging: pediatric surgical specialty, emergency surgery, and incomplete preoperative tumor marker testing.

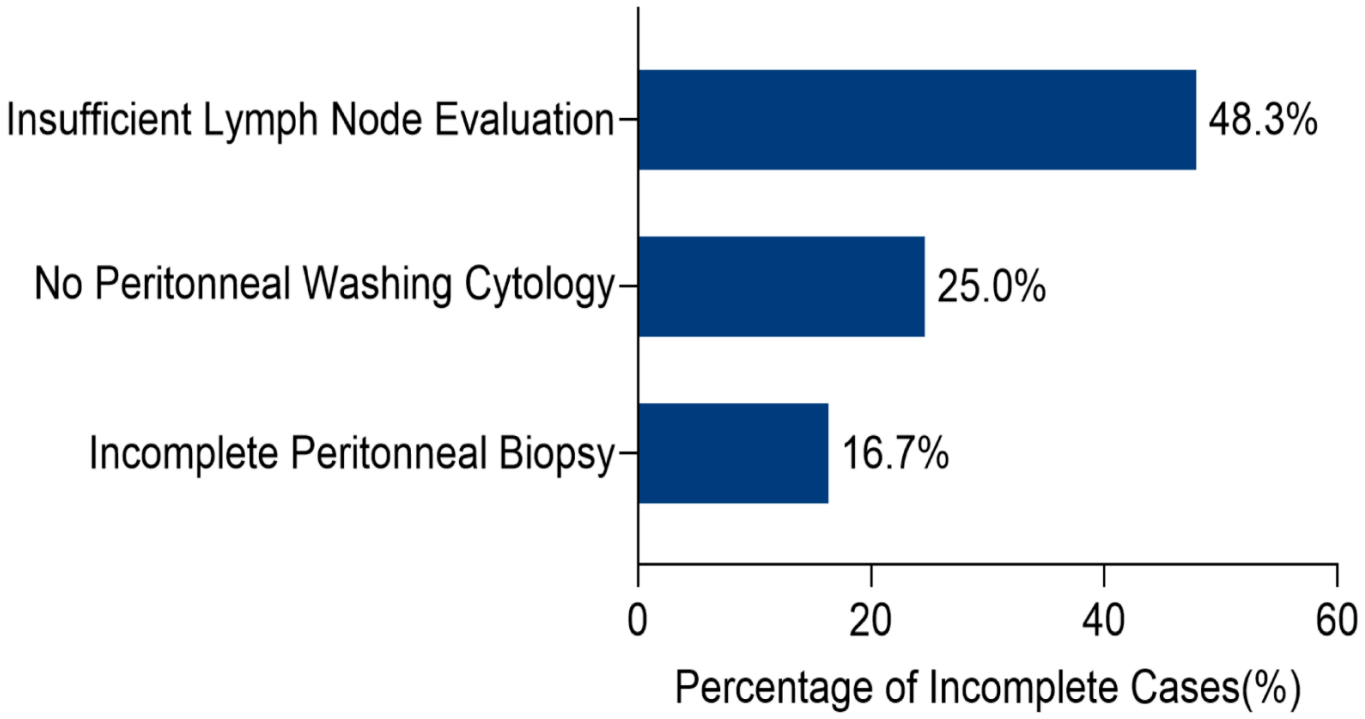


Figure 5

Proportions of specific deficiencies contributing to incomplete surgical staging. Insufficient lymph node evaluation accounted for 48.3% of incomplete cases, followed by absence of peritoneal washing cytology (25.0%) and incomplete peritoneal biopsy (16.7%).