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A Multicenter Prospective Trial Evaluating the Ability of Preoperative Computed Tomography Scan and Serum CA-125 to Predict Suboptimal Cytoreduction at Primary Debulking Surgery for Advanced Ovarian, Fallopian Tube, and Peritoneal Cancer

Rudy S. Suidan, MD^a, Pedro T. Ramirez, MD^b, Debra M. Sarasohn, MD^c, Jerrold B. Teitcher, MD^c, Svetlana Mironov, MD^c, Revathy B. Iyer, MD^d, Qin Zhou, MA^e, Alexia Iasonos, PhD^e, Harold Paul^a, Masayoshi Hosaka^b, Carol A. Aghajanian, MD^{f,g}, Mario M. Leitao Jr, MD^{a,g}, Ginger J. Gardner, MD^{a,g}, Nadeem R. Abu-Rustum, MD^{a,g}, Yukio Sonoda, MD^{a,g}, Douglas A. Levine, MD^{a,g}, Hedvig Hricak, MD^c, and Dennis S. Chi, MD^{a,g}

^a Gynecology Service, Department of Surgery, Memorial Sloan Kettering Cancer Center (MSKCC), New York, NY

^b Department of Gynecologic Oncology, MD Anderson Cancer Center (MDACC), Houston, TX

^c Department of Radiology, MSKCC, New York, NY

^d Department of Radiology, MDACC, Houston, TX

^e Department of Epidemiology and Biostatistics, MSKCC, New York, NY

^f Gynecologic Medical Oncology Service, Department of Medicine, MSKCC, New York, NY

^g Weill Cornell Medical College, New York, NY

Abstract

Objective—To assess the ability of preoperative computed tomography (CT) scan of the abdomen/pelvis and serum CA-125 to predict suboptimal (>1cm residual disease) primary cytoreduction in advanced ovarian, fallopian tube, and peritoneal cancer.

Methods—This was a prospective, non-randomized, multicenter trial of patients who underwent primary cytoreduction for stage III-IV ovarian, fallopian tube, and peritoneal cancer. A CT scan of the abdomen/pelvis and serum CA-125 were obtained within 35 and 14 days before surgery, respectively. Four clinical and 20 radiologic criteria were assessed.

Results—From 7/2001–12/2012, 669 patients were enrolled; 350 met eligibility criteria. The optimal debulking rate was 75%. On multivariate analysis, three clinical and six radiologic criteria were significantly associated with suboptimal debulking: age ≥ 60 years ($p=0.01$); CA-125 ≥ 500 U/mL ($p<0.001$); ASA 3-4 ($p<0.001$); suprarenal retroperitoneal lymph nodes >1cm ($p<0.001$);

Corresponding Author: Dennis S. Chi, MD Memorial Sloan Kettering Cancer Center 1275 York Avenue New York, NY, 10065 gynbreast@mskcc.org (D.S. Chi) Phone: 212-639-5016 Fax: 212-717-3095.

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Conflict of Interest Statement:

The authors declare that there are no conflicts of interest.

diffuse small bowel adhesions/thickening ($p<0.001$); and lesions $>1\text{cm}$ in the small bowel mesentery ($p=0.03$), root of the superior mesenteric artery ($p=0.003$), perisplenic area ($p<0.001$), and lesser sac ($p<0.001$). A 'predictive value score' was assigned for each criterion, and the suboptimal debulking rates of patients who had a total score of 0, 1-2, 3-4, 5-6, 7-8, and 9 were 5%, 10%, 17%, 34%, 52%, and 74%, respectively. A prognostic model combining these nine factors had a predictive accuracy of 0.758.

Conclusions—We identified nine criteria associated with suboptimal cytoreduction, and developed a predictive model in which the suboptimal rate was directly proportional to a predictive value score. These results may be helpful in pretreatment patient assessment.

Keywords

ovarian cancer; CA-125; CT scan; suboptimal cytoreduction

Introduction

Of the estimated 21,980 women diagnosed each year with primary ovarian, fallopian tube, or peritoneal carcinoma in the United States, the majority present with advanced-stage disease [1]. Standard initial therapy for these patients consists of primary cytoreductive surgery, or 'debulking,' followed by platinum and taxane-based chemotherapy [2].

Numerous studies have demonstrated a survival advantage for patients who undergo 'optimal' vs 'suboptimal' debulking [3-6]. Although various cutoff points have been used to define optimal debulking (residual disease ranging from 0 to 3cm), the Gynecologic Oncology Group (GOG) currently uses 1cm as a cutoff [2]. While previously only of prognostic value, this stratification led to significant treatment implications with the publication of GOG-172, a randomized trial in women with optimally debulked ($<1\text{cm}$ residual) ovarian cancer that showed a significant survival advantage for patients who received intravenous paclitaxel plus intraperitoneal cisplatin and paclitaxel compared to those who received intravenous paclitaxel and cisplatin chemotherapy [7]. Intraperitoneal chemotherapy is currently not a treatment option for suboptimally debulked women. It is also important to note that for patients who are suboptimally cytoreduced ($>1\text{cm}$ residual), survival is equivalent regardless of residual tumor size [8,9]. Reported rates of optimal cytoreduction vary widely in the literature, from 15% to 85% [10]. Therefore it appears that a significant proportion of women with advanced ovarian cancer will undergo a debulking procedure with associated morbidity but without a commensurate improvement in survival.

In order to determine which patients would be less likely to benefit from primary surgery, several attempts have been made to predict cytoreductive outcome, using imaging modalities, tumor markers, and laparoscopic scores [11]. Investigators have evaluated the utility of preoperative computed tomography (CT) scan in an effort to identify radiologic predictors, with inconsistent results [12-16]. The use of preoperative CA-125 has also been evaluated in this setting, with a cutoff value of 500 U/mL used by most researchers. Some studies have found CA-125 to be significantly associated with cytoreductive outcome, while others have not [17-23]. Studies attempting to identify preoperative predictors have been limited by their retrospective design, sample size, broad inclusion criteria, and

heterogeneous rates of optimal cytoreduction. The objective of this trial was to prospectively assess the ability of preoperative CT scan of the abdomen/pelvis and serum CA-125 to predict suboptimal primary cytoreduction in patients with advanced epithelial ovarian, fallopian tube, and peritoneal cancer.

Materials and Methods

Patient Eligibility

This was a prospective, non-randomized, multicenter clinical trial approved by the institutional review boards of each institution. All patients 18 years of age with presumed advanced (International Federation of Gynecology and Obstetrics [FIGO] stage III-IV) epithelial ovarian, fallopian tube, and peritoneal cancer who were assessed by an attending gynecologic oncologist for cytoreductive surgery were eligible. A CT scan of the abdomen/pelvis with intravenous and oral contrast and serum CA-125 were obtained within 35 and 14 days before surgery, respectively. Informed consent was obtained from all enrolled patients. This occurred at the initial outpatient visit, before the CT scans were evaluated by a protocol radiologist, and before patients' scheduled surgeries. Demographic data were recorded, along with cytoreductive outcome and histologic confirmation of diagnosis postoperatively. Suboptimal cytoreduction was defined as >1cm residual disease, as classified by the GOG. Patients were excluded if they did not have ovarian, fallopian tube, or peritoneal cancer; if they did not have advanced disease; or if they received neoadjuvant chemotherapy (this was at the discretion of the primary surgeon, usually due to findings on a CT scan that was done in-house, or after in-house radiologic review of outside CT imaging, both of which occurred after the initial visit). Additionally, patients were also excluded if there was significant delay in surgery after CT scan (>35 days) or serum CA-125 (>14 days), or if the CT scan was of poor quality, lacking contrast, or not assessed by a protocol radiologist. Patients with carcinosarcoma, mesothelioma, and mucinous histologies were also excluded, as were patients with germ cell, sex-cord stromal cell, low- malignant potential, and benign tumors.

CT scan and Clinical Criteria

CT scans were performed after administration of intravenous and oral contrast; contiguous slices were acquired, with slice thicknesses ranging from 5 to 7.5 mm. CT scans performed at outside institutions were included in the study only if judged to be of acceptable quality by the study radiologists. Five protocol radiologists, all experienced in body CT, analyzed and interpreted the images before surgery. They recorded the presence or absence of 20 radiologic criteria, including: lesions in the porta hepatis, intersegmental fissure of the liver, gallbladder fossa, gastrohepatic ligament, lesser sac, root of the superior mesenteric artery (SMA), small bowel mesentery, omentum, liver (perihepatic, subcapsular, and intraparenchymal individually), spleen (perisplenic and intraparenchymal individually), pulmonary bases, pleural bases, and retroperitoneal lymph nodes above the renal hilum (including supradiaphragmatic). Other criteria included tumor invading the anterior abdominal wall, presacral extraperitoneal disease, the presence of ascites (graded as mild, moderate, or severe), and diffuse small bowel adhesions/thickening. The latter was interpreted radiologically as angulated bowel loops in the presence of small bowel wall thickening. Thickening was subjectively assessed by the radiologists with no specific

measurement of bowel wall thickness used, as it was dependent on the caliber of that loop of bowel. Pelvic disease involving the adnexae, uterus, and rectosigmoid colon was not assessed as part of this study, as it is generally resectable and does not usually affect cytoreductive status.

Quantitative bi-dimensional measurements were determined for all visualized lesions. Qualitative analysis (QA) was performed by using the following five-point scale to categorize the degree of radiologic certainty that a lesion identified on CT represented a metastatic neoplasm: 1=definitely normal; 2=probably normal; 3=indeterminate; 4=probably metastatic; and 5=definitely metastatic. There were no specific criteria for assigning a QA score; scores were determined by the radiologists based on their judgment, experience, and the characteristics of the lesions (i.e., solid vs cystic, well defined vs poorly defined). In addition to the CT criteria, four clinical criteria were considered as potential predictors of cytoreductive outcome: serum CA-125, age, stage, and American Society of Anesthesiologists (ASA) class as determined by the anesthesia team.

Statistical Analysis

Sample size was calculated as follows: a previous study from our institution suggested that a cutoff value for the preoperative serum CA-125 that correctly identified 90% of optimally cytoreduced patients correlated with a level that would also correctly identify 40% of suboptimally cytoreduced patients [17]. This protocol was designed to test whether the proportion of suboptimally debulked women correctly classified by the CA-125 cutoff was truly 40% or could be as low as 25%. Similarly, it was designed to test whether CT scan findings could correctly classify a desirable proportion of suboptimally cytoreduced patients. For a type I error of 5% and 80% power, it was estimated that 85 suboptimally debulked patients would be required. At the time of protocol design, we assumed an optimal cytoreduction rate of 45% based on our institutional data [17]. However, coinciding with the start of patient accrual, the rate had increased to greater than 75% following a change in surgical paradigm and the incorporation of upper abdominal surgery into the primary cytoreductive effort [6]. This prolonged the accrual period for the study, as it meant that an estimated 340 women with advanced ovarian cancer would need to be included to have 85 suboptimally debulked patients.

All 20 radiologic and four clinical criteria were assessed for their association with suboptimal debulking. Radiologic criteria were considered present if lesions had a QA of 4 or 5 and measured >1cm (measurable lesions only). Criteria were considered absent if lesions had a QA of 1-3 (any size), or if they had a QA of 4 or 5 and measured ≤1cm. Several cutoffs were assessed for age, and the cutoff most predictive of suboptimal debulking was used to group patients. Due to the small number of patients with an ASA class of 1 and 4, patients with an ASA of 3 or 4 were combined and compared to those who had an ASA of 1 or 2. A receiver operating characteristic (ROC) curve was generated with the data from the current study, and the most predictive cutoff value of CA-125 was determined to be 500 U/mL, which is consistent with previously published reports [17,21-23]. Associations between the criteria and debulking outcome were tested using Fisher's exact test for categorical variables and the Wilcoxon Rank-Sum test for continuous

variables. Generalized estimating equations were used to account for differences between the two institution-clusters, assuming independent covariance structure. Based on the results of univariate analysis, backward selection was utilized to build a multivariate model predictive of suboptimal cytoreduction, for which an ROC curve was generated. The radiologic and clinical criteria found to be significant on multivariate analysis were then each assigned a 'predictive value score' according to their odds ratios (OR). Subsequently, the total predictive value score of all patients in the cohort was calculated using their radiologic and clinical findings, and the suboptimal debulking rate corresponding to each total score was determined. All statistical tests were two-sided, and a p value of <0.05 was considered significant. The multivariate model was considered exploratory; therefore, no formal adjustment for multiple comparisons was made. Statistical analysis was performed using SAS statistical software 9.2 (SAS Institute, Cary, NC) and R (R development core team, 2013).

Results

From July 2001 to December 2012, 669 patients were enrolled, and 350 met all eligibility criteria. A CONSORT diagram is shown in Figure 1. Two hundred sixty-eight (76%) of the eligible patients were enrolled at the primary study institution. The optimal debulking rate was 75% (261 patients). Patient and tumor characteristics are shown in Table 1.

On univariate analysis, three clinical and 12 radiologic criteria were found to be significantly associated with suboptimal cytoreduction (Tables 2 and 3). Seventy-one percent (63/89) of suboptimally debulked patients had a CA-125 ≥ 500 U/mL and 41% (106/261) of optimally debulked patients had a CA-125 <500 U/mL. Due to the small number of suboptimally debulked women whose CT scans showed liver intraparenchymal lesions, spleen intraparenchymal lesions, and presacral extraperitoneal disease (<5 patients each), these criteria were excluded from further analysis.

On multivariate analysis, after backward selection, three clinical and six radiologic criteria remained significant: age ≥ 60 years (OR 1.32, $p=0.01$); CA-125 ≥ 500 U/mL (OR 1.47, $p<0.001$); ASA 3-4 (OR 3.23, $p<0.001$); retroperitoneal lymph nodes above the renal hilum (including supradiaphragmatic) >1 cm (OR 1.59, $p<0.001$); diffuse small bowel adhesions/thickening (OR 1.87, $p<0.001$); small bowel mesentery lesions >1 cm (OR 2.28, $p=0.03$); root of the SMA lesions >1 cm (OR 2.4, $p=0.003$); perisplenic lesions >1 cm (OR 2.27, $p<0.001$); and lesser sac lesions >1 cm (OR 4.61, $p<0.001$) (Table 4). ROC curves were generated, with a predictive model utilizing the six CT criteria showing an area under the curve (AUC) of 0.688. The six CT criteria and the preoperative CA-125 combined had an AUC of 0.696. The most accurate model combined the six CT criteria, CA-125, age, and ASA, demonstrating an AUC of 0.758 (Figure S1).

To add clinical utility to our findings, we assigned a 'predictive value score' for the nine criteria significant on multivariate analysis, which was based on their multivariate ORs. Age ≥ 60 years, CA-125 ≥ 500 U/mL, retroperitoneal lymph nodes above the renal hilum (including supradiaphragmatic) >1 cm, and diffuse small bowel adhesions/thickening were each assigned a predictive value score of 1. Perisplenic lesions >1 cm, small bowel

mesentery lesions >1cm, and root of the SMA lesions >1cm were each assigned a score of 2. ASA 3-4 was assigned a score of 3, and lesser sac lesions >1cm were assigned a score of 4 (Table 4). We then calculated the total predictive value score of all patients in our cohort using their clinical and CT scan findings, and determined the suboptimal debulking rate corresponding to each total score. The rate was linearly correlated to the predictive value score. Patients who had a score of 0 (none of the criteria present) had a suboptimal rate of 5%. The suboptimal rates of patients who had a score of 1-2, 3-4, 5-6, and 7-8 were 10%, 17%, 34%, and 52%, respectively. The highest suboptimal rate, 74%, was for patients who had a score of 9 or greater (Table 5).

Discussion

In two high-volume ovarian cancer centers, we identified three clinical and six radiologic criteria associated with suboptimal cytoreduction and developed a predictive model in which the suboptimal rate was directly proportional to a predictive value score. This model had an overall predictive accuracy of 0.758.

Previous investigators assessing the utility of preoperative CT scan in this setting have retrospectively identified different radiologic predictors [12-16]. Axtell et al.'s analysis of 65 patients showed diaphragm disease and large bowel mesentery implants to be significant factors [15]. Dowdy et al.'s review of 89 patients found diffuse peritoneal thickening to be the only variable significantly associated with suboptimal debulking [16]. In our analysis, three out of the six predictive radiologic criteria involved the small bowel, which makes intuitive and physiologic sense. The incorporation of advanced surgical techniques and the ability to resect upper abdominal disease (splenic, perihepatic, etc) has led to higher optimal debulking rates [6,24]. However, there is a limit to how much small bowel and/or mesentery can be resected without compromising essential function. Therefore, extensive disease involving the majority of the small bowel mesentery and serosa is anecdotally cited by expert surgeons as the most common factor precluding optimal debulking.

Chi and colleagues initially reported that a preoperative serum CA-125 >500 U/mL was significantly associated with suboptimal debulking [17]. A follow-up study demonstrated that while the CA-125 was a predictor of upper abdominal disease, it was not necessarily associated with suboptimal cytoreduction if extensive upper abdominal procedures were incorporated into the surgical approach [21]. Other reports have shown conflicting results, and a recent meta-analysis concluded that although a CA-125 >500 U/mL was a strong risk factor for suboptimal debulking, it lacked the accuracy to independently predict surgical outcome [18-20,22,23]. In our study, a CA-125 value $\geq$ 500 U/mL was a statistically significant predictive factor and was the best cutoff based on ROC curve evaluation (not shown). However, it is important to note that it has limited clinical utility on its own, as 29% of patients with a value $\geq$ 500 U/mL were suboptimally debulked, compared to 20% of those with a value <500 U/mL. We consequently feel that the preoperative CA-125 level should be used in combination with the other criteria to guide clinical management.

Regarding our model design, which was exploratory, we assigned equal weights to all the criteria in our initial analysis (not shown) and then calculated the suboptimal rate based

solely on the number of criteria present. The rate increased proportionally to the number of criteria. However, our data revealed that certain factors were more predictive than others (for example, lesser sac lesions >1cm had an OR of 4.61, while age >60 years had an OR of 1.32). The final model was therefore based on weighted criteria with a predictive value score assigned, as this was considered a more accurate way to model the actual effects. In addition, in the model, lesser sac lesions >1cm had a predictive value score of 4, significantly higher than other criteria. The 35 patients who had lesser sac lesions >1cm had a median predictive value score of 8, with a range of 4 to 12. This suggests that in patients with carcinoma that is extensive enough to involve the lesser sac, the disease has likely spread to several other anatomic locations as well.

While previous studies have assessed the utility of preoperative CT scan in predicting outcome, they were limited by their retrospective nature, small sample size, inclusion of early-stage disease, and variable rates of optimal cytoreduction (49% to 78%) [12-16]. Our study's strength lies in its prospective design; the CT scans were evaluated by a dedicated group of radiologists prior to patients' surgeries, thereby guaranteeing their blinding with regard to surgical outcomes and findings. We also had a large patient cohort, with 350 women included. The study was carried out in two institutions, which increases the external validity of our analysis. The two institutions are tertiary cancer centers with a high rate of optimal debulking (75%), and only patients with advanced-stage cancer were included. In our model, we were able to combine the predictive value of radiologic criteria with that of clinical criteria. This not only takes into account patients' extent of disease but also their overall medical status and ability to undergo general anesthesia and extensive surgery. We feel the inclusion of clinical factors increases the strength of our model, as age and medical status are critical factors in the complex decision-making process for gynecologic oncologists when determining if a patient is a candidate for primary debulking, as opposed to neoadjuvant chemotherapy. Although a patient's disease sites may render her amenable for optimal resection based on a surgeon's technical ability and surgical armamentarium, one with a poor overall medical condition may not be able to tolerate the prolonged complicated procedure often necessary to achieve optimal debulking [25].

The main limitation of our trial is the study period needed to accrue the required number of suboptimally cytoreduced patients, as CT imaging technology and surgical practice may have changed over time. Surgeons were aware of preoperative CT findings, as being blinded to the imaging would have been detrimental to patient care. While this can be seen as a potential bias, it is essential to note that all six CT criteria that were significantly associated with suboptimal debulking in our study only came to light when the data was analyzed and the multivariate model built, which occurred after the trial was closed to accrual. Therefore, despite knowledge of patients' preoperative imaging, surgeons were not aware which of these findings would ultimately be associated with suboptimal cytoreduction. Selection bias is another potential limitation, as 48 patients who received neoadjuvant chemotherapy were excluded. This was at the discretion of the attending gynecologic oncologist, who upon reviewing CT imaging after the initial visit, deemed certain patients to not be amenable for optimal primary cytoreduction. This was a subjective assessment based on each surgeon's own experience, judgment, and technical abilities, with no specific criteria employed. These patients did not undergo an attempt at primary debulking, and it is possible that some may

have been optimally cytoreduced. Nonetheless, had these patients undergone primary surgery, it is possible that additional imaging criteria may have been significantly associated with cytoreductive outcome. With regards to the evaluation of imaging, the QA scale used to assess the lesions, while described before [26], has not been validated, and is admittedly used in an attempt to objectively quantify subjective findings. In addition, each CT scan was read by one protocol radiologist. As such, the reproducibility of the findings and interobserver variability were not assessed. We also have not validated our scoring system in another population at this time.

The GOG definition of optimal debulking uses 1cm as a cutoff [2]. However, several studies have shown a survival advantage for patients with no gross residual compared to those with 1cm gross residual [5,9,27]. Based on that data, many gynecologic oncologists currently feel that the goal of primary cytoreduction for ovarian cancer should be complete gross resection to no gross residual. Nevertheless, our trial was designed to assess preoperative predictors based on a definition of optimal debulking that uses a 1cm cutoff. We therefore did not feel it would be statistically valid to report outcomes based on a changed endpoint. One can hypothesize that if preoperative findings suggest that a gross residual of 1cm cannot be achieved, then the same findings would imply that cytoreduction to no residual disease is unlikely. As this assertion cannot be formally supported with the current analysis, we plan on addressing this question with a secondary analysis of our data in the future. It is important to note however that even if the goal of cytoreduction is complete gross resection, that may not necessarily align with the goal of predicting surgical outcome; as there may still be a potential survival benefit for patients with 1cm but grossly visible disease after primary debulking, compared to those who are treated with neoadjuvant chemotherapy [9,27,28,29,30,31].

In our predictive model, the suboptimal debulking rate increased progressively from 5% to 74% based on the predictive value score. With further validation, these results may be helpful in pretreatment patient assessment and counseling, and in guiding clinical management. At this time, we do not advocate a certain cutoff rate above which neoadjuvant chemotherapy should be administered to a patient. We feel it is reasonable for each individual surgeon and center to determine what threshold to use; based on their own experience, outcomes, treatment philosophy, and ability to employ extensive surgical techniques in order to achieve optimal cytoreduction.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
CONSORT diagram of all enrolled patients. CT, computed tomography; IV, intravenous.

Table 1

Patient and Tumor Characteristics (N = 350)

Variable	n (%)
Age (years)	
Median (range)	61 (34 – 86)
Primary site of disease	
Ovary	264 (75%)
Fallopian tube	42 (12%)
Peritoneal	44 (13%)
FIGO Stage	
III A/B	8 (2%)
IIIC	248 (71%)
IV	94 (27%)
Grade	
1	11 (3%)
2	8 (2%)
3	328 (94%)
N/A	3 (1%)
Histology	
Serous	314 (90%)
Endometrioid/Clear cell	2 (0.6%)
Mixed/Other	34 (10%)
Preoperative CA-125 (U/mL)	
Median (range)	860 (9 – 38, 100)
ASA class	
1	10 (3%)
2	158 (45%)
3	178 (51%)
4	3 (1%)
N/A	1 (0.3%)

FIGO, International Federation of Gynecology and Obstetrics; ASA, American Society of Anesthesiologists

Table 2

Clinical Criteria – Univariate Analysis

Criteria	Suboptimal Rate	OR	95% CI	<i>p</i>
Age				
60 years	53/187 (28%)	1.4	1.39 - 1.4	<0.001
< 60 years	36/163 (22%)			
CA-125				
500 U/mL	63/218 (29%)	1.66	1.31 - 2.1	<0.001
< 500 U/mL	26/132 (20%)			
ASA				
3-4	61/181 (34%)	2.54	1.4 - 4.6	0.002
1-2	28/168 (17%)			
Stage				
IV	26/94 (28%)	1.17	0.75 - 1.84	0.49
III	63/256 (25%)			

ASA, American Society of Anesthesiologists

Table 3

Radiologic Criteria – Univariate Analysis

Criteria	Suboptimal Rate		OR	95% CI	p
	Criteria Present	Criteria Absent			
Porta hepatis lesion >1 cm	18/50 (36%)	71/300 (24%)	1.81	1.53 - 2.15	<0.001
Liver intersegmental fissure lesion >1 cm	14/48 (29%)	75/302 (25%)	1.25	0.64 - 2.41	0.51
Gallbladder fossa lesion >1 cm	9/25 (36%)	80/325 (25%)	1.72	1.29 - 2.31	<0.001
Gastrohepatic ligament lesion >1 cm	22/38 (58%)	67/312 (21%)	5.03	2.07 - 12.23	<0.001
Lesser sac lesion >1 cm	20/35 (57%)	69/315 (22%)	4.75	4.38 - 5.16	<0.001
Root of the superior mesenteric artery lesion >1 cm	5/8 (63%)	84/342 (25%)	5.12	4.23 - 6.2	<0.001
Small bowel mesentery lesion >1 cm	27/61 (44%)	62/289 (21%)	2.91	1.53 - 5.51	<0.001
Retroperitoneal lymph nodes above the renal hilum (including supradiaphragmatic) >1 cm	26/72 (36%)	63/278 (23%)	1.93	1.72 - 2.17	<0.001
Omental lesion >1 cm	52/212 (25%)	37/138 (27%)	0.89	0.61 - 1.29	0.53
Perihepatic lesion >1 cm	24/95 (25%)	65/255 (25%)	0.99	0.58 - 1.68	0.97
Subcapsular liver lesion >1 cm	10/44 (23%)	79/306 (26%)	0.85	0.63 - 1.13	0.26
Liver intraparenchymal lesion >1 cm	4/9 (44%)	85/341 (25%)	2.41	1.87 - 3.11	<0.001
Perisplenic lesion >1 cm	26/59 (44%)	63/291 (22%)	2.85	2.27 - 3.58	<0.001
Spleen Intraparenchymal lesion >1 cm	3/7 (43%)	86/343 (25%)	2.24	1.29 - 3.89	0.004
Tumor invading anterior abdominal wall >1 cm	3/11 (27%)	86/339 (25%)	1.1	0.9 - 1.35	0.34
Presacral extraperitoneal disease >1 cm	2/4 (50%)	87/346 (25%)	2.98	2 - 4.44	<0.001
Diffuse small bowel adhesions/thickening	9/24 (38%)	80/326 (25%)	1.85	1.78 - 1.91	<0.001
Abdominal ascites (moderate-severe)	48/154 (31%)	41/196 (21%)	1.71	1.11 - 2.65	0.02
Pulmonary metastasis (lung bases)	3/13 (23%)	86/337 (26%)	0.88	0.66 - 1.15	0.34
Pleural metastasis (lung bases)	4/17 (24%)	85/333 (26%)	0.9	0.6 - 1.34	0.59

All measurable lesions had a QA of 4 or 5.

Table 4

Multivariate Model of Significant Clinical and Radiologic Criteria Predictive of Suboptimal Cytoreduction

Criteria	OR	95% CI	<i>p</i>	Predictive Value Score
Age ≥ 60 years	1.32	1.06 - 1.63	0.01	1
CA-125 ≥ 500 U/mL	1.47	1.28 - 1.69	<0.001	1
ASA 3-4	3.23	1.76 - 5.91	<0.001	3
Retroperitoneal lymph nodes above the renal hilum (including supradiaphragmatic) >1 cm	1.59	1.58 - 1.6	<0.001	1
Diffuse small bowel adhesions/thickening	1.87	1.86 - 1.87	<0.001	1
Perisplenic lesion >1 cm	2.27	1.7 - 3.03	<0.001	2
Small bowel mesentery lesion >1 cm	2.28	1.08 - 4.8	0.03	2
Root of the superior mesenteric artery lesion >1 cm	2.4	1.34 - 4.32	0.003	2
Lesser sac lesion >1 cm	4.61	4.39 - 4.84	<0.001	4

ASA, American Society of Anesthesiologists

Table 5

Predictive Value Score and Suboptimal Cytoreduction (N = 349)

Total Predictive Value Score	Total Patients n (%)	Optimal (n)	Suboptimal (n)	Suboptimal Rate
0	22/349 (6%)	21	1	5%
1 - 2	79/349 (23%)	71	8	10%
3 - 4	109/349 (31%)	91	18	17%
5 - 6	85/349 (24%)	56	29	34%
7 - 8	31/349 (9%)	15	16	52%
9	23/349 (7%)	6	17	74%

*1 patient excluded for a missing American Society of Anesthesiologists class