


RESEARCH

Open Access



Feasibility and outcomes of cytoreductive surgery and HIPEC for peritoneal surface malignancies in low- and middle-income countries: a single-center experience of 232 cases

Suryanarayana Deo^{1*} , Mukurdipi Ray¹, Babul Bansal¹, Sandeep Bhorwal¹, Sushma Bhatnagar², Rakesh Garg², Nishkarsh Gupta², Atul Sharma³, Lalit Kumar³, Sanjay Thulkar⁴, Ekta Dhamija⁴, Sandeep Mathur⁵ and Prasenjit Das⁵

Abstract

Background: Cytoreductive surgery (CRS) and hyperthermic intraperitoneal chemotherapy (HIPEC) has recently emerged as a viable management option for peritoneal surface malignancy (PSM). CRS and HIPEC is a complex, multidisciplinary and resource-intensive surgical procedure. It has a steep learning curve and is associated with significant morbidity and mortality. The expertise is mostly limited to few dedicated high-volume centers located in developed countries. We present a single institutional experience of 232 cases of CRS and HIPEC performed at a tertiary care cancer center in a low- and middle-income country (LMIC).

Methods: A multidisciplinary PSM program was initiated in 2015 at a high-volume public-sector tertiary care cancer center in North India catering largely to patients belonging to low- and middle-income groups. Perioperative protocols were developed, and a prospective structured database was created to capture data. All patients undergoing CRS and HIPEC between January 2015 and December 2020 were identified, and the data was retrospectively analyzed for clinical spectrum, surgical details, and perioperative morbidity and mortality.

Results: Two hundred and thirty-two patients underwent CRS and HIPEC during the study period. Epithelial ovarian carcinoma (56.5%) was the most common malignancy treated, followed by pseudomyxoma peritonei (18.5%), colorectal carcinoma (13.4%), and malignant mesothelioma (5.6%). Optimal CRS could be achieved in 94.4% of patients. Cisplatin and mitomycin were the most common drugs used for HIPEC. A total of 28.0% of patients had morbidity including deep vein thrombosis, subacute intestinal obstruction, sepsis, burst abdomen, lymphocele, urinoma, acute renal failure, and enterocutaneous fistula. The overall treatment-related mortality was 3.5%.

* Correspondence: svsdeo@yahoo.co.in

¹Department of Surgical Oncology, Dr. BRA-IRCH, AIIMS, New Delhi 110029, India

Full list of author information is available at the end of the article



© The Author(s). 2021 **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Conclusions: Results of the current study indicate that it is feasible to establish a successful CRS and HIPEC program for PSM in government-funded hospitals in LMIC facing resource constraints. The most common indication for CRS and HIPEC were carcinoma of the ovary followed by pseudomyxoma peritonei and colorectal carcinoma. Overall morbidity and mortality in the current series are comparable to global standards, reported from high-income countries. A protocol-based multidisciplinary team approach, optimal patient selection, and surgical expertise can help achieve optimal outcomes in government-funded hospitals in LMIC.

Keywords: Peritoneal surface malignancy, Cytoreductive surgery, HIPEC, LMIC, Tertiary care center

Background

Peritoneal surface malignancies (PSM) comprises of a group of neoplasms which either disseminate through or arise from peritoneal membrane [1]. Till recently, patients suffering with PSM were considered incurable, due to lack of effective therapy and limited survival. The therapeutic approach to PSM was nihilistic and involved attempts at debulking surgery and delivering palliative chemotherapy. However, over the last two decades, significant advancements have been made in the field of PSM. Cytoreductive surgery (CRS) in combination with hyperthermic intraperitoneal chemotherapy (HIPEC) has emerged as a promising intervention in a subset of PSM patients [2].

Only a few centers have been able to achieve proficiency in CRS and HIPEC as it is a complex, multidisciplinary and resource-intensive intervention. Initial experience of CRS and HIPEC was marred with high morbidity and mortality and a significant learning curve [3]. In the recent past, an increasing number of centers globally have initiated successful CRS and HIPEC programs, largely due to standardization of patient selection criteria, surgical technique, and perioperative protocols. To consolidate the evidence base, a large number of prospective randomized trials are currently being conducted by multiple centers.

Most of the literature related to CRS and HIPEC has been published by centers from high-income countries (HIC). There is paucity of literature from low- and middle-income countries (LMIC) despite having a significant volume of patients with PSM. The challenges in establishing complex and expensive treatment modality like CRS and HIPEC in LMIC include lack of expertise, resource constraints, high patient volumes, and socioeconomic factors.

In this article, we aim to present our experience of establishing a PSM program at a government-funded tertiary care cancer center in LMIC utilizing pre-existing resources and present outcomes of treatment in 232 PSM patients treated with CRS and HIPEC.

Methods

The data was collected from a prospectively maintained computerized database of the department of surgical

oncology based in a government-funded tertiary care comprehensive cancer center in northern part of India. All patients who had undergone CRS and HIPEC between January 2015 and December 2020 were included in the study. Records of these patients were reviewed for details regarding the clinical spectrum, surgical details, perioperative (i.e., till 30 days after surgery) outcomes including morbidity and mortality. A retrospective analysis was performed.

Details of program and protocol development

The team for management of peritoneal surface malignancies at our center is multidisciplinary in nature. The team includes experienced doctors from the departments of surgical oncology, medical oncology, radiodiagnosis, and pathology. The core CRS and HIPEC team comprises of experienced senior surgical oncologists, dedicated onco-anesthesia & critical care experts, trained nursing and operation theatre technicians. The support team helps in prehabilitation and postoperative care of the patient and includes members from physiotherapy, nutrition, stoma care, and clinical psychology divisions. Initially, all the procedures were performed by two lead senior surgical oncologists experienced in performing complex surgical oncology procedures and re-do abdominal surgeries after attending dedicated CRS and HIPEC workshops/courses and short-term observerships in high-volume PSM centers. Subsequently, trainees were also allowed to perform simple peritonectomies under supervision.

The prehabilitation protocol includes nutritional status assessment using Subjective Global Assessment (SGA) followed by intensive nutritional support in patients with average or poor nutritional status (viz. body mass index less than 18.5, weight loss more than 10% over last 6 months, serum albumin less than 3 g/dL). Assessment of the baseline physical status is done by a "6-min walk test," pulmonary function test (PFT), and cardiopulmonary exercise testing (CPET). Respiratory conditioning is done by the physiotherapy team with incentive spirometry and a program of home exercises. Cardiovascular status assessment and optimization is done by the anesthesiology and cardiology team in patients with such comorbidities.

Standard patient selection criteria based on guidelines available are followed [4]. PSM patients with a good performance status (ECOG PS \leq 1) and no or well-controlled comorbidities are offered CRS and HIPEC. Selected patients with ECOG PS 2 are also offered CRS and HIPEC after prehabilitation. Patients with unfavorable tumor biology (e.g., signet ring cell adenocarcinomas, sarcomatoid variant of malignant mesothelioma), high CT-PCI (i.e., greater than 20), or features on imaging deemed unsuitable for optimal cytoreduction are excluded [5]. CT-PCI is calculated by locating tumor deposits in the 13 regions of the abdomen as described by Koh et al. [6].

The decision to administer neoadjuvant chemotherapy and regimen is taken in the multidisciplinary tumor board meetings. Advanced ovarian cancer patients with high clinical tumor burden are offered neoadjuvant chemotherapy (NACT) followed by interval CRS and HIPEC. Epithelial ovarian cancer patients receive 3 to 6 cycles of standard platinum-based chemotherapy, if platinum naïve or platinum sensitive. Otherwise, they receive second line chemotherapy. Colorectal cancer patients with peritoneal metastases received NACT using standard FOLFOX regime [7]. Meticulous exploratory laparotomy is performed for calculation of PCI and predicting feasibility of optimal CRS. The goal of CRS is to achieve optimal cytoreduction which is defined as no macroscopic residual disease (CC-0) or macroscopic disease nodules \leq 2.5 mm in size (CC-1). Larger residual macroscopic disease (CC-2/CC-3) is considered suboptimal cytoreduction [8]. Total or disease-specific partial peritonectomy is performed to achieve optimal cytoreduction at the discretion of the operating surgeon [9, 10]. Total peritonectomy comprises removal of parietal peritoneum from bilateral hemidiaphragm, anterior abdominal wall, pelvis, paracolic gutter and diaphragmatic recesses, and greater and lesser omentum along with partial visceral peritonectomy as described by Sugarbaker et al. Multivisceral resections are performed when indicated to achieve optimal CRS status.

After completion of cytoreductive surgery, HIPEC is instituted using a Sunchip™ machine (manufactured by GamidaTech® France). A semi-open technique is used with the help of Omnitract™/Thompson™ retractor and suspension of abdominal wall edges. A Steri-Drape™ was used to temporarily cover the laparotomy wound with a central opening to ensure adequate filling of perfusate and for agitation of abdominal contents for uniform distribution of heated perfusate (Fig. 1).

Choice of chemotherapeutic agent for intraperitoneal chemotherapy is based on the standard recommendations. Generally, cisplatin is used for platinum-sensitive ovarian tumors and mitomycin-C for non-platinum-sensitive ovarian malignancies and gastrointestinal malignancies. The choice of drug and dose is decided by the multidisciplinary oncology team. Normal saline is used as carrier solution, and HIPEC is instituted for 45 to 60 min at a temperature range of 41 to 42°C. Standard safety precautions are followed including prevention of spillage, smoke evacuation, and personnel protective equipment. Intraoperatively, standard protocols are followed by anesthesia team pertaining to maintenance of core temperature, hemodynamic stability, infusion of IV fluids/blood products, and maintaining adequate urine output. Postoperatively, patients are monitored in ICU for 24 to 48 h.

The perioperative morbidities related to CRS and HIPEC are documented meticulously in a predesigned pro forma. After discharge, patients are reviewed again by the multidisciplinary team to assess the need for adjuvant therapy based on primary tumor type, surgical outcome, and final histopathology report.

The cost of the CRS and HIPEC treatment is subsidized by the hospital, and patients are charged for disposable HIPEC sets making the treatment affordable to patients belonging to low and middle socioeconomic strata.

Results

A total of 232 patients with PSM underwent CRS and HIPEC between January 2015 and December 2020. The

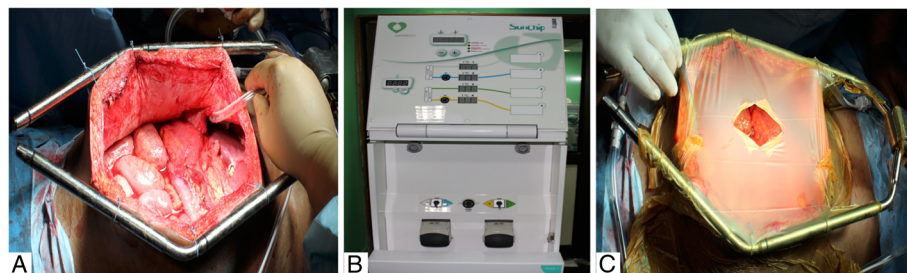


Fig. 1 HIPEC technique. **a** Suspension of abdominal wall edges to Omnitract™ retractor to create a Coliseum. **b** Sunchip™ machine. **c** Coliseum covered with Steri-Drape™ (semi-open)

year-wise frequency of cases is shown in Fig. 2. Most of the protocols were standardized during the first year, and subsequently, minor modifications were made. There was a steady increase in the volume of CRS and HIPEC cases during the study period. However, only a limited number of cases were performed in the year 2020, owing to the pandemic.

The details of clinical profile of patients are shown in Table 1. The mean age was 47.3 years, and there was female preponderance. Nearly one-third of patients (34.9%) had comorbidities, predominantly diabetes and hypertension.

Table 2 shows spectrum of PSM patients undergoing CRS and HIPEC. Ovarian carcinoma, pseudomyxoma peritonei, and colorectal cancers comprised 88.4% of cases in the current series. Rare and uncommon indications comprised 11.6% of cases.

Table 3 shows surgical details of patients undergoing CRS and HIPEC. Mean operating time was 379±108.7 min. The mean peritoneal carcinomatosis index (PCI) was 9.3 with a range of 3 to 26. The mean PCI of non-ovarian cancer group was higher than ovarian cancer group due to usage of neoadjuvant chemotherapy (NACT) leading to downstaging in majority of ovarian cancer patients. 84.7% of ovarian and 40.6% of non-ovarian cancer patients underwent NACT. Total peritonectomy was performed in 21.1% of cases, and this decision was based on disease type and extent of peritoneal

Table 1 Demography and patient profile

Age [mean ± SD]	47.3 ± 9.2 years	
Sex	Male	36 (15.5%)
	Female	196 (84.5%)
Performance status (ECOG)	PS 0/1	214 (92.2%)
	PS 2	18 (7.8%)
	PS 3/4	0%
Comorbidities	None	151 (65.1%)
	Comorbidity	
	• Diabetes mellitus	51 (21.9%)
	• Hypertension	33 (14.2%)
	• Hypothyroidism	12 (5.2%)
• Coronary artery disease	5 (2.2%)	
• COPD	3 (1.3%)	

involvement. 94.4% of patients had an optimal CRS (CC-0/CC-1) before institution of HIPEC. Multivisceral resection (i.e., resection of viscera other than the primary site of malignancy) was performed in 24.5% of patients. Cisplatin was the most common drug used for HIPEC. The patients spent an average of 1.3 days in ICU and 8.1 days in hospital postoperatively.

Table 4 shows details of perioperative morbidity (NCI-CTCAE v5.0 Gr. 3-4) which occurred in 28.0% of patients. The most common major morbidity was deep venous thrombosis followed by subacute intestinal

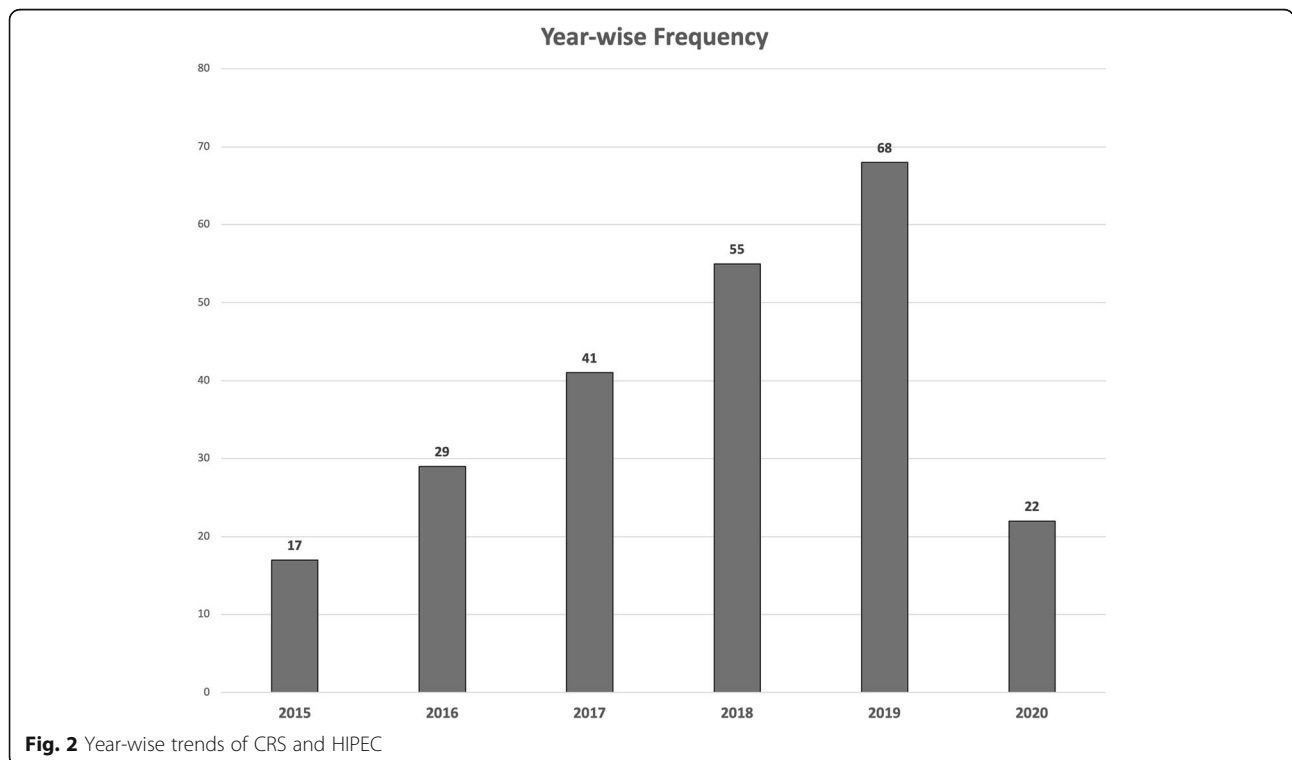


Table 2 Clinical indications for CRS and HIPEC

Clinical indication	Number	Percentage
Carcinoma of the ovary	131	56.5%
Pseudomyxoma peritonei	43	18.5%
Colorectal cancer	31	13.4%
Malignant mesothelioma	13	5.6%
Gastric carcinoma	6	2.6%
Endometrial stromal sarcoma	5	2.2%
Granulosa cell tumor	3	1.3%

obstruction (SAIO), sepsis, burst abdomen, lymphocele, neutropenia, urinoma, acute renal failure, and enterocutaneous fistula

Perioperative mortality occurred in 8 cases (3.5%). Four patients died due to sepsis leading to acute respiratory distress syndrome (ARDS), 2 patients had sudden death on the first postoperative day due to suspected pulmonary embolism, 1 patient succumbed to biliary peritonitis, and 1 patient due to cardiac arrest in postoperative period.

Discussion

Over the last two decades, with the advances made in the field of CRS and HIPEC, peritoneal surface dissemination of abdominal malignancies is increasingly being recognized as a regional disease amenable to potential cure, in a subset of patients. One of the major breakthroughs that helped in mainstreaming CRS is the

surgical standardization of total peritonectomy by Paul H. Sugarbaker in 1995 [9, 11]. Parallel advancements in the field of HIPEC have resulted in increased utilization of CRS and HIPEC as an effective combination therapy for PSM by a number of centers [2]. Last decade has witnessed a spurt in publication of literature pertaining to CRS and HIPEC mainly from HIC. Due to the complexity of treatment, cost factors, and associated higher morbidity and mortality, very few centers from LMIC have ventured in to establish CRS and HIPEC programs despite having a significant volume of patients with PSM. There is a need to share the experience of establishing a CRS and HIPEC program from resource-constrained settings to assess the feasibility, safety, and efficacy.

India has a mixed healthcare system, inclusive of public and private health-care service providers [12]. The public healthcare service is a three-tiered system, providing primary, secondary, and tertiary levels of care. These services are funded by the government to a large extent. However, being a LMIC with a burgeoning population of 1.36 billion, Indian governments are able to dedicate only 1% of the GDP to public healthcare services. Only 16% of the population is covered by some form of health insurance [13]. The average per capita income in India is 150 USD per month, and availing private sector health care facility is beyond the reach of most [14]. This places an undue burden on tertiary health care facilities in the public domain, and starting a new program by using the already strained resources is a difficult proposition.

Table 3 Details of CRS and HIPEC

Operative time [mean ± SD]	379.9 ± 108.7 min	
PCI [mean (range)]	Total (n=232)	9.3 (0–26)
	- Non-ovarian group (n=101)	- 11.1 (0–25)
	- Ovarian group (n=131)	- 7.9 (0–26)
Extent of peritonectomy	Total peritonectomy	49 (21.1%)
	Disease-specific peritonectomy	183 (78.9%)
Types of CRS	Optimal CRS (CC-0/CC-1)	219 (94.4%)
	Suboptimal CRS (CC-2/CC-3)	13 (5.6%)
Multivisceral resections	Hysterectomy/salpingo-oophorectomy	42 (18.1%)
	Appendectomy	38 (16.4%)
	Colectomy	22 (9.5%)
	Anterior/low-anterior resection	3 (1.3%)
	Small intestine -- resection/anastomosis	21 (9.1%)
	Splenectomy +/- distal pancreatectomy	8 (3.5%)
	Cholecystectomy	16 (6.9%)
	Urinary bladder--partial resection	4 (1.7%)
	Total	57 (24.5%)
Drugs for HIPEC	Cisplatin	191 (82.3%)
	Mitomycin C	27 (11.6%)
	Oxaliplatin	7 (3.0%)
	Adriamycin	5 (2.2%)
	Melphalan	2 (0.9%)
ICU stay	1.3 (1–12) days	
Postoperative hospital stay	8.1 (5–26) days	

Table 4 Spectrum and incidence of perioperative morbidity

Morbidity	Number of patients	Percentage
Deep venous thrombosis	15	6.5%
Subacute intestinal obstruction	14	6.0%
Sepsis	12	5.2%
Burst abdomen	10	4.3%
Neutropenia	9	3.9%
Lymphocele	9	3.9%
Urinoma	7	3.0%
Acute renal failure	4	1.7%
Anastomotic leak	4	1.7%
Pulmonary embolism	3	1.3%
Acute respiratory distress syndrome (ARDS)	2	0.9%
GTCS + cardiac arrest (revived)	1	0.4%
Biliary peritonitis	1	0.4%
Overall	65	28.0%

In this article, we present the experience of first 232 cases of CRS and HIPEC at our center. Our hospital is the apex tertiary care hospital in northern part of India, being funded by the government of India. We have established a peritoneal surface malignancy program using the existing infrastructure and man power in our department. The economic model used for this program was mixed in nature. The HIPEC machine was procured using funds from the government of India, and the services were provided free of cost. The patients were only required to buy the consumables used in the operation of HIPEC machine (approximate cost–USD 1200). The patients with income below poverty line were even provided the consumables free of cost using the existing government welfare schemes.

CRS and HIPEC is a time- and resource-intensive intervention, and for initiation of long-term viable CRS and HIPEC program, a good pre-existing healthcare infrastructure and a multidisciplinary team approach is essential. Other important issue is optimal patient selection for CRS and HIPEC. These procedures should only be offered to the group of patients who are likely to benefit, so as to optimize resource utilization. Two factors need to be considered while selecting patients for CRS and HIPEC. First is the disease type, and the other is the extent and volume of peritoneal spread. Based on current literature pseudomyxoma peritonei, mesothelioma, peritoneal metastases of tumors of appendicular and colorectal origin, and ovarian cancers have shown benefit with CRS and HIPEC [15–22]. CT scan of the abdomen and pelvis is used to assess volume and extent of peritoneal spread and helps to determine feasibility of optimal cytoreduction. Performance status of the patient and optimization of comorbidities are key factors in

patient selection process. We followed stringent patient selection criteria in the current study. Two thirds of the patients had no comorbidity, and the remaining had co-existing diseases like diabetes mellitus, hypertension, and hypothyroidism which were well controlled. Patients with aggressive histologies (e.g., signet ring cell adenocarcinoma) were not selected for these procedures.

Spectrum of patients undergoing CRS and HIPEC varies in different studies. Factors which can influence the disease spectrum include type of surgical specialty and referral patterns. Most of the studies evaluating CRS and HIPEC from the west have a preponderance of tumors of gastrointestinal tract origin. In a study published by Levine et al. comprising 1000 patients, 47.2% of the tumors were of appendiceal origin and 24.8% colorectal origin, and only 6.9% were that of ovarian origin [23–25]. In the current study, more than half of the patients had tumors of ovarian origin. Peritoneal metastases of colorectal origin and pseudomyxoma peritonei comprised one fourth of the volume. These trends are likely to change over a time period due to referral patterns and revision of guidelines based on results from ongoing randomized studies.

The average peritoneal carcinomatosis index (PCI) in our series was 9.3, lower than that reported in other contemporary series where mean PCI ranged from 11 to 16 [23, 26–28]. Perhaps, this is because of a stringent selection criteria used and preponderance of cases of carcinoma ovary receiving prior chemotherapy resulting in down staging and low PCI. The mean PCI for non-ovarian cancer patients was 11.1 in our series.

In view of the complexity and variations in protocols reported in literature, every institution planning to start CRS and HIPEC programs should have standard and

uniform protocols pertaining to patient selection, prehabilitation, surgical technique, HIPEC methods, anesthesia, and ICU care for consistent outcomes. Meticulous documentation of patient and treatment details preferably in a structured electronic format is important, as it helps in performing audits for learning and facilitates analysis of data for outcomes.

Preliminary meticulous exploration of the abdomen to document PCI and assess feasibility of optimal CRS is an important step which helps in early decision-making. We suggest a senior and experienced surgeon be involved in this part of the procedure. It is recommended to have a team of surgeons, well versed with the intricacies of CRS, to work together to avoid fatigue and errors. At our institution, two experienced surgeons performed majority of the procedures during the initial phase, and subsequently, trainees were allowed to perform simple peritonectomies under supervision. The surgical goal of CRS is to achieve an optimal cytoreduction status, balancing risk versus benefit. In the current study, 21.1% had total peritonectomy, and the remaining had partial disease-specific peritonectomy. For the HIPEC phase of surgery, adherence to safety protocols using safe and efficacious cytotoxic agents is key to success. Dosages of prior chemotherapy a patient has received should always be kept in mind while deciding the intraperitoneal chemotherapy dose so as to avoid toxicity.

Most of the initial studies reported very high morbidity and mortality with CRS and HIPEC [29, 30]. However, with increasing experience, contemporary studies are reporting an acceptable rate of morbidity and mortality [24, 31–33]. In the current study, perioperative morbidity occurred in 28.0% of patients. The most common morbidities encountered were deep vein thrombosis, subacute intestinal obstruction, sepsis, and burst abdomen. Morbidity of the current study is comparable to the morbidity reported in recent studies. Overall mortality in our experience was 3.5% which was acceptable in comparison to mortalities reported in recent studies ranging from 2 to 8.6%.

Conclusion

In conclusion, outcomes of the current study indicate that it is feasible to implement complex and resource-intensive treatment like CRS and HIPEC in resource-constrained hospitals in LMIC. The key to success is multidisciplinary team approach, protocol-based treatment delivery with strict adherence to patient selection criteria, surgical quality control, and optimal perioperative care.

Abbreviations

CRS: Cytoreductive surgery; HIPEC: Hyperthermic intraperitoneal chemotherapy; PSM: Peritoneal surface malignancy; LMIC: Low- and middle-income country; HIC: High-income country; SGA: Subjective Global

Assessment; PFT: Pulmonary function test; CPET: Cardiopulmonary exercise testing; ECOG: Eastern Cooperative Oncology Group; PS: Performance status; NACT: Neoadjuvant chemotherapy; CC: Completeness of cytoreduction; IV: Intravenous; ICU: Intensive care unit; CT: Computed tomography; PCI: Peritoneal carcinomatosis index; NCI-CTCAE: National Cancer Institute–Common Terminology Criteria for Adverse Events; Gr.: Grade; SAIO: Subacute intestinal obstruction; ARDS: Acute respiratory distress syndrome

Acknowledgements

None

Declarations

.

Authors' contributions

- SD established the PSM program in AIIMS, New Delhi, and is the lead surgeon. He provided extensive guidance in development of the manuscript.
- MR and SBhoriwal are consultant surgeons. They reviewed the manuscript and provided valuable inputs.
- BB analyzed and interpreted the data and wrote the manuscript.
- SBhatnagar, RG, and NG were the lead anesthesiologists and critical care experts. They reviewed the manuscript and provided valuable inputs.
- AS and LK were the lead medical oncologists. They reviewed the manuscript and provided valuable inputs.
- ST and ED were the lead radiologists. They reviewed the manuscript and provided valuable inputs.
- SM and PD were the lead pathologists. They reviewed the manuscript and provided valuable inputs.
- The authors read and approved the final manuscript.

Funding

None

Availability of data and materials

The data was extracted from the computerized database in the Department of Surgical Oncology at AIIMS, New Delhi, and will be available from corresponding author on reasonable request.

Ethics approval and consent to participate

In view of the study being retrospective in nature, the AIIMS Institutional Ethics Committee waived off the requirement for ethical approval and consent.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Author details

¹Department of Surgical Oncology, Dr. BRA-IRCH, AIIMS, New Delhi 110029, India. ²Department of Onco-anesthesia & Palliative Medicine, BRA-IRCH, AIIMS S, New Delhi, India. ³Department of Medical Oncology, BRA-IRCH, AIIMS, New Delhi, India. ⁴Department of Radiodiagnosis, BRA-IRCH, AIIMS, New Delhi, India. ⁵Department of Pathology, AIIMS, New Delhi, India.

Received: 11 March 2021 Accepted: 27 May 2021

Published online: 05 June 2021

References

1. Sugarbaker PH. Management of peritoneal-surface malignancy: the surgeon's role. *Langenbeck's Arch Surg.* 1999;384(6):576–87. <https://doi.org/10.1007/s004230050246>.
2. Neuwirth MG, Alexander HR, Karakousis GC. Then and now: cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (HIPEC), a historical perspective. *J Gastrointest Oncol.* 2016;7(1):18–28. <https://doi.org/10.3978/j.issn.2078-6891.2015.106>.
3. Kusamura S, Baratti D, Deraco M. Multidimensional analysis of the learning curve for cytoreductive surgery and hyperthermic intraperitoneal chemotherapy in peritoneal surface malignancies. *Ann Surg.* 2012;255(2):348–56. <https://doi.org/10.1097/SLA.0b013e3182436c28>.

4. International PSOGI-recommendations for the management of peritoneal metastases. In: PSOGI. <http://www.psogi.com/psogi/international-recommendations-for-the-management-of-peritoneal-metastases/>. Accessed 30 Apr 2020
5. Low RN, Barone RM, Lucero J. Comparison of MRI and CT for predicting the peritoneal cancer index (PCI) preoperatively in patients being considered for cytoreductive surgical procedures. *Ann Surg Oncol*. 2015;22(5):1708–15. <https://doi.org/10.1245/s10434-014-4041-7>.
6. Koh J-L, Yan TD, Glenn D, Morris DL. Evaluation of preoperative computed tomography in estimating peritoneal cancer index in colorectal peritoneal carcinomatosis. *Ann Surg Oncol*. 2009;16(2):327–33. <https://doi.org/10.1245/s10434-008-0234-2>.
7. Zhou S, Jiang Y, Liang J, Pei W, Zhou Z (2021) Neoadjuvant chemotherapy followed by hyperthermic intraperitoneal chemotherapy for patients with colorectal peritoneal metastasis: a retrospective study of its safety and efficacy. *World J Surg Oncol* 19:151. <https://doi.org/https://doi.org/10.1186/s12957-021-02255-w>, 1
8. Sugarbaker PH (1996) Peritoneal carcinomatosis: principles of management. Springer Science & Business Media
9. Sugarbaker PH. Peritonectomy procedures. *Ann Surg*. 1995;221(1):29–42. <https://doi.org/10.1097/0000658-199501000-00004>.
10. Jacquet P, Sugarbaker PH. Current methodologies for clinical assessment of patients with peritoneal carcinomatosis. *J Exp Clin Cancer Res*. 1996;15:49–58.
11. Wimberger P, Wehling M, Lehmann N, Kimmig R, Schmalfeldt B, Burges A, et al. Influence of residual tumor on outcome in ovarian cancer patients with FIGO stage IV disease: an exploratory analysis of the AGO-OVAR (Arbeitsgemeinschaft Gynaekologische Onkologie Ovarian Cancer Study Group). *Ann Surg Oncol*. 2010;17(6):1642–8. <https://doi.org/10.1245/s10434-010-0964-9>.
12. Chokshi M, Patil B, Khanna R, Neogi SB, Sharma J, Paul VK, et al. Health systems in India. *J Perinatol*. 2016;36(5):S9–S12. <https://doi.org/10.1038/jp.2016.184>.
13. Keane M, Thakur R. Health care spending and hidden poverty in India. *Res Econ*. 2018;72(4):435–51. <https://doi.org/10.1016/j.rie.2018.08.002>.
14. India: national income per capita 2015–2021. In: Statista. <https://www.statista.com/statistics/802122/india-net-national-income-per-capita/>. Accessed 27 Apr 2021
15. Chicago Consensus Working Group. The Chicago Consensus on peritoneal surface malignancies: management of ovarian neoplasms. *Cancer*. 2020; 126(11):2553–60. <https://doi.org/10.1002/cncr.32867>.
16. Chicago Consensus Working Group. The Chicago Consensus on peritoneal surface malignancies: management of appendiceal neoplasms. *Ann Surg Oncol*. 2020;27(6):1753–60. <https://doi.org/10.1245/s10434-020-08316-w>.
17. Chicago Consensus Working Group. The Chicago Consensus on peritoneal surface malignancies: management of colorectal metastases. *Cancer*. 2020; 126(11):2534–40. <https://doi.org/10.1002/cncr.32874>.
18. Chicago Consensus Working Group. The Chicago Consensus on peritoneal surface malignancies: management of peritoneal mesothelioma. *Ann Surg Oncol*. 2020;27(6):1774–9. <https://doi.org/10.1245/s10434-020-08324-w>.
19. Trilling B, Brind'Amour A, Hamad R, Tremblay JF, Dubé P, Mitchell A, et al. Two-step cytoreductive surgery and hyperthermic intraperitoneal chemotherapy for pseudomyxoma peritonei with high peritoneal carcinomatosis index. *World J Surg Oncol*. 2021;19(1):60. <https://doi.org/10.1186/s12957-021-02171-z>.
20. Kamada Y, Hida K, Ishibashi H, Sako S, Mizumoto A, Ichinose M, et al. Thirty-three long-term survivors after cytoreductive surgery in patients with peritoneal metastases from colorectal cancer: a retrospective descriptive study. *World J Surg Oncol*. 2021;19(1):31. <https://doi.org/10.1186/s12957-021-02145-1>.
21. Segura-Sampedro JJ, Morales-Soriano R, Arjona-Sánchez Á, Cascales-Campos P. Secondary surgical cytoreduction needs to be assessed taking into account surgical technique, completeness of cytoreduction, and extent of disease. *World J Surg Oncol*. 2020;18(1):92. <https://doi.org/10.1186/s12957-020-01853-4>.
22. Leigh N, Solomon D, Pletcher E, Labow DM, Magge DR, Sarpel U, et al. The importance of primary tumor origin in gastrointestinal malignancies undergoing cytoreductive surgery and hyperthermic intraperitoneal chemotherapy. *World J Surg Oncol*. 2020;18(1):182. <https://doi.org/10.1186/s12957-020-01938-0>.
23. Levine EA, Stewart JH, Shen P, et al. Cytoreductive surgery and hyperthermic intraperitoneal chemotherapy for peritoneal surface malignancy: experience with 1,000 patients. *J Am Coll Surg*. 2014;218(4): 573–85. <https://doi.org/10.1016/j.jamcollsurg.2013.12.013>.
24. Piso P, Nedelcut SD, Rau B, Königsrainer A, Glockzin G, Ströhlein MA, et al. Morbidity and mortality following cytoreductive surgery and hyperthermic intraperitoneal chemotherapy: data from the DGAV StuDoQ Registry with 2149 consecutive patients. *Ann Surg Oncol*. 2019;26(1):148–54. <https://doi.org/10.1245/s10434-018-6992-6>.
25. Moran B, Cecil T, Chandrakumaran K, Arnold S, Mohamed F, Venkatasubramanian A. The results of cytoreductive surgery and hyperthermic intraperitoneal chemotherapy in 1200 patients with peritoneal malignancy. *Color Dis*. 2015;17(9):772–8. <https://doi.org/10.1111/codi.12975>.
26. Cascales Campos P, Gil J, Parrilla P. Morbidity and mortality outcomes of cytoreductive surgery and hyperthermic intraperitoneal chemotherapy in patients with primary and recurrent advanced ovarian cancer. *Eur J Surg Oncol*. 2014;40(8):970–5. <https://doi.org/10.1016/j.ejso.2013.08.013>.
27. Glehen O, Gilly FN, Boutitie F, Bereder JM, Quenet F, Sideris L, et al. Toward curative treatment of peritoneal carcinomatosis from nonovarian origin by cytoreductive surgery combined with perioperative intraperitoneal chemotherapy: a multi-institutional study of 1,290 patients. *Cancer*. 2010; 116(24):5608–18. <https://doi.org/10.1002/cncr.25356>.
28. Tabrizian P, Jibara G, Shrager B, Franssen B, Yang MJ, Sarpel U, et al. Outcomes for cytoreductive surgery and hyperthermic intraperitoneal chemotherapy in the elderly. *Surg Oncol*. 2013;22(3):184–9. <https://doi.org/10.1016/j.suronc.2013.06.001>.
29. Elias D, Goere D, Blot F, Billard V, Pocard M, Kohnen-Shahri N, et al. Optimization of hyperthermic intraperitoneal chemotherapy with oxaliplatin plus irinotecan at 43°C after complete cytoreductive surgery: mortality and morbidity in 106 consecutive patients. *Ann Surg Oncol*. 2007;14(6):1818–24. <https://doi.org/10.1245/s10434-007-9348-1>.
30. Deraco M, Baratti D, Kusamura S. Morbidity and quality of life following cytoreduction and HIPEC. *Peritoneal Carcinomatosis*. 2007:403–18. https://doi.org/10.1007/978-0-387-48993-3_26.
31. Eveno C, Schiavone R, Pocard M, et al. Effect of postoperative morbidity on survival after cytoreductive surgery (CRS) with heated intraperitoneal chemotherapy (HIPEC) for peritoneal metastasis in a series of 700 cases. 2017;35:3565–5. https://doi.org/10.1200/JCO.2017.35.15_suppl.3565.
32. Votanopoulos KI, Newman NA, Russell G, Ithemelandu C, Shen P, Stewart JH, et al. Outcomes of cytoreductive surgery (CRS) with hyperthermic intraperitoneal chemotherapy (HIPEC) in patients older than 70 years; survival benefit at considerable morbidity and mortality. *Ann Surg Oncol*. 2013;20(11):3497–503. <https://doi.org/10.1245/s10434-013-3053-z>.
33. Dranichnikov P, Graf W, Cashin PH. Readmissions after cytoreductive surgery and hyperthermic intraperitoneal chemotherapy—a national population-based study. *World J Surg Oncol*. 2020;18(1):67. <https://doi.org/10.1186/s12957-020-01837-4>.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

