Biomolecules & Biomedicine

RESEARCH ARTICLE

Perioperative hemoglobin trajectories and transient hemodilution during cytoreductive surgery with hyperthermic intraperitoneal chemotherapy

Kimia Ghafouri[1], Martin Ryll[1], Toby N. Weingarten[1], Juraj Sprung[1], Travis E. Grotz[2], Darrell R. Schroeder[3], and Atousa Deljou[1*]

Cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (HIPEC) for peritoneal malignancies involves heated intraperitoneal cisplatin perfusion and liberal intravenous hydration, both of which may affect perioperative hemoglobin (Hb) concentrations. This study aimed to characterize Hb trajectories during HIPEC and determine whether these patterns differ between laparoscopic and open procedures. We retrospectively analyzed 186 HIPEC procedures performed between 2018 and 2023, including 107 laparoscopic and 79 laparotomy cases. Hb concentrations were assessed before HIPEC, from HIPEC initiation to the end of surgery, and on the first postoperative measurement. Changes were compared using two-way repeated-measures analysis of variance (ANOVA), and mixed-effects multivariable regression was used to identify factors associated with intra-to-postoperative Hb shifts. Laparoscopic procedures were shorter and associated with lower fluid administration and blood loss than laparotomy procedures (all $P < 0.001$). Hb declined from baseline to intraoperative nadir in both groups, with reductions of −1.24 g/dL after laparoscopy and −1.62 g/dL after laparotomy (both $P < 0.001$), followed by partial postoperative recovery of +0.84 g/dL and +0.62 g/dL, respectively (both $P < 0.001$). Longer operative duration was associated with reduced postoperative Hb recovery in laparotomy cases (−0.12 g/dL/hour; $P < 0.040$). HIPEC is associated with a modest intraoperative Hb decline followed by early partial recovery, a pattern consistent with transient intraprocedural hemodilution. Recognizing this trajectory may help contextualize intraoperative Hb values and support more nuanced transfusion decision-making.

Keywords: Hyperthermic intraperitoneal chemotherapy, hemoglobin trajectory, cytoreductive surgery, hemodilution, transfusion.

Introduction

Hyperthermic intraperitoneal chemotherapy (HIPEC) is an advanced treatment synergistically employed with cytoreductive surgery (CRS) for managing peritoneal malignancies, including pseudomyxoma peritonei, mesothelioma, and metastatic colorectal or ovarian cancer. This procedure typically commences with a CRS phase, involving surgical tumor debulking, followed by a HIPEC phase. During HIPEC, heated chemotherapeutic agents are instilled and circulated within the peritoneal cavity [1–3]. The rationale for combining hyperthermia with chemotherapy is to enhance the cytotoxic efficacy of cytostatic cisplatin while reducing systemic toxicity [4].

HIPEC induces substantial physiological stress, fluid shifts, and an inflammatory response. Metabolic demand increases as the peritoneal cavity is perfused with a heated chemotherapeutic agent, maintained between 41°C and 43°C. This management triggers a hyperdynamic response, characterized by increased cardiac output, reduced systemic vascular resistance, and elevated oxygen consumption [5–7], potentially leading to electrolyte disturbances, acidosis, and hemodynamic instability [6–9].

The HIPEC phase necessitates intensive intravenous fluid management for several critical reasons: cisplatin's nephrotoxicity demands aggressive intravenous hydration to maintain high urine output and mitigate renal injury; the intraperitoneal perfusate undergoes partial absorption, thereby altering intravascular volume; and this absorption is further amplified by the heated and pressurized perfusate. While several studies have examined perioperative hemoglobin (Hb) levels after CRS-HIPEC, most have focused on perioperative hematologic complications [10, 11]. However, the pattern of Hb changes during and immediately after the HIPEC phase has not been previously characterized, particularly considering the substantial fluid administration during this portion of the procedure. Given that Hb concentration is frequently utilized intraoperatively to assess blood loss and guide clinical decision-making, understanding the anticipated pattern of Hb changes during CRS-HIPEC could offer valuable context for interpreting

[1]Department of Anesthesiology and Perioperative Medicine, Mayo Clinic College of Medicine and Science, Rochester, MN, USA; [2]Department of Hepatobiliary and Pancreatic Surgery, Mayo Clinic College of Medicine and Science, Rochester, MN, USA; [3]Health Sciences Research, Division of Biomedical Statistics and Informatics, Mayo Clinic College of Medicine and Science, Rochester, MN, USA.

*Correspondence to Atousa Deljou: Deljou.Atousa@mayo.edu

DOI: 10.17305/bb.2026.14404

© 2026 Ghafouri et al. This article is available under a Creative Commons License (Attribution 4.0 International, as described at https://creativecommons.org/licenses/by/4.0/).

observed Hb declines. This study aimed to delineate Hb concentration trends throughout the HIPEC phase of the CRS-HIPEC procedure.

Materials and methods

To investigate perioperative fluctuations of Hb levels during HIPEC, a retrospective study was conducted, analyzing adult patients (18 years and older) treated between May 6, 2018, and June 30, 2023, at Mayo Clinic Rochester, Minnesota. This study received approval from the Mayo Clinic Institutional Review Board (IRB protocol 23-006680). In accordance with Minnesota Statute 144.295, all study participants provided prior written authorization for the use of their medical records in research. This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [12].

Study aims

The HIPEC phase of CRS is typically associated with minimal blood loss; however, it has been observed that this phase is consistently accompanied by transient declines in Hb concentrations. The primary aim of this study was to characterize the trajectories of Hb concentrations during the HIPEC phase of CRS-HIPEC procedures.

CRS-HIPEC management

Anesthetic care for CRS-HIPEC procedures is guided by an established institutional protocol. Procedures are performed *via* laparotomy or a laparoscopic approach and consist of two stages. The first, *or cytoreductive stage, is performed via* a midline abdominal incision for extensive and lengthy cytoreduction, or *via* a laparoscopic approach when limited cytoreduction is deemed sufficient. Following the completion of CRS, the HIPEC phase (defined from HIPEC initiation to procedure completion) begins with the placement of inflow and outflow abdominal catheters for abdominal perfusion with a heated chemotherapeutic solution. The perfusate is maintained at a target temperature of 42.5°C, with a perfusion duration of 60–90 min, depending on the specific treatment protocol.

A two-drug regimen is employed in most cases, with nearly all patients receiving cisplatin at a dose of 100 mg/m^2. To mitigate the risk of cisplatin-associated nephrotoxicity, sodium thiosulfate is administered as a 7.5 g/m^2 intravenous bolus over 20 min at the initiation of HIPEC, followed immediately by a continuous infusion of 25.56 g/m^2 over 12 h. The nephroprotective effects of sodium thiosulfate are mediated through its binding with cisplatin and its reactive platinum metabolites, forming inactive, water-soluble platinum–thiosulfate complexes. This mechanism reduces the amount of free, toxic platinum reaching renal tubule cells. This nephroprotective strategy is combined with aggressive intravenous hydration using crystalloids and 5% albumin, targeting a urine output of approximately 1–2 mL/kg/hr. Additional chemotherapeutic agents used in selected protocols include mitomycin C (25 mg/m^2), paclitaxel (175 mg/m^2), and irinotecan (75 mg/m^2). The perfusate volume is standardized at 2 L/m^2. Manual abdominal agitation is employed during the HIPEC phase to promote uniform distribution of the cytostatic solution. During this phase, serial measurements of arterial blood gases, Hb concentrations, and serum electrolytes are performed.

Data collection

Electronic medical records were reviewed to obtain selected demographic and procedural characteristics. Hb concentrations were assessed at three distinct time points: (a) prior to the initiation of HIPEC (pre-HIPEC), (b) at 15- to 20-minute intervals from the start of the HIPEC phase until procedure completion, with the HIPEC nadir defined as the lowest Hb value recorded during this interval, and (c) at the first postoperative measurement, obtained either in the recovery room or following admission to the hospital ward.

Exclusion criteria

To specifically evaluate Hb trajectories primarily attributable to fluid management, confounding from Hb changes related to blood loss was minimized. Therefore, all patients who received intraoperative or early postoperative blood transfusions prior to the first postoperative Hb measurement were excluded. Cases with incomplete documentation or missing serial Hb measurements during the HIPEC phase were also excluded.

Statistical analysis

Demographics, clinical characteristics, and Hb features of the cohort were summarized as counts (percentages) for categorical data and medians (25th to 75th percentile) for continuous data. Patients undergoing multiple eligible CRS-HIPEC procedures during the study period could contribute more than one procedure to the analysis. To characterize Hb trajectories, Hb levels were analyzed at the following perioperative intervals: pre-HIPEC to HIPEC-nadir, and HIPEC-nadir to the first postoperative measurement. To ensure that the study focused solely on Hb trends during the HIPEC phase, the Hb concentration measured immediately before HIPEC initiation served as the reference value for all subsequent Hb changes.

Hb concentrations between different time points and between laparoscopic vs laparotomy surgical approaches were compared using a 2-way repeated measures analysis of variance (ANOVA) with appropriate pairwise post-hoc tests incorporating Bonferroni correction. Mean and 95% confidence intervals (CIs) were calculated for the change in Hb. The distribution of Hb values and changes in Hb were visualized using box and line plots. The influence of demographic and perioperative factors on the magnitude of change in Hb concentrations from HIPEC-nadir to postoperative was analyzed by mixed-effects multivariable regression (with a separate intercept per unique patient to account for intraindividual correlation), with the change (delta) in Hb concentrations as the dependent variable. Data processing and analysis were performed with Python, v3.10 (Python Software Foundation, Wilmington DE, USA) and its libraries pandas, NumPy, SciPy, statsmodels, and pingouin. A P-value <0.05 was considered statistically significant.

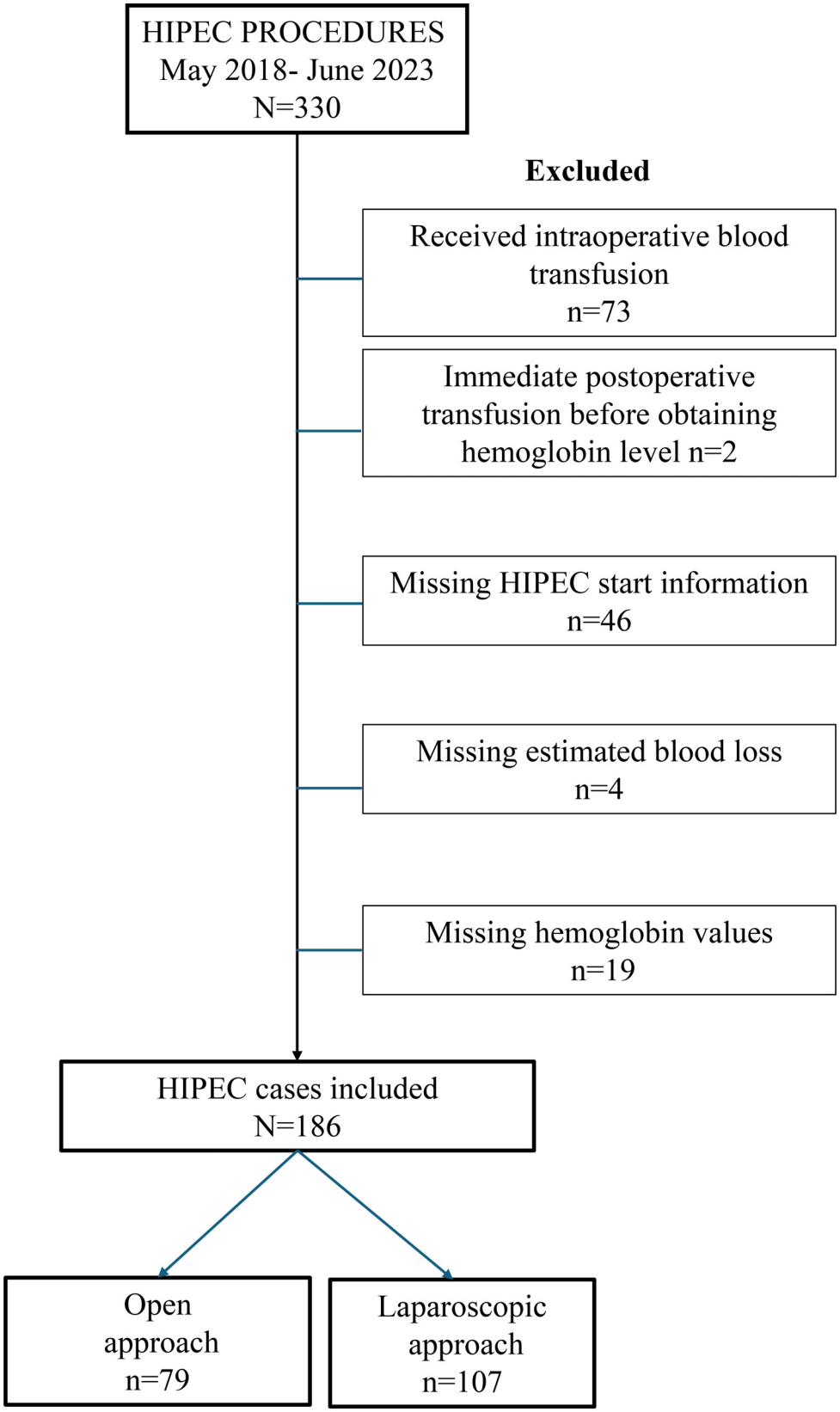

Figure 1. **Flow diagram of study participants.**

Table 1. Patient and procedural characteristics of cytoreductive surgery with hyperthermic intraperitoneal chemotherapy

Characteristics	All cases $n = 186$	Laparoscopic approach $n = 107$	Laparotomy approach $n = 79$	*P* value
Sex (male)	102 (54.8%)	60 (56.1%)	42 (53.2%)	0.806
Age (years)	58.7 [51.6–66.4]	58.4 [50.5–66.7]	58.7 [54.4–65.7]	0.650
Weight (kg)	73.3 [61.9–86.7]	70.7 [60.7–84.4]	75.8 [64.4–93.4]	0.070
Height (cm)	174 [167–180]	173 [167–180]	174 [166–181]	0.568
Procedure duration (hours)	5.7 [3.5–9.3]	3.7 [3.1–4.4]	9.1 [7.8–10.2]	< **0.001**
Crystalloids (L)	3.8 [2.6–5.0]	3.0 [2.0–4.0]	4.8 [4.0–5.7]	< **0.001**
Albumin 5% (L)	1.2 [0.7–2.0]	1.0 [0.5–1.2]	1.6 [1.2–2.2]	< **0.001**
Estimated blood loss (mL)	115 [25–400]	50 [15–100]	400 [238–550]	< **0.001**

Binary variables are presented as counts (percentages), while continuous variables are reported as the median [25th-75th percentile interquartile range].

Table 2. Perioperative hemoglobin concentrations in patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy, stratified by surgical approach

Characteristics	All cases $n = 186$	Laparoscopic approach $n = 107$	Laparotomy approach $n = 79$
Hemoglobin (g/dL)[1]			
Pre-HIPEC	10.6 [9.6–11.9]	10.4 [9.3–11.6]	11.1 [9.9–12.1]
HIPEC-nadir	9.1 [8.3–10.2]	9.1 [8.4–10.1]	9.3 [8.4–10.4]
First postoperative	10.0 [9.1–11.0]	10.0 [9.2–10.8]	9.9 [9.0–11.4]
Δ Hemoglobin (g/dL)[2]			
Pre-HIPEC → HIPEC-nadir	−1.41 [−1.50–(−1.29)]	−1.25 [−1.42–(−1.09)]	−1.62 [−1.80–(−1.45)]
HIPEC-nadir → Postoperatively	0.75 [0.63–0.86]	0.84 [0.70–0.98]	0.62 [0.42–0.82]

[1]Data are presented as the median [25th–75th percentile]. The comparison between laparoscopic and laparotomy approaches yielded $P = 0.396$, determined by a two-way repeated measures ANOVA. [2]Data are presented as the mean [95% CI]. A two-way repeated measures ANOVA revealed a statistically significant difference in hemoglobin levels between time points ($P < 0.001$). **Abbreviations:** ANOVA, analysis of variance; CI, confidence interval; HIPEC, hyperthermic intraperitoneal chemotherapy.

Results

During the study period, 330 CRS-HIPEC procedures were identified. After applying exclusion criteria, the final cohort consisted of 186 HIPEC procedures performed in 151 patients: 107 via laparoscopic and 79 via laparotomy surgical approach (Figure 1). Table 1 summarizes the demographic and procedural characteristics of the study cohort. Compared with laparotomy cases, laparoscopic procedures were significantly shorter (median, 3.7 vs. 9.1 h, $P < 0.001$), involved less crystalloid administration (median 3.0 vs. 4.8 L, $P < 0.001$) and 5% albumin (median 1.0 vs. 1.6 L, $P < 0.001$), and had lower estimated blood loss (median 50 vs. 400 mL, $P < 0.001$).

Table 2 and Figure 2 summarize Hb concentrations and interval changes by surgical approach. The median pre-HIPEC Hb concentration was 10.4 g/dL for laparoscopic and 11.1 g/dL for laparotomy procedures. The HIPEC-nadir Hb concentration was 9.1 g/dL for laparoscopic and 9.3 g/dL for laparotomy cases. The first postoperative Hb concentration was 10.0 g/dL for laparoscopic and 9.9 g/dL for laparotomy procedures. Hb concentration decreased from pre-HIPEC to the HIPEC-nadir (laparoscopic: −1.25 g/dL, $P < 0.001$; laparotomy: −1.62 g/dL, $P < 0.001$), followed by increases to the first postoperative Hb concentration (laparoscopic: 0.84 g/dL, $P < 0.001$; laparotomy: 0.62 g/dL, $P < 0.001$). Hb concentration differed significantly across time points (overall $P < 0.001$ by ANOVA), whereas no significant differences were observed between laparoscopic and laparotomy approaches ($P = 0.396$).

Table 3 presents the results from the multivariable analysis of patient and procedural factors and their associations with changes in Hb concentration from the HIPEC-nadir to the first postoperative value. The first postoperative Hb measurement was obtained a median of 2.73 [0.91 - 6.85] hours after completion of surgery. Higher volumes of crystalloid fluids were associated with greater recovery in Hb levels in both laparoscopic (an increase of 0.19 g/dL per liter of crystalloid; 95% CI, 0.07–0.32; $P = 0.004$) and laparotomy cases (0.20 g/dL per liter; 95% CI, 0.07–0.33; $P = 0.003$). Among patients undergoing laparotomy, longer procedure duration was associated with a smaller recovery in Hb levels, with Hb increasing by 0.12 g/dL less for each additional hour of surgery (95% CI, −0.23 to −0.01; $P = 0.040$).

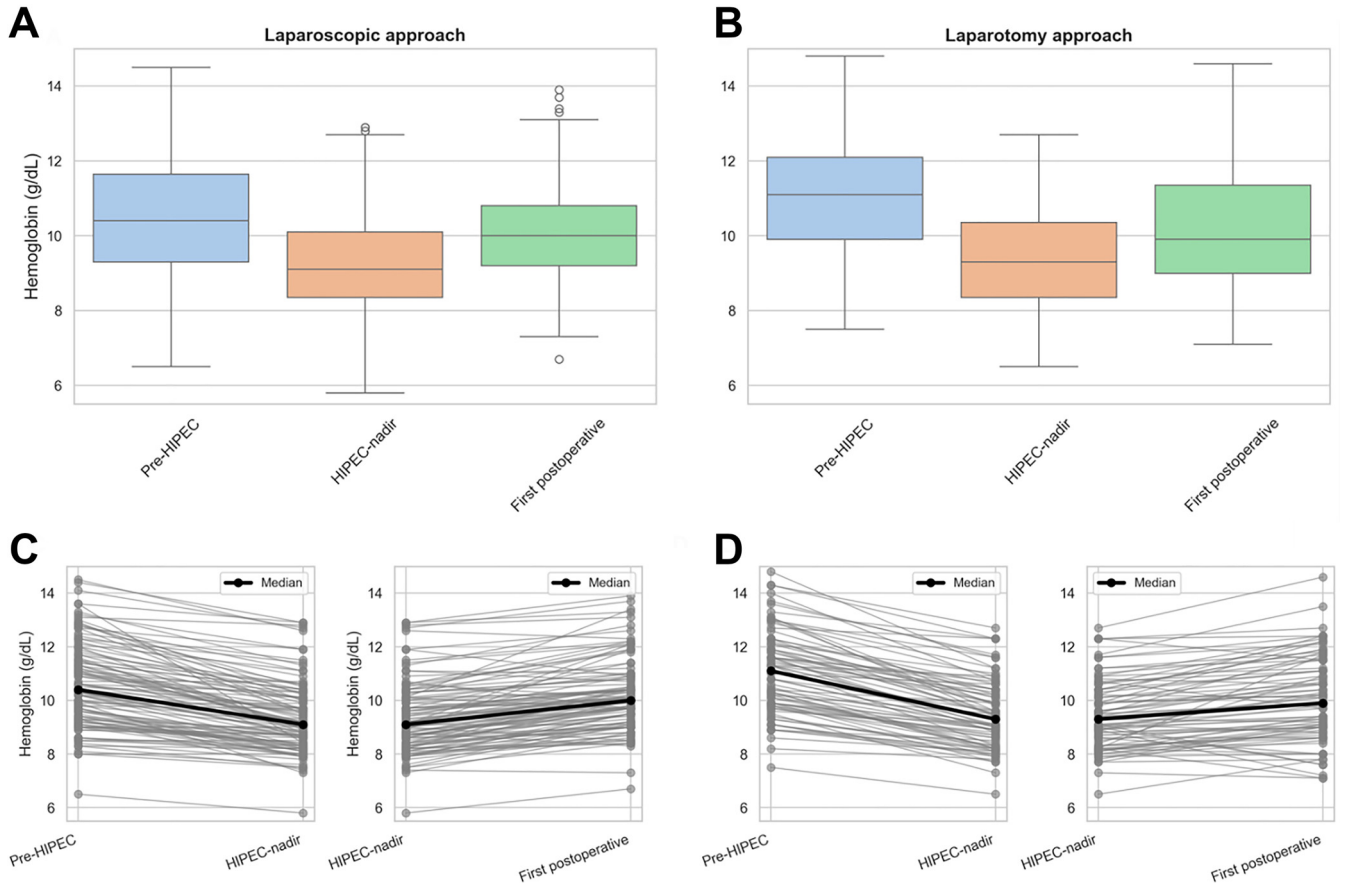

Figure 2. Hemoglobin trajectories during cytoreductive surgery with hyperthermic intraperitoneal chemotherapy according to surgical approach. (**A–B**) Boxplots showing hemoglobin concentrations at the pre-HIPEC measurement, HIPEC nadir, and first postoperative measurement in laparoscopic (A) and laparotomy (B) procedures. C–D, Paired individual hemoglobin trajectories for laparoscopic (C) and laparotomy (D) procedures, displayed separately for the decline from pre-HIPEC to HIPEC nadir and the subsequent change from HIPEC nadir to the first postoperative measurement. Gray lines represent individual procedures, and black lines represent median hemoglobin values at each time point. **Abbreviations:** CRS, cytoreductive surgery; Hb, hemoglobin; HIPEC, hyperthermic intraperitoneal chemotherapy.

Discussion

Our primary finding is that, in a selected cohort of non-transfused patients undergoing CRS–HIPEC, Hb concentrations exhibited a modest decline during the HIPEC phase, followed by partial recovery in the early postoperative period. Due to the non-protocolized timing of postoperative Hb measurements, our findings represent an estimation of early Hb recovery rather than definitive postoperative values. While the underlying mechanism cannot be definitively established from this study, hemodilution is a plausible explanation for the transient decrease in Hb concentration. Notably, increased intraoperative crystalloid administration correlated with more pronounced Hb recovery. Although this observation may reflect variations in perioperative fluid redistribution, postoperative diuresis, or other unmeasured factors, the precise mechanism remains undetermined within the scope of this study. Procedures performed via laparotomy, which typically involve longer operative times, more extensive cytoreduction, and greater blood loss than laparoscopic cases, also demonstrated partial early postoperative recovery of Hb concentrations. However, in patients undergoing laparotomy, a longer surgical duration was associated with less Hb recovery.

In standard surgical practice, tumor debulking precedes HIPEC initiation; therefore, the majority of blood loss is anticipated during CRS rather than the HIPEC phase. Consequently, the observed decline in Hb concentrations during the HIPEC phase is unlikely to be solely attributable to further blood loss [9]. Few studies have documented a decrease in Hb levels associated with CRS-HIPEC [9–11, 13, 14]. Cuenca Apolo et al. [10] reported a decline in Hb concentrations during HIPEC that persisted at 72 h postoperatively. Schmidt et al. [9] demonstrated a 24% reduction in Hb concentration during CRS-HIPEC, which remained significantly lower on postoperative day three. Falcon-Araña et al. [15] observed a mild intraoperative decrease in Hb unrelated to visible bleeding, attributing it to hemodilution or chemotherapy-induced hemolysis. Cripe et al. [14] and Cooksley et al. [13] also reported anemia following CRS-HIPEC, though without discussing potential etiologies.

None of these studies have attempted to elucidate the mechanisms underlying Hb changes specifically during the HIPEC phase of CRS. A plausible explanation for the decline in Hb concentrations during HIPEC is hemodilution resulting from intravenous fluid administration. However, several additional factors may synergistically enhance the systemic absorption

Table 3. Multivariable regression analysis of factors associated with the change in hemoglobin levels from HIPEC nadir to the first postoperative measurement

Covariates	Laparoscopic approach		Laparotomy approach	
	Coefficient [95% CI]	*P*	Coefficient [95% CI]	*P*
Baseline Hb (g/dL)	0.01 [−0.08–0.11]	0.794	−0.09 [−0.22–0.05]	0.232
Sex (male)	−0.16 [−0.56–0.25]	0.452	0.52 [−0.07–1.11]	0.086
Weight (kg)	0.00 [−0.01–0.01]	0.767	0.00 [−0.01–0.01]	0.636
Height (cm)	−0.01 [−0.03–0.01]	0.552	−0.02 [−0.05–0.01]	0.209
Age (years)	−0.01 [−0.02–0.01]	0.403	−0.01 [−0.02–0.01]	0.550
Estimated blood loss (L)	−0.38 [−2.45–1.69]	0.719	−0.26 [−1.17–0.65]	0.582
Total crystalloids (L)	0.19 [0.07–0.32]	**0.004**	0.20 [0.07–0.33]	**0.003**
Total albumin 5% (L)	0.06 [−0.16–0.28]	0.577	−0.08 [−0.34–0.19]	0.579
Duration (hours)	−0.09 [−0.19–0.02]	0.114	−0.12 [−0.23–(−0.01)]	**0.040**

Mixed-effects multivariable regression analyses were conducted independently for laparoscopic and laparotomy approaches. The dependent variable for these analyses was the change in Hb from the HIPEC nadir to the first postoperative measurement. All listed characteristics were simultaneously included as explanatory variables. Results are presented as regression coefficients with 95% CIs. For example, total crystalloid load significantly correlated with greater Hb recovery from HIPEC nadir to the first postoperative measurement: 0;19 g/dL Hb per liter of crystalloid for the laparoscopic approach ($P = 0.004$) and 0.20 g/dL Hb per liter of crystalloid for the laparotomy approach ($P = 0.003$). **Abbreviations:** CI, confidence interval; Hb, hemoglobin; HIPEC, hyperthermic intraperitoneal chemotherapy.

of perfusate from the peritoneal cavity, likely contributing to hemodilution. The peritoneal membrane and its associated lymphatic channels are not merely passive serous surfaces but function as dynamic fluid-exchange interfaces. It has been demonstrated that during peritoneal dialysis, a substantial portion of fluid instilled into the peritoneal cavity is absorbed into the circulation via capillary and lymphatic routes, particularly under increased intraperitoneal pressure [16, 17]. Furthermore, the instillation of both heated and pressurized perfusate during HIPEC substantially promotes convective fluid movement into the intravascular space [18]. Additionally, elevated body temperature increases endothelial and mesothelial permeability, facilitating trans-barrier fluid movement [19, 20]. Finally, cytotoxic agents may increase peritoneal permeability [21], and with enhanced transperitoneal transport facilitated by hyperthermic conditions and elevated intra-abdominal pressure [18, 22], the net result is intravascular volume expansion leading to hemodilution. The spontaneous, albeit partial, recovery of Hb concentrations in the early postoperative period suggests that hemodilution may have contributed to the observed decline in Hb. However, the present study was not designed to determine the underlying mechanism, and no causal conclusions can be drawn. HIPEC exposes patients to substantial thermal stress, large fluid shifts, and changes in intravascular volume, all of which stimulate antidiuretic hormone release [23]. As the body enters a spontaneous diuretic phase after surgery, contraction of intravascular volume leads to an increase in Hb concentrations. Recognizing that the Hb decline observed during the HIPEC phase may be transient could aid clinicians in interpreting intraoperative Hb values when making transfusion decisions. Accordingly, awareness of these Hb concentration dynamics may be useful when considering transfusion decisions during the HIPEC phase, particularly given the partial early postoperative recovery observed in our cohort. Further studies are needed to determine whether these findings may influence transfusion practices.

Strengths and limitations

This study benefits from a sizable and well-characterized cohort of patients undergoing CRS-HIPEC, coupled with well-established protocolized intraoperative management and frequent Hb determinations. This allowed for a detailed analysis of Hb concentration changes across key intraoperative and postoperative time points. Our observations are applicable only to CRS-HIPEC procedures where patients did not receive perioperative transfusions. Excluding transfused patients enabled us to focus on Hb fluctuations related to procedural aspects of the HIPEC phase, particularly the effects of intensive intraoperative fluid administration. Because the timing of the first postoperative Hb assessment was not standardized, the observed postoperative Hb recovery should be interpreted as an estimate rather than a precise characterization of Hb recovery kinetics. However, given that postoperative Hb measurements were obtained either in the recovery room or upon arrival to the hospital ward—both relatively soon after procedure completion—we believe our findings provide a reasonable approximation of the early postoperative Hb recovery trajectory following HIPEC. Future studies employing linear mixed-effects models with uniformly timed serial Hb measurements could provide more accurate insight into intraoperative Hb dynamics during HIPEC and during postoperative recovery; however, they are not essential to support the principal findings of the present study. Finally, given substantial differences between laparoscopic and laparotomy procedures, direct comparisons and separate regression models should be considered exploratory. While our study reflects

the experience of a single center and its specific practices, which may vary from other institutions, the overall findings are consistent with the existing literature.

Conclusion

In conclusion, in this selected cohort of non-transfused patients undergoing CRS-HIPEC, we observed a modest but transient decline in Hb concentration during the HIPEC phase of the procedure, reflecting perioperative Hb dynamics during a phase not typically associated with significant bleeding. This decline was self-limited and demonstrated partial recovery in the early postoperative period. Although the underlying mechanism cannot be definitively determined from this observational study, the temporal pattern is consistent with a dilutional effect associated with the large-volume fluid administration commonly required during the HIPEC phase. Our findings should be interpreted within the context of this highly selected cohort and should not be generalized to the broader CRS-HIPEC patient population.

Acknowledgments

We acknowledge Ms. Kimberly Cureton, RRT, LRT, Data Specialist at the Anesthesia Clinical Research Unit (ACRU), for her assistance with data extraction.

Conflicts of interest: T.N.W. receives consulting fees from Merck & Co., Takeda Pharmaceuticals, and Trevena Inc. None of the other authors report conflicts of interest.

Funding: Authors received no specific funding for this work.

Data availability: De-identified data is available upon reasonable request from the corresponding author.

Submitted: 10 May 2026
Accepted: 08 July 2026
Published online: 10 July 2026

References

[1] Kusamura S, Barretta F, Yonemura Y, et al. The role of hyperthermic intraperitoneal chemotherapy in pseudomyxoma peritonei after cytoreductive surgery. JAMA Surg 2021;156:e206363. https://doi.org/10.1001/jamasurg.2020.6363

[2] Pletcher E, Gleeson E, Labow D. Peritoneal cancers and hyperthermic intraperitoneal chemotherapy. Surg Clin North Am 2020;100:589–613. https://doi.org/10.1016/j.suc.2020.02.009

[3] Van Stein RM, Aalbers AGJ, Sonke GS, van Driel WJ. Hyperthermic intraperitoneal chemotherapy for ovarian and colorectal cancer: a review. JAMA Oncol 2021;7:1231–8. https://doi.org/10.1001/jamaoncol.2021.0580

[4] Dunne M, Regenold M, Allen C. Hyperthermia can alter tumor physiology and improve chemo- and radio-therapy efficacy. Adv Drug Deliv Rev 2020;163–164:98–124. https://doi.org/10.1016/j.addr.2020.07.007

[5] Esquivel J, Angulo F, Bland RK, Stephens AD, Sugarbaker PH. Hemodynamic and cardiac function parameters during heated intraoperative intraperitoneal chemotherapy using the open "coliseum technique". Ann Surg Oncol 2000;7:296–300. https://doi.org/10.1007/s10434-000-0296-2

[6] Kim MH, Yoo YC, Bai SJ, Lee KY, Kim N, Lee KY. Physiologic and hemodynamic changes in patients undergoing open abdominal cytoreductive surgery with hyperthermic intraperitoneal chemotherapy. J Int Med Res 2021;49:0300060520983263. https://doi.org/10.1177/0300060520983263

[7] Schluermann CN, Hoeppner J, Benk C, Schmidt R, Loop T, Kalbhenn J. Intra-abdominal pressure, cardiac index and vascular resistance during hyperthermic intraperitoneal chemotherapy: a prospective observational study. Minerva Anestesiol 2016;82:160–9. PMID: 25971283.

[8] Miao N, Pingpank JF, Alexander HR, et al. Cytoreductive surgery and continuous hyperthermic peritoneal perfusion in patients with mesothelioma and peritoneal carcinomatosis: hemodynamic, metabolic, and anesthetic considerations. Ann Surg Oncol 2009;16:334–44. https://doi.org/10.1245/s10434-008-0253-z

[9] Schmidt C, Creutzenberg M, Piso P, Hobbhahn J, Bucher M. Perioperative anaesthetic management of cytoreductive surgery with hyperthermic intraperitoneal chemotherapy. Anaesthesia 2008;63:389–95. https://doi.org/10.1111/j.1365-2044.2007.05380.x

[10] Cuenca Apolo D, Puppo Moreno A, Muñoz Casares C, et al. Profile of haemostasis and coagulation in patients with peritoneal carcinomatosis undergoing cytoreductive surgery with hyperthermal chemotherapy. Eur J Surg Oncol 2025;51:109497. https://doi.org/10.1016/j.ejso.2024.109497

[11] Pintado MC, Lasa Unzúe I, Gómez Sanz R, et al. Hematological alterations after cytoreductive surgery and hyperthermic intraperitoneal chemotherapy. J Clin Med 2023;12(13):4323. https://doi.org/10.3390/jcm12134323

[12] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61:344–9. https://doi.org/10.1016/j.jclinepi.2007.11.008

[13] Cooksley TJ, Haji-Michael P. Post-operative critical care management of patients undergoing cytoreductive surgery and heated intraperitoneal chemotherapy (HIPEC). World J Surg Oncol 2011;9:169. https://doi.org/10.1186/1477-7819-9-169

[14] Cripe J, Tseng J, Eskander R, Fader AN, Tanner E, Bristow R. Cytoreductive surgery and hyperthermic intraperitoneal chemotherapy for recurrent ovarian carcinoma: analysis of 30-day morbidity and mortality. Ann Surg Oncol 2015;22:655–61. https://doi.org/10.1245/s10434-014-4026-6

[15] Falcón Araña L, Fuentes-García D, Roca Calvo MJ, et al. Alterations in hemostasis during cytoreductive surgery and hyperthermic intraperitoneal chemotherapy in patients with peritoneal carcinomatosis. Cir Esp 2015;93:496–501. https://doi.org/10.1016/j.cireng.2015.01.007

[16] Stachowska-Pietka J, Waniewski J, Flessner MF, Lindholm B. Distributed model of peritoneal fluid absorption. Am J Physiol Heart Circ Physiol 2006;291:H1862–74. https://doi.org/10.1152/ajpheart.01320.2005

[17] Teitelbaum I. Peritoneal dialysis. N Engl J Med 2021;385:1786–95. https://doi.org/10.1056/NEJMra2100152

[18] Facy O, Al Samman S, Magnin G, et al. High pressure enhances the effect of hyperthermia in intraperitoneal chemotherapy with oxaliplatin: an experimental study. Ann Surg 2012;256:1084–8. https://doi.org/10.1097/SLA.0b013e3182582b38

[19] Lim PQ, Han IH, Seow KM, Chen KH. Hyperthermic intraperitoneal chemotherapy (HIPEC): an overview of the molecular and cellular mechanisms of actions and effects on epithelial ovarian cancers. Int J Mol Sci 2022;23(17):10078. https://doi.org/10.3390/ijms231710078

[20] Wagner P, Boone B, Ramalingam L, et al. Histologic and immunohistochemical alterations associated with cytoreductive surgery and heated intraperitoneal chemotherapy. Ann Surg Oncol 2015;22 Suppl 3:S588–95. https://doi.org/10.1245/s10434-015-4580-6

[21] Shido A, Ohmura S, Yamamoto K, Kobayashi T, Fujimura T, Yonemura Y. Does hyperthermia induce peritoneal damage in continuous hyperthermic peritoneal perfusion? World J Surg 2000;24:507–11. https://doi.org/10.1007/s002689910081

[22] Kusamura S, Azmi N, Fumagalli L, et al. Phase II randomized study on tissue distribution and pharmacokinetics of cisplatin according to different levels of intra-abdominal pressure (IAP) during HIPEC (NCT02949791). Eur J Surg Oncol 2021;47:82–8. https://doi.org/10.1016/j.ejso.2019.06.022

[23] Segar WE, Moore WW. The regulation of antidiuretic hormone release in man: I. Effects of change in position and ambient temperature on blood ADH levels. J Clin Invest 1968;47:2143–51. https://doi.org/10.1172/JCI105900

Related article

1. Clinicopathological factors of ovarian clear cell carcinoma: A single institutional analysis of 247 cases in China

   You Wu et al., Biomol Biomed, 2024