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Intraoperative Low-Dose Glucocorticoids in Surgical Patients With Abdominal Sepsis: A Multicenter Retrospective Cohort Study

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ABSTRACT

Background and Aims: Abdominal sepsis refers to a severe and potentially life-threatening condition characterized by the presence of infection, inflammation, and tissue damage within the abdominal cavity. Glucocorticoids (GCs) play an important role in regulation of the host immune and inflammation responses involved in sepsis and surgery. This study aimed to investigate the potential impact of intraoperative GCs administration on the clinical outcome of surgical patients with abdominal sepsis.

Methods: This retrospective cohort study included a 1:1 propensity score–matched cohort of surgical patients afflicted with abdominal sepsis at two medical centers from January 2008 to December 2022. Patients were classified into low-GCs, high-GCs, and non-GCs groups according to the dosage of steroids used intraoperatively, and in-hospital mortality was designated as the primary outcome.

Results: This study included a total of 476 patients, with 217 in the non-GCs group, 213 in the low-GCs group, and 46 in the high-GCs group. The overall in-hospital mortality rate was 7.56%. After propensity score matching (PSM), there were 168 cases in both the low-GCs group and the non-GCs group, with no significant differences observed between the groups regarding mortality rate, length of hospital-stay, and duration of intensive care unit (ICU) stay. In patients with septic shock, the use of low-dose GCs increased the urine output and decreased the requirements for vasopressors on the first postoperative day, however, it had no impact on the in-hospital mortality or ICU stay. Moreover, prophylactic use of GCs during anesthesia induction did not decrease the incidence of intraoperative hypotension or necessity of vasopressors use.

Conclusion: Intraoperative administration of low-dose GCs demonstrates a transient improvement in hemodynamics of patients with septic shock, however, it did not lead to improved clinical outcomes. Further research remains necessary to elucidate the optimal perioperative dosing strategy.

Abbreviations: GC, glucocorticoid; GR, glucocorticoid receptor; HIS, hospital information system; HPA, hypothalamic-pituitary-adrenal; ICU, intensive care unit; IQR, interquartile range; PLA, People's Liberation Army; POD1, first postoperative day; PSM, propensity score matching; SD, standard deviation; SOFA, Sequential Organ Failure Assessment; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

Tianzhu Tao and Yue Shi contributed equally to this study.

1 | Introduction

Sepsis, a life-threatening organ dysfunction caused by a dysregulated host response to infection, is an urgent medical and health-care problem affecting millions of people worldwide [1]. Recent data suggests that sepsis accounts for approximately 11 million fatalities annually, representing nearly 20% of all global deaths [2]. The burden of sepsis is disproportionately high in low- and middle-income countries, where limited access to timely and quality healthcare significantly worsens mortality rates and long-term morbidity associated with the condition [3]. Despite substantial improvement in the understanding of the molecular mechanisms underpinning sepsis pathogenesis, mortality from sepsis remains unacceptably high. Current treatment modalities in clinical practice remain largely restricted to supportive care. Furthermore, survivors of sepsis commonly face enduring cognitive impairment, physical disability, and a sustained heightened risk of mortality postdischarge [4].

Animal and preclinical research has revealed that the immune cell-derived cytokines activate the hypothalamic-pituitary-adrenal (HPA) axis, which plays a vital role in maintaining homeostasis during the course of disease [5, 6]. However, it has been estimated that dysfunction of the HPA axis occurs in 10%–20% of critically ill patients, escalating to approximately 60% in patients with septic shock [7, 8]. Glucocorticoids (GCs) play a pivotal role as regulators of significant pathophysiological processes, including inflammation, immunity, vasoreactivity, and metabolism. Despite the long-standing use in treating septic patients since the mid-20th century, the safety and efficacy of GCs remain contentious [9]. The 2016 Surviving Sepsis Campaign guidelines recommend intravenous hydrocortisone only if fluid resuscitation and vasopressor therapy fail to restore hemodynamic stability [1]. Subsequently, two large-scale randomized trials (APROCCHSS trial and ADRENAL trial) investigating adjunctive hydrocortisone in septic shock were published [10, 11]. The ADRENAL trial (enrolled 3658 patients) demonstrated that hydrocortisone treatment did not improve 90-day survival but did reduce the duration of mechanical ventilation and shock. Conversely, the APROCCHSS trial (enrolled 1241 patients) found that patients randomized to GCs exhibited lower 90-day mortality [10]. Such disparities may stem from variations in study design and patient heterogeneity (including infection site, etiology, comorbidity, etc) [11].

Intra-abdominal infection ranks among the primary causes of sepsis, second only to pulmonary infection [12, 13]. Timely surgical intervention to achieve source control of infection is crucial for eligible patients to prevent disease progression. Septic patients with abdominal infections are at a high risk of developing septic shock in the early stages, making hemodynamic management more challenging during anesthesia [14]. Theoretically, GCs could mitigate the inflammatory response during surgery, regulate vascular reactivity, and preserve endothelial barrier function, thereby enhancing hemodynamic stability and organ perfusion. However, akin to a double-edged sword, the potential side effects (e.g., secondary infections, fluid retention, hypernatremia) cannot be disregarded during clinical application [15, 16]. Currently, there is a paucity of research concerning the therapeutic efficacy of GCs in the treatment of surgical septic patients. In this study, we conducted a retrospective cohort analysis utilizing clinical data from septic patients undergoing surgery at two prominent medical centers in China. Our primary objective was to investigate the potential impact of intraoperative GCs administration on patients' outcome and hemodynamic parameters.

2 | Materials and Methods

We conducted a 15-year retrospective observational study involving abdominal septic patients underwent surgical procedures in two large-scale medical centers (the First Medical Center of the Chinese People's Liberation Army [PLA] General Hospital and the Air Force Medical Center) in Beijing, China. Together, the two hospitals accommodate a total of 5500 beds and perform over 100,000 surgical procedures annually. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for reporting observational studies. Ethical approval was obtained from the Ethics Committee Board of the First Medical Center of the Chinese PLA General Hospital and the Ethics Committee Board of the Air Force Medical Center. Informed patient consent was waived due to the observational nature of the study. The primary study was registered in the Clinical Trials (trial number NCT06756750).

2.1 | Study Population and Setting

Surgical patients with severe abdominal infections between January 2008 and December 2022 were initially identified through electronic searches of the hospital information system (HIS) database. Individuals with preoperative diagnosis of (septic shock OR infectious peritonitis OR abdominal infection OR intestinal fistula OR biliary fistula OR pancreatic fistula OR sepsis OR digestive tract perforation OR bowel perforation OR gastric perforation OR appendicular perforation OR suppurative cholangitis OR suppurative appendicitis OR suppurative cholecystitis OR suppurative peritonitis OR anastomotic fistula OR abdominal abscess OR intestinal torsion OR intestinal necrosis OR gangrenous appendicitis OR pancreatitis) were initially selected, and then two authors (T. T. and Y. S.) independently reviewed the medical records to identify eligible patients.

The inclusion criteria for this study comprised the following points: (1) Presence of evident abdominal infections; (2) Conformity to the sepsis 3.0 diagnostic criteria; (3) Underwent general anesthesia and surgical procedures; (4) Age over 18 years old. Sepsis was defined in accordance with the Sepsis 3.0 criteria, indicating suspected infection and an acute increase in Sequential Organ Failure Assessment (SOFA) score exceeding 2 points. A baseline score of 0 was assumed in cases where the presence of pre-existing organ dysfunction was unknown. Septic shock is defined as persistent hypotension despite adequate fluid replacement, requiring the use of vasopressors. Hypotension was defined as systolic blood pressure < 90 mmHg or mean blood pressure < 65 mmHg.

The abdominal infection site was verified through manual review of medical records, primarily based on clinical presentations, culture results, blood routine examination, inflammatory biomarkers, or radiological findings. Patients with a history of severe

cardiopulmonary, hepatic, renal dysfunction, or those with infections originating outside the abdomen, or individuals undergoing unplanned surgery due to postoperative complications were excluded. Additionally, any patients receiving preoperative GC therapy were excluded in further analysis, thus ensuring that intraoperative GC effects are isolated.

2.2 | Data Extraction

Data were collected from various systems, including the HIS, Laboratory and Radiology Reporting Systems, Anesthesia Information System, and Follow-up System, to gather information on patient demographics, medical history, intraoperative management (surgery and anesthesia), perioperative monitoring indicators, and outcomes. Dosage of GCs was documented in hydrocortisone equivalents, with 1 mg of prednisolone/prednisone/methylprednisolone equaling 5 mg of hydrocortisone, and 1 mg of dexamethasone equaling 20 mg of hydrocortisone. Detailed information of intraoperative GCs, including prednisone, hydrocortisone, dexamethasone, and methylprednisolone, was meticulously extracted in terms of time and dose. Low-dose corticosteroid treatment was defined as total hydrocortisone (or equivalent) usage of less than 200 mg during the operation. To evaluate the association between prophylactic GCs during anesthesia induction and patient hemodynamic status, the following information was extracted: occurrence of intraoperative hypotension, fluid infusion, blood transfusion, urine output, vasoactive drug usage (type and dosage), and lactate levels. Clinical outcomes assessed in this study included in-hospital mortality, 1-year postoperative mortality, length of intensive care unit (ICU) and hospital stay, urine output and vasopressor use within the first postoperative day (POD1), and so forth.

For missing data, a complete-case analysis was conducted when the proportion of missing values for a given variable was less than 5%. For variables with 5%–15% missing data, multiple imputation using chained equations (MICE) was performed under the assumption that data were missing at random (MAR). The multiple imputation process employed a multivariate algorithm that incorporated all available covariates and outcomes to generate plausible values [17]. Sensitivity analyses were subsequently conducted to ensure the robustness of the results following imputation [18]. Variables with more than 15% missing data were excluded from the analysis to minimize bias.

2.3 | Statistical Analysis

The study cohort was stratified into three groups based on intraoperative GCs dosage: the low-GCs group (equivalent dose of hydrocortisone ≤ 200 mg), high-GCs group (equivalent dose of hydrocortisone > 200 mg), and non-GCs group. Normally distributed continuous variables were presented as mean $\pm$ standard deviation (SD), while nonnormally distributed variables were expressed as median (interquartile range, IQR). Categorical data were depicted as proportions (percentages). Group differences in continuous variables were assessed using the t test or Mann–Whitney U-test, and dichotomous variables were compared using the χ^2 test or Fisher's exact test as appropriate.

Propensity score matching (PSM) was performed to adjust for confounding factors [19]. Propensity scores were calculated using a multivariable logistic regression model that included the dependent variable. Covariates included in generating the propensity score included age, sex, sepsis shock, admission diagnosis, past medical history, operation duration, intraoperative bleeding, and intraoperative fluid therapy. Matching was established at a 1:1 ratio using the nearest neighbor method with an adjustment tolerance of 0.01 without replacement. The balance of variables between the groups before and after matching was assessed using the standardized mean difference [20]. A post-hoc power analysis was conducted to assess the adequacy of the sample size for detecting differences in in-hospital mortality in the matched cohorts. Statistical analyses were performed using SPSS Statistics (version 25.0, IBM Corp.) and R software (version 4.3.0). A two-tailed p value of less than 0.05 was considered statistically significant.

3 | Results

3.1 | Patient Characteristics

A total of 476 patients fulfilled the inclusion criteria and finally included in the data analysis (Figure 1). The demographics and characteristics were summarized in Table 1. The average age of participants was 56.00 ± 16.80 years, with a predominance of male patients (71.22%, 339 patients). Gastrointestinal (GI) diseases were the most frequent causes of sepsis (50.63%, 241 patients), with digestive tract perforation being the most frequent among them (49.79%, 120 patients). Initial monotherapy with β-lactam antibiotics was the most frequently administered treatment (79.83%, 380 patients), with cephalosporins, particularly cefoperazone and ceftriaxone, being the most commonly used. Carbapenems, primarily imipenem and meropenem, were the second most frequently employed. The in-hospital mortality rate was 7.56% (Table 2), with an additional three deaths during the subsequent 1-year follow-up.

Intraoperative adjunctive GCs therapy was administered to 259 patients (54.41%), with 213 (82.24%) receiving a low dose of GCs (≤ 200 mg hydrocortisone or equivalent) and 46 patients (17.76%) receiving more than 200 mg hydrocortisone or equivalent. Methylprednisolone was the most commonly used intraoperative corticosteroid, administered to 153 patients (59.07%), followed by dexamethasone (119 patients, 45.95%), with a combination of both used for 13 patients. In the entire cohort, a higher percentage of septic shock (40.55% [88/217] vs. 27.70% [59/213], $p = 0.005$) and prevalence of diabetes (19.82% [43/217] vs. 11.27% [24/213], $p = 0.015$) were observed in the non-GCs group compared with the low-GCs group before matching. After PSM, there was no statistical difference in baseline characteristics between the two groups.

3.2 | Effects of Intraoperative Low Dose GCs Therapy on Clinical Outcomes

Table 2 presented a comparison of clinical outcomes between the low-GCs group and non-GCs group before and after matching. One-to-one PSM yielded 336 patients, with 168 patients allocated

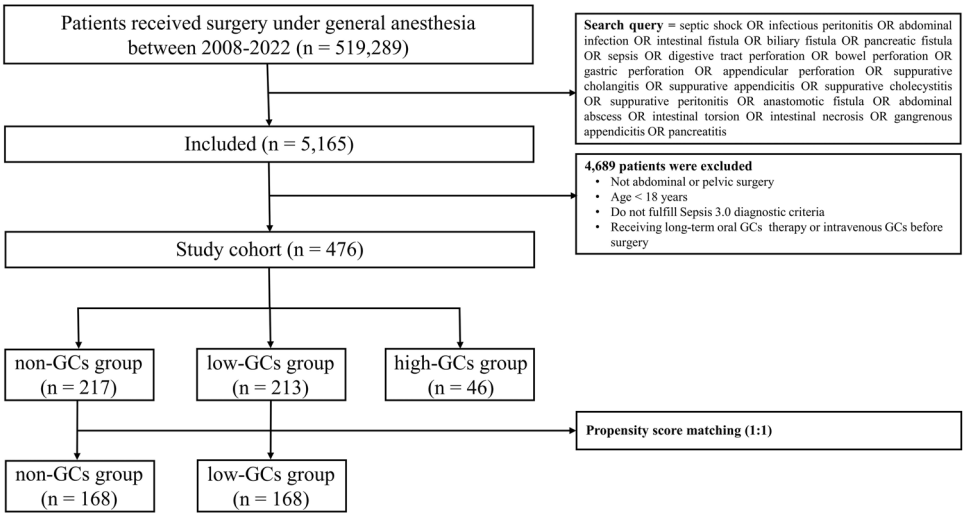

FIGURE 1 | Flow diagram of the study participants.

to each study arm. Before PSM, patients in low-GCs group had higher intraoperative urine output (2.36 ± 1.89 mL/kg/h vs. 1.86 ± 1.49 mL/kg/h, $p = 0.002$), shorter ICU stays (3.65 days, IQR 1.87–8.12 vs. 4.54 days, IQR 2.04–12.18, $p = 0.043$) and reduced use of vasopressors (18.31% [39/213] vs. 26.27% [57/217], $p = 0.048$) on the POD1. After PSM, the low-GCs group exhibited a higher intraoperative urine output compared with non-GCs group (2.39 ± 1.90 mL/kg/h vs. 1.82 ± 1.43 mL/kg/h, $p = 0.002$). However, no significant difference was observed between groups in terms of in-hospital mortality (7.74% [13/168] vs. 3.57% [6/168], $p = 0.098$), postoperative ICU admissions (55.95% [94/168] vs. 61.31% [103/168], $p = 0.319$), incidence of intraoperative hypotension (73.21% [123/168] vs. 75.60% [127/168], $p = 0.617$) or vasopressor use within the POD1 (25.60% [43/168] vs. 18.45% [31/168], $p = 0.114$).

3.3 | The Impact of Intraoperative Low Dose GCs in Septic Shock Patients

Out of the total patient cohort, 174 individuals (36.55%) presented with septic shock before undergoing surgery. Among these patients, 86 (49.43%) received adjuvant GCs therapy. Baseline characteristics and clinical outcomes of patients with septic shock were presented in Tables 3 and 4, respectively. After PSM, a significantly lower proportion of vasopressor use were observed in low-GCs group compared with non-GCs group on the POD1 (21.43% [9/42] vs. 42.86%, [18/42], $p = 0.035$). Additionally, there was a higher urine output (1.45 mL/kg/h, IQR 1.32–2.22 vs. 1.16 mL/kg/h, IQR 0.46–1.49, $p = 0.031$) on the POD1 in the low-GCs group. However, there was no significant difference in postoperative ICU admissions (80.95% [34/42] vs. 85.71% [36/42], $p = 0.558$) or in-hospital death (9.52% [4/42] vs. 11.90% [5/42], $p > 0.999$) between the two groups.

3.4 | Effects of GCs During Anesthesia Induction on Intraoperative Hemodynamic Stability

To determine the prophylactic use of GCs on the hemodynamic status during surgical procedures, patients who received a low dose of GCs during anesthesia induction were identified. PSM was performed to find the best matching cases. After PSM, a total of 296 patients were divided into low-GCs or non-GCs groups, with 148 patients in each group (Table 5). The baseline characteristics in the two groups were shown in Supplementary material (Table S1).

As shown in Table 5, the administration of GCs during induction did not have a significant effect on the incidence of intraoperative hypotension (75.68% [112/148] vs. 76.35% [113/148], $p = 0.892$) or proportion of overall vasopressors use. Norepinephrine and dopamine seemed to be more commonly used in non-GCs group, whereas phenylephrine was more prevalent in low-GCs group. There appeared to be a trend toward a decreased dose of vasopressors in low-GCs group, but the difference did not reach statistical significance.

Further analysis was performed in the subgroup of septic shock patients. PSM was utilized to ensure comparability, resulting in 40 matched patients in each group (Table 5). Higher intraoperative urine output was observed in septic shock patients receiving GCs during induction (2.09 mL/kg/h, IQR 1.34–3.20 vs. 1.20 mL/kg/h, IQR 0.64–2.11, $p = 0.026$). However, there was no significant difference in terms of the incidence of intraoperative hypotension (82.50% [33/40] vs. 72.50% [29/40], $p = 0.284$) or vasopressor dosage, implying that prophylactic GCs use seemed to have minimal effects on the intraoperative hemodynamic status in patients with septic shock.

3.5 | Effects of High Dose GCs on Clinical Outcomes in Septic Surgical Patients

Forty-six patients received a high dose of GCs, with a median dose of 400 mg hydrocortisone or its equivalent. This subgroup generally presented with more severe conditions, as indicated by a higher prevalence of underlying diseases, preoperative SOFA scores, incidence of septic shock, lactate levels, and longer surgery time (Table 6). Before PSM, high-GCs group showed greater intraoperative blood loss compared with low-GCs (100.00 mL, IQR 100.00–375.00 vs. 50.00 mL, IQR 20.00–200.00, $p < 0.001$),

TABLE 1 | Baseline characteristics of septic patients undergoing abdominal surgery.

Characteristic	Total ($n = 476$)	Before propensity score matching			After propensity score matching		
		Non-GCs ($n = 217$)	Low-GCs ($n = 213$)	p Value	Non-GCs ($n = 168$)	Low-GCs ($n = 168$)	p Value
Age (years)	56.00 ± 16.80	57.29 ± 17.37	55.22 ± 16.59	0.205	57.00 (42.00–67.00)	55.00 (44.75–66.00)	0.912
Sex				0.762			0.808
Male	339 (71.22)	153 (70.51)	153 (71.83)		120 (71.43)	122 (72.62)	
Female	137 (28.78)	64 (29.49)	60 (28.17)		48 (28.57)	46 (27.38)	
BMI	25.77 (22.49–27.34)	25.00 (22.32–27.34)	26.04 (22.32–27.34)	0.205	25.39 (22.49–27.34)	26.13 (22.47–27.34)	0.375
ASA physical status class				0.028			0.372
II–III	344 (72.27)	151 (69.59)	168 (78.87)		124 (73.81)	131 (77.98)	
IV–V	132 (27.73)	66 (30.41)	45 (21.13)		44 (26.19)	37 (22.02)	
Underlying conditions	184 (38.66)	87 (40.09)	70 (32.86)	0.120	54 (32.14)	54 (32.14)	> 0.999
CHD	38 (7.98)	13 (5.99)	19 (8.92)	0.247	10 (5.95)	11 (6.55)	0.822
Hypertension	113 (23.74)	57 (26.27)	40 (18.78)	0.063	39 (23.21)	30 (17.86)	0.224
Diabetes	78 (16.39)	43 (19.82)	24 (11.27)	0.015	21 (12.50)	21 (12.50)	> 0.999
Renal dysfunction	27 (5.67)	14 (6.45)	10 (4.69)	0.428	6 (3.57)	7 (4.17)	0.777
Preoperative SOFA	3.00 (2.00–4.00)	3.00 (2.00–4.00)	3.00 (2.00–4.00)	0.014	3.00 (2.00–4.00)	3.00 (2.00–4.00)	0.450
Preoperative diagnosis							
Septic shock	174 (36.55)	88 (40.55)	59 (27.70)	0.005	56 (33.33)	54 (32.14)	0.816
GI disease	241 (50.63)	104 (47.93)	112 (52.58)	0.334	94 (55.95)	93 (55.36)	0.913
Biliary disease	118 (24.79)	58 (26.73)	57 (26.76)	0.994	45 (26.79)	39 (23.21)	0.450
Pancreatic disease	41 (8.61)	22 (10.14)	12 (5.63)	0.084	10 (5.95)	10 (5.95)	> 0.999
Trauma	19 (3.99)	5 (2.30)	11 (5.16)	0.117	3 (1.79)	8 (4.76)	0.125
Other disease	65 (13.66)	32 (14.75)	25 (11.74)	0.358	20 (11.90)	20 (11.90)	> 0.999
Malignancy	59 (12.39)	24 (11.06)	28 (13.15)	0.507	14 (8.33)	17 (10.12)	0.572
Antibiotics				0.605			0.627
Quinolones	23 (4.83)	12 (5.53)	9 (4.23)		12 (5.53)	9 (4.23)	
β-lactam	380 (79.83)	179 (82.49)	171 (80.28)		179 (82.49)	171 (80.28)	
Aminoglycosides	16 (3.36)	6 (2.76)	9 (4.23)		6 (2.76)	9 (4.23)	
Glycopeptides	45 (9.45)	15 (6.91)	22 (10.33)		15 (6.91)	22 (10.33)	
Oxazolidinones	7 (1.47)	2 (0.92)	1 (0.47)		2 (0.92)	1 (0.47)	
Chloramphenicol	1 (0.21)	0 (0.00)	0 (0.00)		0	0	

(Continues)

TABLE 1 | (Continued)

Characteristic	Total ($n = 476$)	Before propensity score matching			After propensity score matching		
		Non-GCs ($n = 217$)	Low-GCs ($n = 213$)	*p* Value	Non-GCs ($n = 168$)	Low-GCs ($n = 168$)	*p* Value
Fusosporic acids	2 (0.42)	1 (0.46)	1 (0.47)		1 (0.46)	1 (0.47)	
Antifungal agents	2 (0.42)	2 (0.92)	0 (0.00)		2 (0.92)	0 (0.00)	
Total fluid input (mL/kg/h)	16.81 (11.91–22.94)	16.30 (11.54– 23.77)	17.05 (12.00–22.77)	0.831	15.53 (11.49–21.91)	18.45 (12.54–23.17)	0.132
Blood transfusion	242 (50.84)	48 (22.12)	43 (20.19)	0.624	35 (20.83)	33 (19.64)	0.786
Intraoperative blood loss (mL)	50.00 (20.00–200.00)	50.00 (2.00–200.00)	50.00 (20.00–200.00)	0.006	50.00 (5.00–162.50)	50.00 (20.00–150.00)	0.148
Lactate (mmol/L)	1.40 (0.97–1.80)	1.30 (0.91–1.76)	1.33 (0.98–1.75)	0.767	1.22 (0.89–1.72)	1.40 (0.98–1.79)	0.257
Type of surgery				0.582			0.820
Emergency surgery	294 (61.76)	135 (62.21)	127 (59.62)		109 (64.88)	107 (63.69)	
Elective surgery	182 (38.24)	82 (37.79)	86 (40.38)		59 (35.12)	61 (36.31)	
Surgical time (min)	133.00 (85.75–195.00)	120.00 (69.00–184.00)	130.00 (94.00–195.00)	0.008	123.50 (75.00–190.00)	120.00 (88.00–171.00)	0.959

Note: Data presented as *n* (%), mean ± SD or median (IQR).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CHD, coronary heart disease; GI disease, gastrointestinal disease; SOFA, Sequential Organ Failure Assessment score.

necessitating a higher rate of blood product transfusion (52.17% [24/46] vs. 20.19% [43/213], $p < 0.001$). The higher doses of GCs administered may be partially attributed to intraoperative allogeneic blood transfusions, as these patients had already received a loading dose during the induction period. After PSM, the baseline parameters between the two groups were comparable. The high-GCs group showed a higher likelihood of ICU admission following surgery (94.59%, [35/37] vs. 78.38%, [29/37], $p = 0.041$) (Table 7). However, no significant difference in ICU length of stay (6.35 days, IQR 2.17–11.89 vs. 6.81 days, IQR 2.94–14.64, $p = 0.295$), hospital length of stay (20.00 days, IQR 13.00–32.00 vs. 23.30 days, IQR 12.00–33.00, $p = 0.689$), or in-hospital mortality (5.41% [2/37] vs. 16.22% [6/37], $p = 0.261$) was observed between the two groups. These findings suggested that administering higher doses of steroids did not confer any beneficial effects on patient outcomes, underscoring the importance of cautious application.

4 | Discussion

This retrospective analysis, evaluating over 500,000 surgical cases spanning 15 years across two large hospitals, ultimately included 476 abdominal septic patients who underwent surgical interventions. To mitigate potential bias, individuals receiving long-term oral or intravenous steroids before surgery were excluded. PSM was then employed to address any demographic or pathological baseline imbalances between groups. Our principal findings indicate that the use of low-dose steroids increases urine output in septic shock patients and significantly reduces the need for vasopressors on the POD1, however, it does not decrease in-hospital mortality or ICU stay. Compared with low-dose steroids, the use of high-dose GCs did not demonstrate a clinical advantage in improving outcomes for septic patients undergoing abdominal surgery.

GI diseases are the leading cause of abdominal sepsis and substantially contribute to mortality rates [21]. This study identified digestive tract perforation as a prevalent condition, accounting for approximately 50% of all cases among patients with GI diseases. The primary surgical interventions employed in clinical settings, beyond exploratory laparotomy, include perforation repair, subtotal gastrectomy, and bowel resection, performed using either open or laparoscopic techniques. Notably, laparoscopic repair of perforated ulcers is gaining increased adoption, with 16 patients in this study successfully managed using this approach. Biliary infections were predominantly caused by biliary stones, with the common bile duct (50.85%), gallbladder (33.90%), and intrahepatic bile duct (25.42%) identified as the most frequently affected sites. The primary surgical procedures for managing biliary infections included cholecystectomy, lithotomy, exploratory laparotomy, or endoscopic retrograde cholangiopancreatography (ERCP). The cohort comprised 41 patients with pancreatic diseases, among whom 36 had pancreatitis or its complications, while 5 were diagnosed with pancreatic cancer. Of these patients, nearly 70% (24 individuals) underwent percutaneous nephroscopic necrosectomy for the removal of pancreatic necrotic tissues, while the remaining patients underwent ERCP.

Anesthesiologists may encounter significant challenges in management for septic patients undergoing surgery. First, septic

TABLE 2 | Low dose of GCs on clinical outcomes of septic patients undergoing surgical procedures.

Characteristic	Total ($n = 476$)	Before propensity score matching			After propensity score matching		
		Non-GCs ($n = 217$)	Low-GCs ($n = 213$)	p Value	Non-GCs ($n = 168$)	Low-GCs ($n = 168$)	p Value
Intraoperative hemodynamics							
Hypotension	316 (73.49)	154 (70.97)	162 (76.06)	0.232	123 (73.21)	127 (75.60)	0.617
The frequency of hypotension	4.00 (0.00–15.25)	2.00 (0.00–15.00)	6.00 (1.00–16.00)	0.061	3.00 (0.00–17.00)	5.00 (0.75–15.00)	0.699
Duration of MAP < 60 mmHg (min)	5.00 (0.00–25.00)	5.00 (0.00–25.00)	5.00 (0.00–20.00)	0.261	5.00 (0.00–26.25)	5.00 (0.00–15.00)	0.589
Intraoperative urine output (mL/kg/h)	2.10 ± 1.74	1.86 ± 1.49	2.36 ± 1.89	0.002	1.82 ± 1.43	2.39 ± 1.90	0.002
ICU admission after surgery	302 (63.45)	125 (57.60)	133 (62.44)	0.306	94 (55.95)	103 (61.31)	0.319
SOFA on the POD1	2.00 (1.00–3.00)	2.00 (1.00–4.00)	2.00 (1.00–3.00)	0.028	2.00 (1.00–3.00)	1.50 (1.00–3.00)	0.101
Mechanical ventilation on the POD1	58 (12.18)	23 (10.60)	31 (14.55)	0.216	19 (11.31)	22 (13.10)	0.617
Use of vasopressors on the POD1	113 (23.74)	57 (26.27)	39 (18.31)	0.048	43 (25.60)	31 (18.45)	0.114
Urine output on the POD1 (mL/kg/h)	1.45 (0.99–1.68)	1.45 (0.87–1.53)	1.45 (1.13–1.82)	0.029	1.45 (1.00–1.58)	1.45 (1.16–1.72)	0.239
Length of ICU stay (days)	4.32 (2.00–10.83)	4.54 (2.04–12.18)	3.65 (1.87–8.12)	0.043	4.50 (2.09–11.61)	3.79 (1.95–8.05)	0.156
Length of hospital stay (days)	15.00 (8.00–26.25)	14.00 (8.00–26.00)	15.00 (8.00–24.00)	0.959	14.00 (8.00–23.48)	13.00 (7.00–24.25)	0.905
In-hospital death	36 (7.56)	16 (7.37)	10 (4.69)	0.244	13 (7.74)	6 (3.57)	0.098

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ICU, intensive care unit; MAP, mean arterial pressure; POD1, first postoperative day; SOFA, Sequential Organ Failure Assessment score.

TABLE 3 | Baseline characteristics of patients with septic shock.

Characteristic	Before propensity score matching			After propensity score matching		
	Non-GCs ($n = 88$)	Low-GCs ($n = 59$)	p Value	Non-GCs ($n = 42$)	Low-GCs ($n = 42$)	p Value
Age (years)	58.49 ± 18.18	54.19 ± 17.17	0.153	59.00 (40.00–67.00)	58.00 (45.25–66.00)	0.744
Sex			0.309			0.659
Male	58 (65.91)	34 (57.63)		25 (59.52)	23 (54.76)	
Female	30 (34.09)	25 (42.37)		17 (40.48)	19 (45.24)	
BMI	25.95 (22.49–27.34)	26.71 (22.76–27.34)	0.717	26.50 (21.30–27.34)	26.51 (22.64–27.34)	0.664
ASA physical status class			0.238			0.649
II–III	45 (51.14)	36 (61.02)		26 (61.90)	28 (66.67)	
IV–V	43 (48.86)	23 (38.98)		16 (38.10)	14 (33.33)	
Underlying conditions	41 (46.59)	21 (35.59)	0.186	15 (35.71)	17 (40.48)	0.653
CHD	7 (7.95)	6 (10.17)	0.643	2 (4.76)	4 (9.52)	0.672
Hypertension	23 (26.14)	13 (22.03)	0.571	8 (19.05)	9 (21.43)	0.786
Diabetes	22 (25.00)	6 (10.17)	0.025	5 (11.90)	6 (14.29)	0.746
Renal dysfunction	8 (9.09)	3 (5.08)	0.558	4 (9.52)	3 (7.14)	> 0.999
Preoperative SOFA	4.00 (3.00–6.00)	4.00 (2.50–5.00)	0.153	4.00 (3.00–6.00)	3.50 (3.00–4.75)	0.153
Preoperative diagnosis						
GI disease	46 (52.27)	34 (57.63)	0.523	23 (54.76)	24 (57.14)	0.826
Biliary disease	13 (14.77)	8 (13.56)	0.837	5 (11.90)	6 (14.29)	0.746
Pancreatic disease	12 (13.64)	6 (10.17)	0.53	8 (19.05)	5 (11.90)	0.365
Trauma	1 (1.14)	3 (5.08)	0.355	1 (2.38)	2 (4.76)	> 0.999
Other disease	20 (22.73)	9 (15.25)	0.264	6 (14.29)	6 (14.29)	> 0.999
Malignancy	13 (14.77)	9 (15.25)	0.936	5 (11.90)	8 (19.05)	0.365
Total fluid input (mL/kg/h)	17.87 (12.34– 26.14)	19.87 (15.77–25.17)	0.324	17.22 (11.48–29.49)	20.85 (15.73–27.01)	0.202
Blood transfusion	29 (32.95)	18 (30.51)	0.755	13 (30.95)	12 (28.57)	0.811
Intraoperative blood loss (mL)	100.00 (20.00–212.50)	100.00 (50.00–200.00)	0.831	50.00 (6.25–100.00)	100.00 (50.00–200.00)	0.058
Lactate (mmol/L)	1.60 (1.12–2.73)	1.50 (1.10–2.55)	0.698	1.95 (1.31–3.25)	1.52 (1.10–2.49)	0.055
Type of surgery			0.845			0.643
Emergency surgery	61 (69.32)	40 (67.80)		27 (64.29)	29 (69.05)	
Elective surgery	27 (30.68)	19 (32.20)		15 (35.71)	13 (30.95)	
Surgical time (min)	142.50 (96.75–205.00)	145.00 (98.00–184.50)	0.973	124.00 (86.25–207.50)	147.50 (100.00–187.50)	0.434

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CHD, coronary heart disease; GI disease, gastrointestinal disease; SOFA, Sequential Organ Failure Assessment score.

shock was more frequent among patients with intra-abdominal infections [22]. The severe inflammatory response in sepsis leads to increased blood vessel permeability, impaired vascular tone, and reduced responsiveness to vasoactive drugs, possibly culminating in septic cardiomyopathy. Second, the effects of anesthetics further diminish systemic vascular resistance and venous return, exacerbating the risk of persistent intraoperative hypotension [23]. Third, intra-abdominal septic patients often undergo prolonged fasting and GI decompression, and they are typically older individuals with underlying cardiovascular conditions. Therefore, resuscitation with adequate fluids and vasoactive drugs is of particular importance in maintaining homeostasis [24].

However, a significant proportion of patients exhibit poor responsiveness to vasoactive drugs, particularly in the presence

TABLE 4 | Low dose of GCs on clinical outcomes of patients with septic shock.

Characteristic	Before propensity score matching			After propensity score matching		
	Non-GCs ($n = 88$)	Low-GCs ($n = 59$)	p Value	Non-GCs ($n = 42$)	Low-GCs ($n = 42$)	p Value
Intraoperative events						
Hypotension	72 (81.82)	44 (74.58)	0.291	34 (80.95)	33 (78.57)	0.786
The frequency of hypotension	5.00 (1.00–17.25)	3.00 (0.00–14.00)	0.321	8.50 (1.00–17.00)	4.50 (1.00–13.00)	0.392
Duration of MAP < 60 mmHg (min)	10.00 (0.00–40.00)	10.00 (0.00–20.00)	0.249	5.00 (0.00–30.00)	5.00 (0.00–20.00)	0.647
Intraoperative urine output (mL/kg/h)	1.48 (0.58–2.09)	2.09 (1.12–3.25)	0.018	1.60 (0.68–2.09)	2.26 (0.91–3.93)	0.069
ICU admission after surgery	72 (81.82)	49 (83.05)	0.848	34 (80.95)	36 (85.71)	0.558
SOFA on the POD1	2.00 (1.00–4.00)	2.00 (0.00–3.00)	0.128	2.50 (1.00–4.75)	1.00 (0.00–3.00)	0.070
Mechanical ventilation on the POD1	12 (13.64)	7 (11.86)	0.754	4 (9.52)	6 (14.29)	0.500
Use of vasopressors on the POD1	36 (40.91)	12 (20.34)	0.009	18 (42.86)	9 (21.43)	0.035
Urine output on the POD1 (mL/kg/h)	1.33 (0.60–1.74)	1.45 (1.26–1.96)	0.026	1.16 (0.46–1.49)	1.45 (1.32–2.22)	0.031
Length of ICU stay (days)	5.44 (1.95–16.62)	3.73 (2.02–9.35)	0.159	4.83 (2.90–15.50)	3.49 (1.88–9.69)	0.144
Length of hospital stay (days)	17.00 (9.75–32.25)	16.00 (9.00–28.50)	0.509	17.00 (11.25–31.50)	19.00 (9.25–29.75)	0.730
In-hospital death	10 (11.36)	5 (8.47)	0.571	4 (9.52)	5 (11.90)	> 0.999

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ICU, intensive care unit; MAP, mean arterial pressure; POD1, first postoperative day; SOFA, Sequential Organ Failure Assessment score.

TABLE 5 | Intraoperative hemodynamics in patients receiving GCs during anesthesia induction.

Characteristic	After propensity score matching			After propensity score matching (septic shock patients)		
	Non-GCs ($n = 148$)	Low-GCs ($n = 148$)	p Value	Non-GCs ($n = 40$)	Low-GCs ($n = 40$)	p Value
Intraoperative events						
Hypotension	112 (75.68)	113 (76.35)	0.892	33 (82.50)	29 (72.50)	0.284
The frequency of hypotension	8.50 (2.00–21.00)	10.00 (3.00–18.00)	0.619	10.00 (2.00–19.00)	6.00 (2.00–15.00)	0.626
Duration of MAP < 60 mmHg (min)	5.00 (0.00–30.00)	5.00 (0.00–20.00)	0.731	25.00 (5.00–45.00)	15.00 (5.00–25.00)	0.366
Vasoactive medications						
Norepinephrine	34 (22.97)	25 (16.89)	0.190	18 (45.00)	17 (42.50)	0.822
Dose of norepinephrine (μg)	4153.50 (1683.00–4307.00)	1476.00 (320.00–4307.00)	0.074	4153.50 (1644.00–4307.00)	1476.00 (506.00–4307.00)	0.140
Phenylephrine	37 (25.00)	55 (37.16)	0.024	15 (37.50)	22 (55.00)	0.116
Dose of phenylephrine (μg)	1896.00 (660.00–4115.00)	1740.00 (110.00–4357.50)	0.823	4115.00 (1894.00–5108.50)	1595.00 (108.00–4778.75)	0.271
Dopamine	18 (12.16)	14 (9.46)	0.454	5 (12.50)	5 (12.50)	> 0.999
Dose of dopamine (mg)	28.64 (8.85–36.29)	3.00 (2.00–24.32)	0.091	36.29 (36.29–36.29)	20.00 (19.00–20.00)	0.090
Total fluid input (mL/kg/h)	15.27 (11.34–21.38)	17.64 (12.29–22.46)	0.202	18.54 (13.02–28.58)	20.49 (11.97–25.08)	0.756
Intraoperative urine output (mL/kg/h)	2.09 (0.90–2.09)	2.06 (1.07–2.73)	0.103	1.20 (0.64–2.11)	2.09 (1.34–3.20)	0.026
ICU admission after surgery	87 (58.78)	90 (60.81)	0.722	34 (85.00)	33 (82.50)	0.762
Mechanical ventilation on the POD1	19 (12.84)	22 (14.86)	0.614	5 (12.50)	4 (10.00)	> 0.999
Use of vasopressors on the POD1	40 (27.03)	26 (17.57)	0.051	15 (37.50)	8 (20.00)	0.084
Urine output on the POD1 (mL/kg/h)	1.45 (0.95–1.58)	1.45 (1.05–1.73)	0.349	1.42 (0.73–1.84)	1.45 (1.14–2.00)	0.298
Length of ICU stay (days)	3.61 (1.93–10.11)	3.58 (1.87–8.38)	0.504	5.42 (1.58–14.54)	3.15 (1.22–8.51)	0.383
Length of hospital stay (days)	14.00 (8.00–23.30)	14.00 (8.00–25.25)	0.676	16.00 (11.75–27.75)	19.00 (9.75–39.00)	0.802
In-hospital death	13 (8.78)	7 (4.73)	0.165	6 (15.00)	2 (5.00)	0.264

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ICU, intensive care unit; MAP, mean arterial pressure; POD1, first postoperative day.

TABLE 6 | Baseline characteristics of septic patients receiving high dose of glucocorticoids.

Characteristic	Before propensity score matching			After propensity score matching		
	Low-GCs ($n = 213$)	High-GCs ($n = 46$)	p Value	Low-GCs ($n = 37$)	High-GCs ($n = 37$)	p Value
Age (years)	55.22 ± 16.59	53.50 ± 14.73	0.517	54.00 ± 15.06	55.49 ± 14.22	0.664
Sex			0.990			0.611
Male	153 (71.83)	33 (71.74)		27 (72.97)	25 (67.57)	
Female	60 (28.17)	13 (28.26)		10 (27.03)	12 (32.43)	
BMI	26.04 (22.32–27.34)	27.34 (23.44–27.34)	0.110	26.37 (23.15–27.34)	27.34 (23.14–27.34)	0.715
ASA physical status class			< 0.001			0.219
II–III	168 (78.87)	25 (54.35)		27 (72.97)	22 (59.46)	
IV–V	45 (21.13)	21 (45.65)		10 (27.03)	15 (40.54)	
Underlying conditions	70 (32.86)	27 (58.70)	0.001	16 (43.24)	20 (54.05)	0.352
CHD	19 (8.92)	6 (13.04)	0.560	7 (18.92)	5 (13.51)	0.528
Hypertension	40 (18.78)	16 (34.78)	0.017	11 (29.73)	11 (29.73)	> 0.999
Diabetes	24 (11.27)	11 (23.91)	0.023	6 (16.22)	10 (27.03)	0.259
Renal dysfunction	10 (4.69)	3 (6.52)	0.887	2 (5.41)	1 (2.70)	> 0.999
Preoperative SOFA	3.00 (2.00–4.00)	4.00 (2.00–5.00)	0.007	3.00 (2.00–4.00)	4.00 (2.00–5.00)	0.479
Preoperative diagnosis						
Sepsis shock	59 (27.70)	27 (58.70)	< 0.001	21 (56.76)	20 (54.05)	0.815
GI disease	112 (52.58)	25 (54.35)	0.828	15 (40.54)	22 (59.46)	0.104
Biliary disease	57 (26.76)	3 (6.52)	0.003	9 (24.32)	3 (8.11)	0.058
Pancreatic disease	12 (5.63)	7 (15.22)	0.051	5 (13.51)	6 (16.22)	0.744
Trauma	11 (5.16)	3 (6.52)	0.992	2 (5.41)	1 (2.70)	> 0.999
Other disease	25 (11.74)	8 (17.39)	0.297	6 (16.22)	5 (13.51)	0.744
Malignancy	28 (13.15)	7 (15.22)	0.709	6 (16.22)	6 (16.22)	> 0.999
Total fluid input (mL/kg/h)	17.05 (12.00–22.77)	17.74 (12.81–23.92)	0.414	17.37 (12.92–23.81)	17.49 (12.50–22.90)	0.780
Blood transfusion	43 (20.19)	24 (52.17)	< 0.001	12 (32.43)	15 (40.54)	0.469
Intraoperative blood loss (mL)	50.00 (20.00–200.00)	100.00 (100.00–375.00)	< 0.001	100.00 (50.00–300.00)	100.00 (50.00–200.00)	0.456
Lactate (mmol/L)	1.33 (0.98–1.75)	1.75 (1.28–4.15)	< 0.001	1.53 (0.90–2.50)	1.70 (1.27–3.40)	0.121
Type of surgery			0.209			0.338
Emergency surgery	127 (59.62)	32 (69.57)		21 (56.76)	25 (67.57)	
Elective surgery	86 (40.38)	14 (30.43)		16 (43.24)	12 (32.43)	
Surgical time (min)	130.00 (94.00–195.00)	189.00 (142.75–224.50)	< 0.001	170.00 (140.00–216.00)	176.00 (125.00–220.00)	0.897

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CHD, coronary heart disease; GI disease, gastrointestinal disease; SOFA, Sequential Organ Failure Assessment score.

of vasoplegia. Mechanisms through which steroids may influence perioperative hemodynamics include enhanced vascular responsiveness to vasopressors, increased catecholamine production, and preserved myocardial contractility [25]. GCs play a crucial permissive role in the action of catecholamines on vascular smooth muscle [26]. In our study, we observed a trend toward reduced vasoconstrictor dosage (norepinephrine, phenylephrine, and dopamine) in patients receiving low doses of GCs, although this did not reach statistical significance. Specifically, the administration of low doses of GCs was associated with increased intraoperative urine output and decreased vasopressors use on the POD1 in septic shock patients. Previous study has demonstrated that low-dose GC therapy can reduce in-hospital mortality in patients with refractory septic shock

TABLE 7 | Clinical outcomes of septic patients receiving high dose of glucocorticoids.

Characteristic	Before propensity score matching			After propensity score matching		
	Low-GCs ($n = 213$)	High-GCs ($n = 46$)	p Value	Low-GCs ($n = 37$)	High-GCs ($n = 37$)	p Value
Intraoperative events						
Hypotension	162 (76.06)	39 (84.78)	0.198	34 (91.89)	31 (83.78)	0.477
The frequency of hypotension	6.00 (1.00–16.00)	7.50 (1.00–20.75)	0.235	7.00 (3.00–25.00)	7.00 (1.00–20.00)	0.622
Duration of MAP < 60 mmHg (min)	5.00 (0.00–20.00)	15.00 (5.00–43.75)	0.002	10.00 (0.00–20.00)	10.00 (0.00–40.00)	0.402
Intraoperative urine output (mL/kg/h)	2.09 (1.11–2.90)	1.24 (0.67–2.43)	0.018	1.91 (0.89– 2.81)	1.14 (0.67–2.38)	0.163
ICU admission after surgery	133 (62.44)	44 (95.65)	< 0.001	29 (78.38)	35 (94.59)	0.041
SOFA on the POD1	2.00 (1.00–3.00)	3.00 (1.25–4.00)	0.012	2.00 (1.00–3.00)	2.00 (1.00–3.00)	0.435
Mechanical ventilation on the POD1	31 (14.55)	4 (8.70)	0.292	5 (13.51)	4 (10.81)	> 0.999
Use of vasopressors on the POD1	39 (18.31)	17 (36.96)	0.005	9 (24.32)	13 (35.14)	0.309
Urine output on the POD1 (mL/kg/h)	1.45 (1.13–1.82)	1.31 (0.51–1.72)	0.072	1.45 (1.10–1.97)	1.45 (0.83–1.67)	0.195
Length of ICU stay (days)	3.65 (1.87–8.12)	9.43 (3.41–17.57)	< 0.001	6.35 (2.17–11.89)	6.81 (2.94–14.64)	0.295
Length of hospital stay (days)	15.00 (8.00–24.00)	23.65 (12.75–37.00)	< 0.001	20.00 (13.00–32.00)	23.30 (12.00–33.00)	0.689
In-hospital death	10 (4.69)	10 (21.74)	< 0.001	2 (5.41)	6 (16.22)	0.261

Note: Data presented as n (%), mean ± SD or median (IQR).
Abbreviations: ICU, intensive care unit; MAP, mean arterial pressure; POD1, first postoperative day; SOFA, Sequential Organ Failure Assessment score.

following emergency laparotomy for lower intestinal perforation. This aligns with the findings of our study, which suggest that low-dose GCs may offer clinical benefits to surgical patients with septic shock [27]. While the hemodynamically stabilizing effects of GCs have been extensively studied in septic shock patients in ICUs or emergency departments, the perioperative efficacy and safety of GCs remain relatively underexplored for surgical septic patients in the operating room [28]. Further research is necessary to elucidate the transient improvement effects of low-dose GCs on hemodynamics as observed in this study, and to optimize the dosage and duration of GCs use postoperatively.

Empirical antimicrobial therapy (EAT) is the cornerstone of sepsis therapy, and the SSC guidelines recommended administering antimicrobials immediately, ideally within 1 h of sepsis recognition [29]. Of all antibiotics, β-lactam antibiotics were among the most used pharmaceuticals in our cohort, which was consistent with guideline recommendations that EAT of abdominal sepsis should cover a broad spectrum of pathogens, such as broad-spectrum β-lactam/β-lactamase inhibitor combinations or carbapenems [30]. And current study revealed that clinical cure was higher in the continuous infusion group of β-lactam antibiotics versus intermittent infusion group, emphasizing the need for further optimizing antibiotic regimens [31]. Additionally, an important aspect of GCs for surgical patients during anesthesia is their anti-inflammatory properties. Surgery triggers the innate immune system, initiating a systemic inflammatory response that can potentially lead to multiple organ dysfunction [32]. Minimizing perioperative inflammation with GCs has been extensively reported in clinical settings. Sanket et al. demonstrated that preoperative administration of GCs may be associated with lower of complication rates and shorter length of stay as a likely consequence of attenuating the postsurgical inflammatory response [33]. Studies have demonstrated a reduction in postoperative complications, such as postoperative nausea and vomiting, pain, and cognitive dysfunction, in patients who received GCs during anesthesia [34–36]. Specially, the use of GCs in surgical patients with sepsis may have a more profound effect on adrenal function and immunity. On the one hand, the excessive production of pro-inflammatory mediators in sepsis may lead to Critical Illness-Related Corticosteroid Insufficiency, and surgical stress can exacerbate the occurrence of adrenal insufficiency. Therefore, adjunctive therapy with low doses of GCs is likely to prevent adrenergic crises and associated hemodynamic instability [37]. On the other hand, preserving immune function is crucial for clearing invading pathogens. However, the impact of GCs on the immune response is controversial. It has been established that long-term use of GCs can lead to profound immune suppression, leading some researchers to question the use of immunosuppressive drugs, such as GCs, in patients with severe infections [38, 39].

In contrast, recent basic research has clearly demonstrated a role for GCs in dampening the exaggerated immune response while preserving pathogen clearance. In patients with septic shock, stress doses of hydrocortisone exert beneficial effects by improving hemodynamics, decreasing pro-inflammatory mediators and oxidative stress, without compromising opsonization-dependent phagocytic neutrophil functions [40]. Additionally, clinical research has also revealed that perioperative use of short-term, low-dose GCs did not impact wound infection rates in elective noncardiac surgery [41, 42]. Therefore, a better understanding of the immunological effects of GCs may provide rationale for their use in sepsis, particularly in patients experiencing septic shock.

The recommendation of 200–300 mg of hydrocortisone as a supraphysiologic dose is based on the observation that this would approximate the amount of cortisol produced by a maximally stimulated adrenal gland [43]. Some researchers have begun to consider high doses of GCs in sepsis due to GC resistance, which refers to the inadequate response of the glucocorticoid receptor (GR) to regulate the transcription of GR-responsive genes, despite seemingly adequate plasma cortisol levels [44]. Schumer et al. identified that treatment with high doses of GCs (3 mg/kg dexamethasone or 30 mg/kg methylprednisolone) significantly reduced the mortality rate from 38.40% to 10.40% [9]. However, subsequent studies reported that short courses of high-dose GCs are associated with worsened secondary infections and increased mortality [45]. In this study, 46 patients received a dose of over 200 mg of hydrocortisone (or equivalent), and a large proportion of these patients experienced septic shock and received blood transfusions. Patients in the high-dose group had higher in-hospital mortality and longer ICU stay compared with the low-dose group. After PSM, it was revealed that there was no significant relationship between the dosage of GCs and patient prognosis. Therefore, the use of high-dose steroids in surgical patients with sepsis needs to be approached with caution.

This investigation, although insightful, is not without its limitations. First, patients received GCs at varying doses and types, and although equivalent conversions were utilized, the pharmacological effects may vary slightly. Second, we mainly observed the use of steroids and clinical data 1 day before and after surgery. Considering the dynamic nature of the disease, the effect of a single dosage of steroids may be limited, especially on the long-term outcomes. Third, this study was retrospective in nature, and inherent to retrospective studies, there may be missing valuable information and the potential for selection bias. Finally, the number of cases included in the final analysis was relatively small due to strict inclusion criteria and PSM, ultimately leading to a small number of recorded events and limiting the potential generalizability of our conclusions.

5 | Conclusion

The findings of this study have several important clinical implications. First, the observation that low-dose GCs transiently improved hemodynamics in septic shock patients without significantly affecting mortality or ICU length of stay suggests that GCs may serve as hemodynamic stabilizers rather than definitive therapeutic agents for improving survival. Second, the lack of significant benefits from high-dose GCs highlights the necessity for cautious use, weighing potential hemodynamic advantages against the risks of adverse effects such as immunosuppression and secondary infections. Moreover, future randomized control trials are needed to optimize GC dosing strategies, including timing, dosage, and duration, and to explore their effects on long-term outcomes, such as quality of life and functional recovery.

Author Contributions

Tianzhu Tao: conceptualization, funding acquisition, investigation, methodology, writing–review and editing. **Yue Shi:** data curation, software, writing–original draft. **Xiaofei Ye:** methodology, software. **Weidong Mi:** conceptualization, funding acquisition, writing–review and editing. **Jingsheng Lou:** conceptualization, data curation, investigation, writing–review and editing.

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Ethics Statement

This study was approved by the Ethics Committee Board of the First Medical Center of the Chinese PLA General Hospital and the Ethics Committee Board of the Air Force Medical Center, and was registered with the ClinicalTrials (trial number NCT06756750).

Consent

Informed consent was not required as the data were anonymized and this study was conducted as a noninterventional observational analysis.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are available at (https://doi.org/10.6084/m9.figshare.25757187.v1).

Transparency Statement

The lead author Weidong Mi, Jingsheng Lou affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.