The American Journal of Surgery 220 (2020) 648–653

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Impact of glucocorticoid supplementation on reducing perioperative complications in patients on long-term glucocorticoid medication: A propensity score analysis using a nationwide inpatient database

Hideyuki Mouri [a, b, *], Taisuke Jo [c], Hiroki Matsui [b], Kiyohide Fushimi [d], Hideo Yasunaga [b]

[a] Department of Anesthesiology and Intensive Care Medicine, Kanazawa University Graduate School of Medical Sciences, Kanazawa University, 13-1 Takara-machi, Kanazawa, 920-8641, Japan
[b] Department of Clinical Epidemiology and Health Economics, School of Public Health, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan
[c] Department of Health Services Research, Graduate School of Medicine, The University of Tokyo, 1-5-45 Yushima, Bunkyo-ku, Tokyo, 113-8519, Japan
[d] Department of Health Policy and Informatics, Tokyo Medical and Dental University Graduate School of Medicine, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan

ARTICLE INFO

Article history:
Received 11 September 2019
Received in revised form
17 January 2020
Accepted 29 January 2020

Keywords:
Adrenal insufficiency
Chronic steroid use
Glucocorticoid supplementation
Perioperative
Propensity score

ABSTRACT

Background: Perioperative glucocorticoid supplementation has been suggested as a potentially effective precaution against perioperative adrenal crisis in patients on long-term glucocorticoid medication.
Methods: This retrospective cohort study used a national inpatient database in Japan. We included patients who underwent general surgery and those who received long-term glucocorticoid medication before surgery. A one-to-one propensity score-matched analysis was performed to compare patients who received 100 mg hydrocortisone during surgery with those who received no supplementation. The primary outcome was use of vasopressor agents on the day of surgery. The secondary outcomes included bleeding, perioperative infection, wound dehiscence, postoperative length of stay, and in-hospital mortality.
Results: Among the 807 propensity score-matched pairs, there was no significant difference in use of vasopressor agents between patients with and without glucocorticoid supplementation (24.5% vs. 21.9%; P = 0.22) and no significant differences in any secondary outcomes.
Conclusions: Perioperative glucocorticoid supplementation was not associated with decreased morbidity or mortality.

Introduction

Adrenal crisis is a life-threatening disorder that can be caused by adrenal insufficiency. Surgery is one of the major precipitating causes of adrenal crisis among patients who are abruptly withdrawn from exogenous corticosteroid.[1]

Perioperative glucocorticoid supplementation has been used for more than 65 years as a feasible option for surgical patients on long-term glucocorticoid medication.[2,3] Some review articles proposed a rational regimen for perioperative glucocorticoid supplementation.[1,4,5]

However, previous studies with small sample sizes showed no significant association between perioperative glucocorticoid supplementation and prevention of adrenal crisis. Two small randomized controlled trials found no significant difference in blood pressure during the perioperative period between the hydrocortisone supplementation group and the placebo group.[6,7] Similarly, two retrospective studies on patients with inflammatory bowel disease showed no significant difference in hemodynamic instability between the groups with and without glucocorticoid supplementation.[8,9] Meanwhile, glucocorticoid supplementation may be associated with an increased risk of complications related to excessive dosage of corticosteroid, including gastrointestinal bleeding, psychosis, hyperglycemia, wound dehiscence, anastomotic leakage, and systemic infection.[10]

We hypothesized that perioperative glucocorticoid supplementation is associated with hemodynamic stability. The aim of this study was to evaluate the impact of glucocorticoid medication

* Corresponding author.
E-mail address: hmouri-tky@umin.ac.jp (H. Mouri).

https://doi.org/10.1016/j.amjsurg.2020.01.051
0002-9610/

on early perioperative outcomes in patients on long-term glucocorticoid, using a large national inpatient database in Japan.

Materials and methods

Data source

This study was approved by the Institutional Review Board of The University of Tokyo. The requirement for informed consent was waived because of the anonymous nature of the data. This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[11]

The study was a retrospective nationwide cohort study using the Diagnosis Procedure Combination database in Japan. The details of the database have been described elsewhere.[12] Briefly, administrative claims data and detailed patient data are collected for all inpatients discharged from hospitals participating in the database. All 82 academic hospitals in Japan are required to participate in the database, while participation by community hospitals is voluntary. The database contains the following data: age; sex; height and weight; dates of hospital admission and discharge; discharge status and in-hospital death; diagnoses, comorbidities at admission, and complications after admission recorded with text data in Japanese and International Classification of Diseases, 10th revision (ICD-10) codes; and activities of daily living based on the Barthel Index. The Diagnostic Procedure Combination database has separate input columns for each of the following 10 components of the patient's Barthel Index: feeding, bathing, grooming, dressing, bowels, bladder, toilet use, transfer, morbidity, and stairs. In accordance with the Barthel Index scoring system, scores of 0 to 3 points are recorded for each component. The Barthel Index score is calculated by summing the individual points of the 10 components. The physicians in charge are responsible for entering patient data for diagnoses and outcomes including the Barthel Index score at discharge. In a validation study of diagnoses and procedure records in the database, the sensitivity and specificity of the primary diagnoses were 78.9% and 93.2%, respectively.[12]

Data extraction

We identified patients aged ≥20 years who underwent general surgery from July 2010 to March 2017. Among these patients, those who received ≥5 mg/day prednisolone (or equivalent) within 3 months before surgery were identified using outpatient data, because adrenocortical insufficiency is likely to occur in patients exceeding 5 mg/day prednisolone (or equivalent).[4] We excluded patients who had adrenal insufficiency at admission, those who received surgery at ≥8 days after admission, those who were readmitted at <8 days after discharge, and those who received steroids other than 100 mg hydrocortisone during surgery. We divided the patients into two groups: those who received intravenous 100 mg hydrocortisone during surgery for perioperative glucocorticoid supplementation (hydrocortisone group) and those who did not receive glucocorticoid supplementation during surgery (control group).

Variables and outcomes

The baseline variables included age, sex, treatment year, body mass index (BMI), type of admission, Barthel index, academic hospital, comorbidities, and type of surgery. BMI was classified into five categories (<18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, and ≥30 kg/m^2). The primary outcome was use of vasopressor agents on the day of surgery, defined as continuous intravenous administration of adrenaline, noradrenaline, dopamine, or vasopressin. The secondary outcomes were postoperative length of stay, in-hospital mortality, perioperative bleeding (defined as use of blood transfusion), postoperative respiratory infection, abdominal infection, urinary tract infection, ileus, venous thromboembolism, and wound dehiscence. The postoperative disease categories and their ICD-10 codes evaluated in this study are listed in Supplementary Table 1.

Statistical analysis

Continuous variables were reported as median (interquartile range). Categorical variables were reported as number (percentage). We performed a propensity score-matched analysis to adjust for measured confounding factors. Propensity scores were estimated using a multivariable logistic regression model with baseline independent variables. The independent variables included the following potential confounders: age, sex, steroid dose (equivalent dose of prednisolone) before surgery, treatment year, BMI, type of admission, Barthel index, academic hospital, comorbidities at admission, and type of surgery. The C-statistic was calculated to evaluate the discrimination of the model. A one-to-one propensity score-matched analysis using nearest-neighbor matching was performed based on the estimated propensity scores between the hydrocortisone group and the control group. The propensity scores were matched using a caliper with a width of 0.25 standard deviation. Standardized differences were computed to examine the balance in covariates between the two groups, and absolute standardized differences of >10% were considered imbalanced.[13]

We compared the outcomes between the hydrocortisone group and the control group. We also performed subgroup analyses for use of vasopressor agents on the day of surgery in the propensity score-matched patients stratified by two anesthesia time categories (below median and above median) and three types of surgery (minor [hernioplasty], moderate [cholecystectomy, colon resection, hysterectomy], and major [coronary artery bypass grafting, pancreatectomy]).[10] Moreover, a sensitivity analysis was performed. We defined the inclusion criterion as treatment with ≥5 mg/day prednisolone (or equivalent) once within 21 days, 22 to 60 days, or 61 to 90 days before surgery rather than within 3 months. We assumed that patients who had been given the steroid at least once during the period had been taking steroids throughout the surgery.

We used Fisher's exact test to compare use of vasopressor agents on the day of surgery, in-hospital mortality, and proportion of each complication. Postoperative length of stay was analyzed by the Mann–Whitney *U* test. We performed a multivariable logistic regression analysis to assess the relationship between patient-level factors and the use of vasopressors after adjustment for within-hospital clustering by means of a generalized estimating equation. An interaction term was used to evaluate the effect modification between the steroid dose before surgery and hydrocortisone, between comorbidities and hydrocortisone, and between the type of surgery and hydrocortisone. Point estimates were reported with the 95% confidence interval (95% CI). All reported P-values were two-sided, and values of $P < 0.05$ were considered significant. All statistical analyses were performed using IBM SPSS Statistics for Windows version 23.0 (IBM, Armonk, NY) and Stata Statistical Software Release 15 (Stata Corp., College Station, TX).

Results

We identified 19,561 patients who received 5 mg/day prednisolone (or equivalent) within 3 months before surgery (Table 1). After exclusions, the number of eligible patients was 14,561 (Fig. 1). Among the patients, the mean age was 63.7 (standard deviation

Table 1
Baseline patient characteristics in the unmatched and propensity score-matched cohorts.

	Unmatched cohort					Propensity score-matched cohort				
	Control		Hydrocortisone		Standardized difference (%)	Control		Hydrocortisone		Standardized difference (%)
	(n = 13,753)		(n = 808)			(n = 807)		(n = 807)		
Age (years), mean (SD)	64.5	(13.6)	63.7	(13.2)	6.5	64.5	(13.6)	64.3	(13.6)	1.9
Male, n (%)	7746	(56.3)	449	(55.6)	−1.5	424	(52.5)	448	(55.5)	6.0
Steroid dose before surgery, n (%)										
5–10 mg	3927	(28.6)	348	(43.1)	30.6	360	(44.6)	347	(43.0)	−3.2
10–20 mg	2935	(21.3)	251	(31.1)	22.2	243	(30.1)	251	(31.1)	2.2
20–30 mg	1742	(12.7)	71	(8.8)	−12.6	81	(10.0)	71	(8.8)	−4.2
30–40 mg	743	(5.4)	43	(5.3)	−0.4	43	(5.3)	43	(5.3)	0
≥40 mg	4406	(32.0)	95	(11.8)	−50.6	80	(9.9)	95	(11.8)	6.0
Treatment year, n (%)										
2010	805	(5.9)	36	(4.5)	−6.3	47	(5.8)	36	(4.5)	−6.2
2011	1728	(12.6)	106	(13.1)	1.7	98	(12.1)	106	(13.1)	3.0
2012	2212	(16.1)	114	(14.1)	−5.5	111	(13.8)	114	(14.1)	1.1
2013	2444	(17.8)	141	(17.5)	−0.8	142	(17.6)	141	(17.5)	−0.3
2014	2627	(19.1)	173	(21.4)	5.7	161	(20.0)	173	(21.4)	3.7
2015	2889	(21.0)	185	(22.9)	4.6	199	(24.7)	184	(22.8)	−4.4
2016	1048	(7.6)	53	(6.6)	−4.1	49	(6.1)	53	(6.6)	2.0
Body mass index (kg/m^2), n (%)										
<18.5	1790	(13.0)	82	(10.1)	−9.0	75	(9.3)	82	(10.2)	2.9
18.5–22.9	6351	(46.2)	369	(45.7)	−1.0	372	(46.1)	369	(45.7)	−0.7
23.0–24.9	2507	(18.2)	173	(21.4)	8.0	164	(20.3)	173	(21.4)	2.7
25.0–29.9	2495	(18.1)	148	(18.3)	0.5	164	(20.3)	148	(18.3)	-5.0
≥30.0	478	(3.5)	26	(3.2)	−1.4	24	(3.0)	25	(3.1)	0.7
Missing	132	(1.0)	10	(1.2)	2.7	8	(1.0)	10	(1.2)	2.4
Barthel Index, n (%)										
0–49	739	(5.4)	46	(5.7)	1.4	56	(6.9)	46	(5.7)	−5.1
50–99	1176	(8.6)	86	(10.6)	7.1	87	(10.8)	86	(10.7)	−0.4
100	11,150	(81.1)	624	(77.2)	−9.5	620	(76.8)	623	(77.2)	0.9
Missing	688	(5.0)	52	(6.4)	6.2	44	(5.5)	52	(6.4)	4.2
Type of admission, n (%)										
Emergency	1607	(11.7)	119	(14.7)	9.0	123	(15.2)	119	(14.7)	−1.4
Type of hospital, n (%)										
Academic	6325	(46.0)	418	(51.7)	11.5	423	(52.4)	418	(51.8)	−1.2

Abbreviation: SD, standard deviation.

13.2) years, 8195 (56.3%) were men, 11,774 (80.9%) had a Barthel index score of 100, and 808 (5.5%) received 100 mg hydrocortisone for perioperative supplementation. Before propensity-score matching, several variables were imbalanced between the patients with and without perioperative hydrocortisone supplementation, including distribution of steroid dose before surgery, hospital type, ulcerative colitis, rheumatic disease, metastatic solid tumor, gastrectomy, hepatectomy, hernioplasty, rectal resection, and hysterectomy (Tables 1 and 2). The one-to-one propensity score-matched cohort included 807 pairs. The C-statistic was 0.71. After propensity-score matching, the baseline characteristics were well balanced between the two groups (Tables 1 and 2).

Table 3 shows the outcomes of interest between the two groups after propensity-score matching. There was no significant difference in use of vasopressor agents on the day of surgery (hydrocortisone vs. control, 24.5% vs. 21.9%, P = 0.22). The other perioperative outcomes did not differ significantly between the two groups.

In the subgroup analyses classified by anesthesia time, a total of 37 patients were excluded because missing data for anesthesia time in both groups. The median anesthesia time was 270 min. A total of 792 patients had a shorter anesthesia time and 795 patients had a longer anesthesia time. Perioperative glucocorticoid supplementation was not associated with lower use of vasopressor agents in the shorter anesthesia time group (80/398 (20.1%) vs. 64/394 (16.2%), P = 0.17) or the longer anesthesia time group (119/397 (30.0%) vs. 111/388 (28.6%), P = 0.70). Correspondingly, another subgroup analysis showed no significant difference in the use of vasopressors between the hydrocortisone and control groups among patients who underwent minor, moderate, or major surgery after propensity-score matching (Supplementary Table 2).

The multivariable analysis showed that hydrocortisone use was not associated with vasopressor use (odds ratio [OR], 1.55; 95% CI, 0.89–2.70). The interaction term for hydrocortisone between steroid doses before surgery was not significant. We found an interaction between ulcerative colitis and hydrocortisone (OR, 2.08; 95% CI, 1.05–4.11) and between stoma closure and hydrocortisone (OR, 0.22; 95% CI, 0.05–0.93) (Supplementary Table 3).

The sensitivity analysis included 6,649 patients within 21 days before surgery (442 in the hydrocortisone group, 6,207 in the control group), 5,451 patients within 22 to 60 days (277 in the hydrocortisone group, 5,174 in the control group), and 2,461 patients within 61 to 90 days (87 in the hydrocortisone group, 2,374 in the control group). Propensity-score matching created 442, 277, and 81 pairs, respectively. There was no significant difference in the use of vasopressor agents on the day of surgery (hydrocortisone vs. control, 111/42 [25.1%] vs. 97/442 [22.0%], P=0.30; 67/277 [24.2%] vs. 60/277 [21.7%], P=0.54; and 20/81 [24.7%] vs. 18/81 [22.2%], P=0.85, respectively) between the two groups.

Discussion

We examined 14,561 patients who underwent surgery and those who received 5 mg/day prednisolone (or equivalent) within 3 months before surgery, using a national inpatient database in Japan. The results showed no significant differences in the proportions of

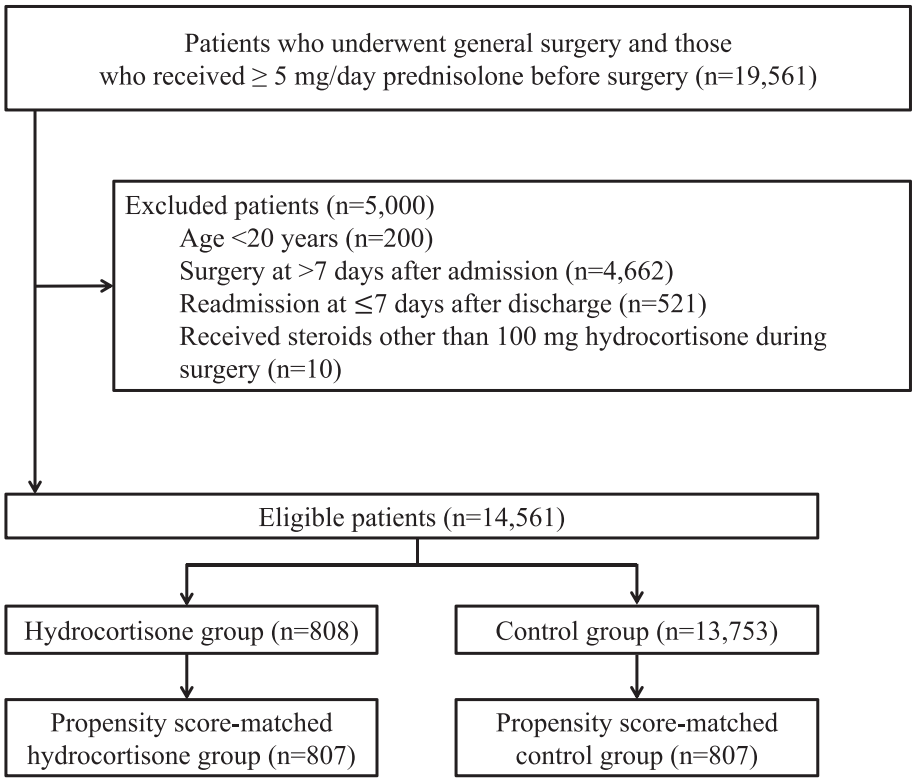

Fig. 1. Flow diagram for selection of the study population.

vasopressor use, bleeding, perioperative infection, wound dehiscence, venous thromboembolism, postoperative length of stay, and in-hospital mortality between patients with and without perioperative glucocorticoid supplementation.

Two previous case reports described that long-term corticosteroid-dependent patients died of refractory hypotension resulting from adrenal crisis.[2,3] Perioperative glucocorticoid supplementation is considered a potentially effective precaution against perioperative adrenal crisis according to expert opinion.[4] However, data have been lacking on the benefits versus risks of perioperative glucocorticoid supplementation. Small-sized studies showed no significant differences in hemodynamic instability, perioperative complications, or proven adrenal crisis between patients with and without perioperative glucocorticoid supplementation.[8,14,15] Two randomized controlled trials examined about 20 patients who presented for surgery while on long-term glucocorticoid medication.[6,7] The patients were randomized to receive either perioperative glucocorticoid supplementation or control medication. There were no significant perioperative differences in hemodynamic parameters between the two groups. A 2012 Cochrane review[20] of these two randomized controlled studies was unable to either recommend or advise against the use of supplemental perioperative steroids for patients with adrenal insufficiency based on the available evidence. In 2013, however, this Cochrane review was retracted after the eligibility criteria and interpretation of the evidence were challenged.[21] Since then, no randomized controlled studies examining the necessity of perioperative glucocorticoid supplementation have been published.medication.

The patients were randomized to receive either perioperative glucocorticoid supplementation or control medication. There were no significant perioperative differences in hemodynamic parameters between the two groups.[20]Several previous studies used blood pressure as an outcome measure,[6,7,14–17] while the present study examined use of vasopressor agents as a measure for hemodynamic instability. The latter approach can identify refractory hypotension requiring continuous vasopressor use, rather than temporary hypotension.[14,15,18]

The necessity for perioperative glucocorticoid supplementation is physiologically plausible because intraoperative hypotension with decreased cortisol can occur in patients on long-term steroid.[16] However, our findings revealed no significant differences in any clinical outcomes between those with and without perioperative glucocorticoid supplementation. Based on our results, it may not be necessary to use perioperative glucocorticoid supplementation for prevention of adrenal crisis. Our results suggest that patients on long-term steroid may be able to receive only their usual dose of steroid without perioperative glucocorticoid supplementation.

One of the strengths of the present study was the use of propensity-score matching. Previous studies on perioperative glucocorticoid supplementation were solely focused on patients with organ transplantation, inflammatory bowel disease, or craniosynostosis.[7,9,14,17,19] To the best of our knowledge, this is the first study to examine perioperative glucocorticoid supplementation for patients who underwent various surgeries.

This study has several limitations. First, recoded diagnoses in administrative data are generally not well validated. Second, the study was based on retrospective analyses, and the treatment allocation was not random.

In conclusion, the present study did not demonstrate an association between perioperative glucocorticoid supplementation and use of vasopressor agents.

Table 2
Comorbidities and types of surgery in the unmatched and propensity score-matched cohorts.

	Unmatched cohort					Propensity score-matched cohort				
	Control		Hydrocortisone		Standardized difference (%)	Control		Hydrocortisone		Standardized difference (%)
	(n = 13,753)		(n = 808)			(n = 807)		(n = 807)		
Comorbidities, n (%)										
Asthma	699	(5.1)	47	(5.8)	3.2	52	(6.4)	47	(5.8)	−2.6
Crohn's disease	171	(1.2)	20	(2.5)	9.1	20	(2.5)	20	(2.5)	0
Ulcerative colitis	576	(4.2)	59	(7.3)	13.4	53	(6.6)	59	(7.3)	2.9
Hypertension	2488	(18.1)	151	(18.7)	1.5	140	(17.3)	151	(18.7)	3.5
Myocardial infarction	100	(0.7)	15	(1.9)	10.0	9	(1.1)	14	(1.7)	5.2
Chronic heart failure	369	(2.7)	25	(3.1)	2.5	29	(3.6)	25	(3.1)	−2.8
Peripheral vascular disease	144	(1.0)	13	(1.6)	4.9	13	(1.6)	13	(1.6)	0
Cerebrovascular disease	294	(2.1)	23	(2.8)	4.5	20	(2.5)	23	(2.9)	2.3
Chronic pulmonary disease	1161	(8.4)	73	(9.0)	2.1	80	(9.9)	73	(9.0)	−3.0
Rheumatic disease	1398	(10.2)	142	(17.6)	21.6	130	(16.1)	141	(17.5)	3.6
Peptic ulcer disease	1036	(7.5)	57	(7.1)	−1.8	61	(7.6)	57	(7.1)	−1.9
Mild liver dysfunction	800	(5.8)	50	(6.2)	1.6	70	(8.7)	49	(6.1)	−10.0
Diabetic mellitus without complications	2054	(14.9)	148	(18.3)	9.1	123	(15.2)	148	(18.3)	8.3
Diabetic mellitus with complications	291	(2.1)	20	(2.5)	2.4	19	(2.4)	20	(2.5)	0.8
Renal dysfunction	514	(3.7)	42	(5.2)	7.1	50	(6.2)	42	(5.2)	−4.3
Malignancy	2409	(17.5)	121	(15.0)	−6.9	114	(14.1)	121	(15.0)	2.5
Metastatic disease	1412	(10.3)	46	(5.7)	−16.9	39	(4.8)	46	(5.7)	3.9
Types of surgery, n (%)										
Spine surgery	1559	(11.3)	99	(12.3)	2.8	95	(11.8)	99	(12.3)	1.5
Surgical clipping for cerebral aneurysms	126	(0.9)	9	(1.1)	2.0	13	(1.6)	9	(1.1)	−4.3
Lobectomy	1406	(10.2)	75	(9.3)	−3.2	76	(9.4)	75	(9.3)	−0.4
Coronary artery bypass grafting	100	(0.7)	5	(0.6)	−1.3	6	(0.7)	5	(0.6)	−1.5
Gastrectomy	680	(4.9)	60	(7.4)	10.3	50	(6.2)	60	(7.4)	4.9
Cholecystectomy	809	(5.9)	66	(8.2)	9.0	73	(9.0)	66	(8.2)	−3.1
Hepatectomy	1094	(8.0)	88	(10.9)	10.1	93	(11.5)	87	(10.8)	−2.4
Pancreatectomy	254	(1.8)	19	(2.4)	3.5	23	(2.9)	19	(2.4)	−3.1
Hernioplasty	1292	(9.4)	33	(4.1)	−21.3	34	(4.2)	33	(4.1)	−0.6
Appendectomy	320	(2.3)	33	(4.1)	10.0	33	(4.1)	33	(4.1)	0
Adhesiotomy	238	(1.7)	13	(1.6)	−0.9	13	(1.6)	13	(1.6)	0
Colostomy	592	(4.3)	22	(2.7)	−8.6	18	(2.2)	22	(2.7)	3.2
Stoma closure	922	(6.7)	46	(5.7)	−4.2	46	(5.7)	46	(5.7)	0
Ileal resection	388	(2.8)	27	(3.3)	3.0	25	(3.1)	27	(3.3)	1.4
Colectomy	1779	(12.9)	121	(15)	5.9	133	(16.5)	121	(15)	−4.1
Rectal resection	1511	(11)	58	(7.2)	−13.3	45	(5.6)	58	(7.2)	6.6
Nephrectomy	350	(2.5)	27	(3.3)	4.7	23	(2.9)	27	(3.3)	2.9
Hysterectomy	333	(2.4)	7	(0.9)	−12.2	8	(1.0)	7	(0.9)	−1.3

Table 3
Comparisons of outcomes between the propensity score-matched patients.

	Control		Hydrocortisone		P-value
	(n = 807)		(n = 807)		
Vasopressor, n (%)	177	(21.9)	198	(24.5)	0.22
In-hospital death, n (%)	14	(1.7)	19	(2.4)	0.38
Sepsis, n (%)	82	(10.2)	86	(10.7)	0.81
Respiratory infection, n (%)	24	(3.0)	22	(2.7)	0.76
Abdominal infection, n (%)	46	(5.7)	37	(4.6)	0.31
Urinary infection, n (%)	7	(0.9)	5	(0.6)	0.56
Ileus, n (%)	8	(1.0)	4	(0.5)	0.25
Myocardial infarction, n (%)	1	(0.1)	0	(0.0)	1
Venous thromboembolism, n (%)	9	(1.1)	9	(1.1)	1
Dehiscence, n (%)	9	(1.1)	16	(2.0)	0.16
Transfusion, n (%)	85	(10.5)	99	(12.3)	0.27
Postoperative length of stay (days), median (interquartile range)	13	(9–22)	14	(10–22)	0.11

P-values for categorical outcomes were obtained by Fisher's exact test. P-values for continuous outcomes were obtained by the Mann–Whitney *U* test.

Funding

This work was supported by grants from the Ministry of Health, Labour and Welfare, Japan (H30-Policy-Designated-004 and H29-ICT-General-004) and the Ministry of Education, Culture, Sports, Science and Technology, Japan (17H04141).

Author contributions

Hideyuki Mouri, MD: Study design, data analysis, data interpretation, and manuscript preparation; Taisuke Jo, MD, PhD: Study design, data analysis, data interpretation, and manuscript preparation; Hiroki Matsui, MPH: Data analysis and data interpretation; Kiyohide Fushimi, MD, PhD: Data collection and data

interpretation; Hideo Yasunaga, MD, PhD: Study design, data collection, data analysis, data interpretation, and manuscript preparation. All authors approved the final manuscript.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2020.01.051.

References

1. Cooper MS, Stewart PM. Corticosteroid insufficiency in acutely ill patients. *N Engl J Med*. 2003;348(8):727–734.
2. Fraser CG, Preuss FS, Bigford WD. Adrenal atrophy and irreversible shock associated with cortisone therapy. *J Am Med Assoc*. 1952;149(17):1542–1543.
3. Lewis L, Robinson RF, Yee J, et al. Fatal adrenal cortical insufficiency precipitated by surgery during prolonged continuous cortisone treatment. *Ann Intern Med*. 1953;39(1):116–126.
4. Coursin DB, Wood KE. Corticosteroid supplementation for adrenal insufficiency. *J Am Med Assoc*. 2002;287(2):236–240.
5. Jung C, Inder WJ. Management of adrenal insufficiency during the stress of medical illness and surgery. *Med J Aust*. 2008;188(7):409–413.
6. Glowniak JV, Loriaux DL. A double-blind study of perioperative steroid requirements in secondary adrenal insufficiency. *Surgery*. 1997;121(2):123–129.
7. Thomason JM, Girdler NM, Kendall-Taylor P, et al. An investigation into the need for supplementary steroids in organ transplant patients undergoing gingival surgery. A double-blind, split-mouth, cross-over study. *J Clin Periodontol*. 1999;26(9):577–582.
8. Zaghiyan K, Melmed G, Murrell Z, Fleshner P. Are high-dose perioperative steroids necessary in patients undergoing colorectal surgery treated with steroid therapy within the past 12 months? *Am Surg*. 2011;77(10):1295–1299.
9. Lamore 3rd RF, Hechenbleikner EM, Ha C, et al. Perioperative glucocorticoid prescribing habits in patients with inflammatory bowel disease: a call for standardization. *JAMA Surg*. 2014;149(5):459–466.
10. Toner AJ, Ganeshanathan V, Chan MT, et al. Safety of perioperative glucocorticoids in elective noncardiac surgery: a systematic review and meta-analysis. *Anesthesiology*. 2017;126(2):234–248.
11. von Elm E, Altman DG, Egger M, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ*. 2007;335(7624):806–808.
12. Yamana H, Moriwaki M, Horiguchi H, et al. Validity of diagnoses, procedures, and laboratory data in Japanese administrative data. *J Epidemiol*. 2017;27(10):476–482.
13. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res*. 2011;46(3):399–424.
14. Zaghiyan K, Melmed G, Murrell Z, Fleshner P. Safety and feasibility of using low-dose perioperative intravenous steroids in inflammatory bowel disease patients undergoing major colorectal surgery: a pilot study. *Surgery*. 2012;152(2):158–163.
15. Zaghiyan K, Melmed GY, Berel D, et al. A prospective, randomized, non-inferiority trial of steroid dosing after major colorectal surgery. *Ann Surg*. 2014;259(1):32–37.
16. Kehlet H, Binder C. Adrenocortical function and clinical course during and after surgery in unsupplemented glucocorticoid-treated patients. *Br J Anaesth*. 1973;45(10):1043–1048.
17. Aytac E, Londono JM, Erem HH, et al. Impact of stress dose steroids on the outcomes of restorative proctocolectomy in patients with ulcerative colitis. *Dis Colon Rectum*. 2013;56(11):1253–1258.
18. Zaghiyan KN, Murrell Z, Melmed GY, Fleshner PR. High-dose perioperative corticosteroids in steroid-treated patients undergoing major colorectal surgery: necessary or overkill? *Am J Surg*. 2012;204(4):481–486.
19. Wei AT, Madsen C, Al-Sheemy A, Kumar AR. Does perioperative steroid use improve clinical outcomes in open repair of craniosynostosis? *J Craniofac Surg*. 2015;26(1):226–231.
20. Yong SL, Coulthard P, Wrzosek A. Supplemental perioperative steroids for surgical patients with adrenal insufficiency. *Cochrane Database Syst Rev*. 2012;12:CD005367.
21. Yong SL, Coulthard P, Wrzosek A. WITHDRAWN: Supplemental perioperative steroids for surgical patients with adrenal insufficiency. *Cochrane Database Syst Rev*. 2013;10:CD005367.