Journal on Surgery

www.journalonsurgery.org

Research Article

Open Access, Volume 2

The Impact of Preoperative Hemoglobin Concentration and Erythropoietin Administration on Renal Tumors Patients with Inferior Vena Cava Tumor Thrombus Underwent Robot-Assisted Laparoscopic Inferior Vena Cava Thrombectomy

Junting Liu; Jie Lin; Meng Yi; Li Liu; Mingyu Han; Lingling Zhou; Leiying Zhang; Yuanyuan Luo; Fang Sun; Yingwei Song; Deqing Wang*

Department of Transfusion Medicine, The First Medical Center of Chinese PLA General Hospital, 301 Hospital, 28# Fuxing Road, Beijng 100853, China.

Abstract

Introduction: The impact of preoperative hemoglobin (Hb) concentration and recombinant human erythropoietin (rh-EPO) treatment on renal tumors (RTs) patients with inferior vena cava (IVC) tumor thrombus who underwent robot-assisted laparoscopic inferior vena cava thrombectomy (RAL-IVCTE) were not well studied.

Materials and methods: We retrospectively analyzed the demographic and clinical data of 61 patients with RTs who underwent RAL-IVCTE. We conducted several multiple linear regression analysis models to explore the association of preoperative Hb concentration, perioperative rh-EPO administration and RBC transfusion, Hb concentration, postoperative complications and days stay in intensive care unit (ICU).

Results: 43 (70.49%) patients received RBC transfusion and 19 (31.15%) patients received rh-EPO treatment perioperative. Multiple linear regression analysis revealed that lower preoperative Hb concentration patients had a significantly more intraoperative and postoperative RBC transfusion (r = -0.053; 95% CI = -0.099 to -0.007; p = 0.025); patients received more preoperative rh-EPO treatment had significantly higher discharge Hb concentration (r =3.306; 95% CI = 0.707 to 5.906; p = 0.014), less days stay in ICU (r = -0.539; 95% CI = -0.957 to -0.122; p = 0.012). In addition, perioperative rh-EPO administration was not significantly associated with RBC transfusion demand and postoperative complications.

Conclusions: Lower preoperative Hb concentration related with more RBC transfusion in RTs patients underwent RAL-IVCTE. Preoperative rh-EPO administration appears to be beneficial for patients.

Keywords: Hemoglobin; Erythropoietin; Renal tumors; Inferior vena cava.

Manuscript Information: *Received: Nov 14, 2022; Accepted: Dec 12, 2022; Published: Dec 19, 2022*

Correspondance: *Deqing Wang, Department of Transfusion Medicine, The First Medical Center of Chinese PLA General Hospital, 301 Hospital, 28# Fuxing Road, Beijng 100853, China. Email: deqingw@vip.sina.com*

Citation: *Liu J, Lin J, Yi M, Liu L, Han M, et al. The Impact of Preoperative Hemoglobin Concentration and Erythropoietin Administration on Renal Tumors Patients with Inferior Vena Cava Tumor Thrombus Underwent Robot-Assisted Laparoscopic Inferior Vena Cava Thrombectomy. J Surgery. 2022; 2(2): 1069.*

Introduction

RTs is a malignancy of urinary system, accounting for 2%-3% of adult malignancies [1]. Although the prevalence of locally advanced RTs with inferior vena cava (IVC) tumor thrombus is relatively low, occurred in 4-10% of patients [2], tumor thrombi could migrate proximally to the right atrium [3] and lead to poor prognosis. For RTs with IVC tumor thrombus, surgery could effectively improve the prognosis [4]. As one of the most difficult operations in urology, RAL-IVCTE has a complicated procedure, great operation trauma and a lot intraoperative bleeding. Therefore, it is necessary to keep patients in good condition as far as possible before operation. However, in clinical observation, we found that RTs patients with IVC tumor thrombus had a high prevalence of preoperative anemia and great demand for allogeneic RBC transfusion. Although several researches reported the high transfusion rate in patients underwent RAL-IVCTE [5,6], studies on the effect of Hb concentration on RTs patients with IVC thrombus who underwent RAL-IVCTE are few, and lack of study on the effect of drug treatment of anemia for these patients, which is very important for patient blood management.

As a kind of Erythropoiesis-Stimulating Agents (ESAs), rh-EPO could improve the Hb levels in anemic patients. However, the use of ESAs on surgical patients remains contrversial. Some studies have reported the use of perioperative ESAs reduce the need for allogeneic blood transfusion [7,8]. Other studies have found rh-EPO may lead increased thrombotic events [9,10]. Nevertheless, the rh-EPO treatment influence for other clinically outcomes such as ischemic events, thromboembolic events and mortality, the number of events was too small and the variability in results was too large to detect statistically significant and clinically relevant differences [11]. In this study, we retrospectively analyzed the effects of rh-EPO administration on RTs patients underwent RAL-IVCTE.

Materials and methods

We retrospectively analyzed the data of 61 in-patients with RTs who underwent RAL-IVCTE in the first medical central of Chinese PLA General Hospital (PLAGH) from March 2014 to December 2018. Age less than 18 years old, unknown preoperative hemoglobin and laboratory data, and cases with unknown demographics were excluded. The study was approved by the Chinese PLAGH ethics committee.

Demographic and clinical data including age, gender, body mass index (BMI), smoking status in one year, drinking status within 2 weeks, laboratory data, size of renal tumor, clinical stage, IVC thrombus classification, Charlson comorbidity index (CCI), hypertension, American Society of Anaesthesiologists (ASA) score, pathologic results were collected. Postoperative complications were recorded according to the Clavien classification system[12]. Administration of rh-EPO during hospitalization was recorded, 10,000 international unit (IU) per dose. The decision and the amount to use rh-EPO was by the preference of the treating surgeon. Transfusion was recorded in patients received at least one unit of packed RBC transfused in perioperative period.

Anemia was defined as Hb <120 g/L for women and < 130 g/L for men according to the 2011 WHO guidelines: no anemia (Hb ≥ 120 g/L in women and Hb ≥ 130 g/L in men), mild anemia (110 g/L ≤ Hb < 120 g/L in women and 110 g/L ≤ Hb < 130 g/L in men) and moderate-to-severe anemia (Hb < 110 g/L). Patients' last Hb concentration before discharge was defined as discharge Hb concentration.

Statistical significance was defined as P <0.05, Confidence Intervals (CIs) are reported at the 95% level. Stata 15.1 was used to analyze the data and draw graphics.

Patient demographics and baseline characteristics were analyzed using descriptive statistics and are presented as percentage or mean ± *SD*. The student *t* test was used to examine the association between continuous variables, and Pearson χ^2 test or the Fisher's exact test was used to examine the association between categorical variables. We conducted several Multiple Linear Regression (MLR) analysis models. In these MLR analysis models, a stepwise method was selected, treating intraoperative and postoperative RBC transfusion volume, days stay in ICU, postoperative complication grade and the discharge Hb concentration, respectively, as the dependent variable and the following parameters as independent variables including the last preoperative Hb concentration, rh-EPO injection dose preoperative, rh-EPO injection dose postoperative, estimated blood loss, ASA grade, size of renal tumor, IVC thrombus classification, TNM stage grouping, history of targeted drug therapy (no, yes), affected kidney (right, left), pathology (other, clear cell), tobacco use in past year (no, yes), alcohol intake within 2 weeks(no, yes), sex, age (continuous years), BMI, CCI, white blood cell count, platelet count, international normalised ratio, blood urea nitrogen value, albumin value, aspartate aminotransferase value, creatinine value.

In these MLR analysis models, marginal probabilities were calculated using Stata. Regression-predicted effects of preoperative Hb concentration on intraoperative and postoperative RBC transfusion volume, and rh-EPO administration on days stay in ICU and the discharge Hb concentration were plotted using marginal predictive plotting.

Results

We included data for 61 patients, 21 women (34.43%) and 40 (65.57%) men with a mean age of 55.8 years (SD 13.0, range 21.7 to 86.3). In the present study, a total of 41 patients (67.21%) had anemia, of which 13 (21.31%) patients had mild anemia and 28 (45.90%) patients had moderate-to-severe anemia (including 1 patient had severe anemia). Table 1 shows the basic characteristics of patients. 43 (70.49%) patients received perioperative RBC transfusion, including 42 (68.85%) patients received intraoperative and postoperative RBC transfusion and 1 (1.64%) patient received preoperative RBC transfusion. 19 (31.15%) patients received perioperative rh-EPO treatment.

Table 1: Baseline characteristics of patients (n=61).

Variable	N (*% or SD*)
Age (years)	55.8 (13.0)
BMI (kg/m^2)	24.4 (3.2)
Gender	
Female	21 (34.43%)
Male	40 (65.57%)
Preoperative Hb concentration (g/L)	116.4 (20.7)
Preoperative anemia	
Mild anemia	13 (21.31%)
Moderate-to-severe anemia	28 (45.90%)
Tobacco use in past year	15 (24.59%)
Alcohol intake within 2 weeks	9 (14.75%)
Hypertension	18 (29.51%)
CCI≥1	22 (36.07%)
History of targeted drug therapy	17 (27.87%)
Affected kidney	
Right	45 (73.77%)
Left	16 (26.23%)
Pathology	
Renal clear cell carcinoma	41 (67.21%)
Other	20 (32.79%)
Size of renal tumor (cm)	7.9 (4.0)
TNM stage grouping	
Stage III	56 (91.80%)
Stage IV	5 (8.20%)
IVC thrombus classification	
Level I~ II	29 (47.54%)
Level III~ IV	32 (52.46%)
ASA grade	
I- II	32 (52.46%)
III~ IV	29 (47.54%)
Estimated blood loss (1000ml)	1.57 (2.17)
Total cost, K$	18.85 (7.75)
Intraoperative and postoperative RBC transfusion (%)	42 (68.85%)
Perioperative rh-EPO treatment (%)	19 (31.15%)

N; Number: SD; Standard Deviation: BMI; Body Mass Index: CCI; Charlson Comorbidity Index: TMN; Tumor Node Metastasis: IVC; Inferior Vena Cava: ASA; American Society Of Anaesthesiologists: Rh-EPO; Recombinant Human Erythropoietin: RBC; Red Blood Cell. 1unit RBC Was From 200ml Whole Blood.

In the MLR analysis of intraoperative and postoperative RBC transfusion volume, lower the last preoperative Hb concentration (r = -0.053; p = 0.025) and Charlson comorbidity index (r = -1.387; p = 0.032), smaller size of tumor (r = -0.310; p = 0.010), and more estimated blood loss (r = 3.859; p < 0.001) were related with more intraoperative and postoperative RBC transfusion. Perioperative rh-EPO therapy was not significantly associated with the need of RBC transfusion (Supplementary Table S1). The analysis could account for the observed variation of the volume intraoperative and postoperative RBC transfusion in 89.0% patients (R^2 = 0.890).

Figure 1 shows the relationship of the last preoperative Hb concentration and the intraoperative and postoperative RBC transfusion volume. Figure 2 shows the relationship of the last preoperative Hb concentration and the predicted intraoperative and postoperative RBC transfusion volume in MLR model. Lower preoperative Hb level was significantly associated with more perioperative RBC transfusion. The intraoperative and postoperative transfusion RBC transfusion volume increased by 0.53 units for every 10 g/L decrease in preoperative Hb concentration.

In the MLR analysis of the discharge Hb concentration, higher preoperative Hb concentration (r = 0.383; p < 0.001), the first postoperative Hb concentration (r = 0.605; p < 0.001), preoperative platelet count (r = 0.054; p = 0.003) and ASA grade (r = 9.194; p < 0.001); more intraoperative and postoperative RBC transfusion (r = 0.602; p = 0.032) and preoperative rh-EPO injection (r = 3.306; p = 0.014); lower postoperative complication grade (r = -3.966; p = 0.039) were related with higher discharge Hb concentration (Table 2). The analysis could account for the observed variation of the discharge Hb concentration in 65.1% patients (R^2 = 0.651).

Table 2: Multiple linear regression analysis of the discharge Hb concentration.

The discharge Hb concentration	r	95% CI	*P*	Beta	Adjusted R^2 of the model
the last preoperative Hb concentration	0.383	0.189 to 0.577	<0.001	0.434	0.651
preoperative rh-EPO injection dose	3.306	0.707 to 5.906	0.014	0.219	
Intraoperative and postoperative RBC transfusion volume	0.602	0.054 to 1.150	0.032	0.295	
ASA grade	9.194	4.258 to 14.129	<0.001	0.325	
IVC	-3.407	-7.467 to 0.652	0.098	-0.165	
postoperative complication grade	-3.966	-7.719 to -0.213	0.039	-0.251	
the first postoperative Hb concentration	0.605	0.364 to 0.846	<0.001	0.637	
CCI	-4.558	-9.370 to 0.253	0.063	-0.161	
the last preoperative platelet count	0.054	0.020 to 0.088	0.003	0.278	

CCI: Charlson comorbidity index: IVC: inferior vena cava: ASA: American Society of Anaesthesiologists; Hb: hemoglobin; rh-EPO: Recombinant human erythropoietin; RBC: red blood cell; CI: confidence interval.

Figure 3 shows the relationship of the preoperative rh-EPO administration and the predicted discharge Hb concentration in MLR model. When patients injected 4 doses rh-EPO preoperative, the predicted median Hb could be 119 g/L (the red circle).

We graded complications of patients according to Clavien classification of surgical complications. In the MLR analysis of postoperative complication grade, higher Charlson comorbidity index (r = 0.407; p = 0.011) and more intraoperative and postoperative RBC transfusion (r = 0.075; p < 0.001) were related with higher postoperative complication grade (Table 3). Perioperative rh-EPO injection was not significantly associated with higher complication grade. The analysis could account for the observed variation of the postoperative complication grade in 58.8% patients (R^2 = 0.588).

There were 4 thrombotic events in patients, 1 in rh-EPO treatment patients, 3 in non-rh-EPO treatment patients. And there was no significant difference between the two groups population (p = 0.085, data not shown).

Table 3: Multiple linear regression analysis of postoperative complication grade.

Postoperative complication grade	r	95% CI	*P*	Beta	Adjusted R^2 of the model
Intraoperative and postoperative RBC transfusion volume	0.075	0.049 to 0.101	<0.001	0.582	0.588
IVC thrombus classification	0.254	-0.008 to 0.515	0.057	0.194	
CCI	0.407	0.098 to 0.716	0.011	0.228	
History of targeted drug therapy	0.299	-0.033 to 0.631	0.076	0.160	
Tobacco use in past year	-0.435	-0.881 to 0.012	0.056	-0.163	

CCI: Charlson Comorbidity Index; IVC: Inferior Vena Cava; RBC: Red Blood Cell; CI: Confidence Interval.

In the MLR analysis of days stay in ICU, more preoperative rh-EPO injection (r = -0.539; p = 0.012), smaller size of tumor (r = -0.145; p = 0.022), lower grade of postoperative complication (r = 1.055; p = < 0.001), IVC thrombus classification (r = 0.833; p = 0.008) and ASA (r = 1.235; p = 0.002) were related with less days stay in ICU (Supplementary Table S1). The analysis could account for the observed variation of the days stay in ICU in 54.6% patients (R^2 = 0.546).

Figure 4 shows the relationship of the preoperative rh-EPO injection dose and the predicted days stay in ICU in the MLR analysis. The days stay in ICU decreased 0.5 day for every dose increase of rh-EPO injection. When patients injected 4 doses rh-EPO preoperative, the predicted median days stay in ICU could be 0.2 day (the bule circle).

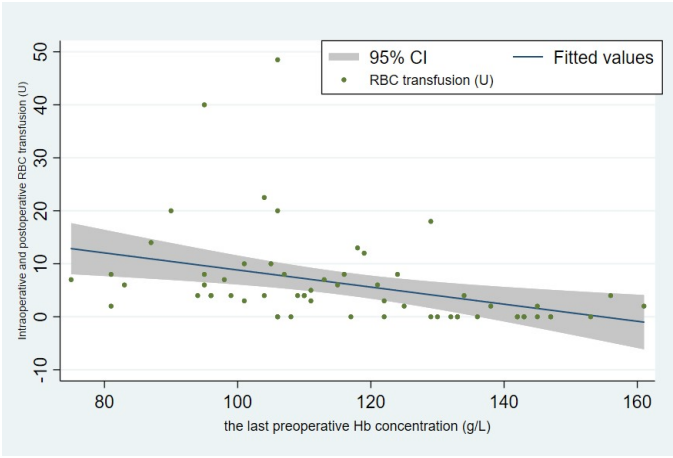

Figure 1: The last preoperative Hb concentration and intraoperative and postoperative RBC transfusion.

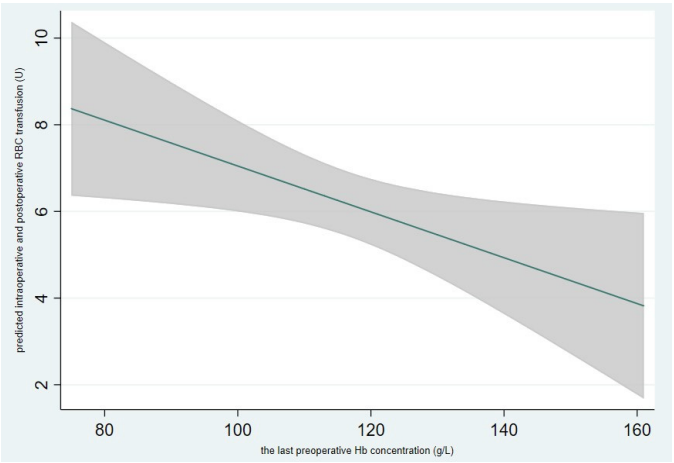

Figure 2: The last preoperative Hb concentration and the adjusted median RBC transfusion volume.

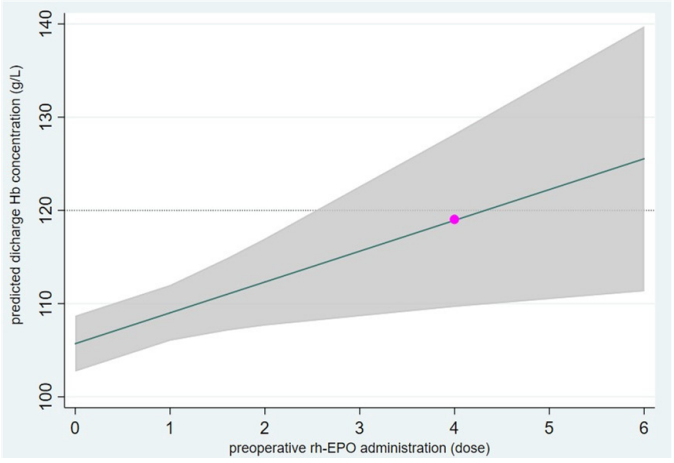

Figure 3: Preoperative rh-EPO administration and adjusted median discharge Hb concentration.

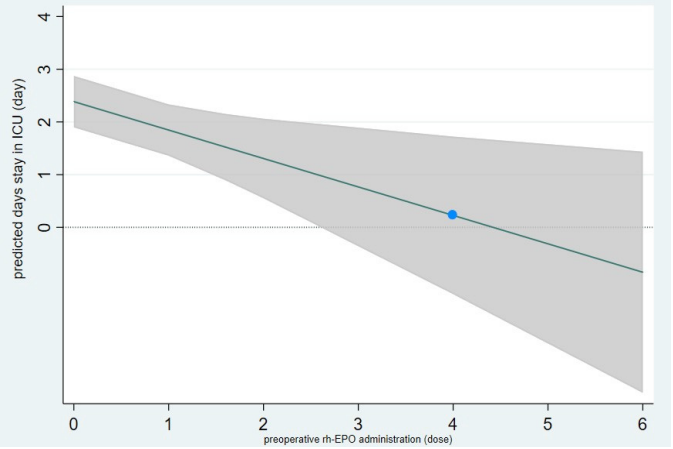

Figure 4: Preoprative rh-EPO administration and the adjusted median days stay in ICU.

Discussion

In this study, the incidence of preoperative anemia is very striking in RTs patients underwent RAL-IVCTE, 67.21% patients with anemia, and 45.90% patients with moderate-to-severe anemia. In present study, we found that patients lower preoperative Hb concentration associated with more RBC transfusion. This result was similar with a widely accepted finding that preoperative anemia increased the perioperative RBC transfusion demand. Rh-EPO is one of the common agents to increase the Hb concentration in clinic, and 31.15% patients received rh-EPO perioperative treatment in our study. We mainly analyzed the relationship of rh-EPO administration and RBC transfusion, discharge Hb concentration, postoperative complication and days stay in ICU. As far as we know, this is the first study of the impact of preoperative Hb concentration and rh-EPO treatment on RTs patients underwent RAL-IVCTE.

The 1-year disease-specific survival for untreated Renal Cell Carcinoma (RCC) with venous tumor thrombus was 29% [13], but the 1-year survival was 60% for surgery patients even with distant metastases at the time of diagnosis [14]. RTs patients with IVC thrombus could benefit from a robot-assisted strategy and achieve quick recovery [15]. RAL-IVCTE is highly intricated, even surgeons with advanced robotic skill required a long operation time [16]. One of the major risks of this surgery is bleeding, which lead to a relatively high rate of blood transfusion. In our study, 42 (68.85%) patients received intraoperative and postoperative RBC transfusion. The Hb concentration of patients was an important factor relate to intraoperative and postoperative RBC transfusion volume (Figure 1), with increased by 0.53 units for every 10 g/L decrease in preoperative Hb concentration (Figure 2). However, the preoperative and postoperative rh-EPO treatment were not associated with RBC transfusion volume in this study. The negative result may be due to the short rh-EPO treatment interval and relatively low dose of rh-EPO administration before operation. Among the patients who used rh-EPO before operation, the time from admission to surgery was 13.8 ± 3.5 days. However, Hb and hematocrit usually increased within 2-6 weeks after rh-EPO treatment. Our result was similar with a prospective randomized multicenter trial study in patients undergoing right hemicolectomy for carcinoma [17] which patients with preoperative rh-EPO treatment for 5-10 days, that rh-EPO not reduce the need of RBC transfusion.

In present study, our result showed that more preoperative rh-EPO injection, rather than postoperative treatment, was significantly related with higher discharge Hb concentration. The increase of Hb is related to the improvement of patients' Quality of Life (QOL) or fatigue. Several studies have found that changes in Hb levels in patients with cancer and anemia caused by erythropoietin are associated with changes in their QOL [18-20], and the greatest incremental QOL gain associated with a 10 g/L change in Hb occurred around hemoglobin 120 g/L (range, 110-130 g/L) [21]. Therefore, we recommend that clinicians should use rh-EPO as soon as possible for patients with preoperative anemia to maintain a relatively high concentration of Hb in the perioperative period.

Although a previous review showed that rh-EPO treatment in RCC is not indicated for anemia in RCC is an infrequent clinical problem [22], and also some studies assessing rh-EPO safety in anemic patients with chronic renal disease have found adverse effects including thromboembolic, cardiovascular and stroke events, preoperative anemia in RTs patients with IVC is common, and compared patients with chronic disease, the perioperative dosing strategies of surgical patients are more variable in timing, dose and duration [23,24]. In addtion, the effect of rh-EPO treatment on postoperative adverse events reminds controversial for the quality of the evidence was not high due to inconsistency in findings and small number of events were reported. Several studies found that rh-EPO therapy reduced the risk for acute kidney injury [25], all-cause-mortality and end-stage renal disease[26], and other studies have shown that rh-EPO administration did not associated with an increased thromboembolic risk [27,28]. In this study, we graded complications of patients according to Clavien classification of surgical complications[12]. We found that preoperative treatment of rh-EPO not significantly associated with postoperative adverse complication grade. After that, we analyzed the thrombotic events: 4 thrombotic events in patients, 3 in rh-EPO treatment patients, 1 in non-rh-EPO treatment patients. And there was no significant difference between the two groups population (p = 0.085, data not shown). Of note, in this study, we found that more RBC transfusion was associated with higher grade postoperative complications. This is consistent with some large and high-quality studies of the adverse effects of RBC transfusion on surgical patients [29,30]. RTs patients underwent RAL-IVCTE have a relatively high risk of bleeding and a high probability of allogeneic RBC transfusion. In our present study, rh-EPO treatment was not significantly related to RBC transfusion requirements. However, from the perspective of the whole perioperative period, the preoperative rh-EPO administration did improve the level of Hb in patients. Clinicians should pay enough attention to preoperative anemia in patients, give them treatment as soon as possible to improve the Hb concentration. The early and adequate preoperative rh-EPO administration may indirectly reduce the demand for perioperative RBC transfusion, and then reduce the occurrence of postoperative complications.

We found in the present study that more preoperative, rather than postoperative rh-EPO administration, was related with shorter ICU or postoperative hospital stay (data not shown), which was similar to several other studies [31,32]. There may be several reasons for this clinical benefit of rh-EPO. On the one hand, as a hematopoietic hormone that regulates RBC production, rh-EPO could improve the symptoms associated with anemia. On the

other hand, in addition to stimulating hematopoiesis, rh-EPO can also act as a tissue protectant with anti-inflammatory, cell stabilizing, and antiapoptotic effects on multiple organ systems including renal, cardiac and neurological systems [33,34]. However, the minimum effective rh-EPO dose required to benefit patients is unknown. In some previous reports, rh-EPO treatment protocols vary from multiple doses given over a period of 3 to 4 weeks preoperatively at weekly intervals [35,36] to 10 days preoperative daily given with extent to postoperative [37]. The United States Food and Drug Administration approved a regimen of four subcutaneous injection of epoetin-α, 600 IU/kg of body weight, administered at 3, 2 and 1 week before surgery and again on the day of operation [38]. In the present study, we found if patients injected 4 doses rh-EPO preoperative, the predicted median days stay in ICU could be 0.2 day (Figure 4), and the median discharge Hb concentration could be 119 g/L (Figure 3). Furthermore, we found it was postoperative but not preoperative rh-EPO treatment associated with higher total hospital costs (Supplementary Table S1). Considering this is a retrospective study, this finding could be due to a selection bias such that patients received more postoperative rh-EPO treatment and less preoperative treatment, but this is unlikely because there were 13 patients received preoperative and 14 patients received postoperative rh-EPO treatment, and the average injection doses were 2.4 and 2.9, respectively. Our study indicated that early and adequate administration of rh-EPO before operation can be beneficial to RAL-IVCTE patients. We recommend at least 4 doses preoperative rh-EPO administrate for these patients.

Supplementary table S1: Multiple linear regression analysis of the factors associated with intraoperative and postoperative RBC transfusion volume, days stay in ICU and total hospital fee.

	r	95% CI	*P*	Beta	Adjusted R2 of the model
Intraoperative and postoperative RBC transfusion volume					0.890
the last preoperative Hb concentration	-0.053	-0.099 to -0.007	0.025	-0.123	
BMI	-0.262	-0.541 to 0.018	0.066	-0.093	
CCI	-1.387	-2.648 to -0.127	0.032	-0.100	
Size of renal tumor	-0.310	-0.542 to -0.077	0.010	-0.138	
estimated blood loss	3.895	3.506 to 4.283	<0.001	0.946	
Days stay in ICU					0.546
IVC thrombus classification	0.833	0.230 to 1.436	0.008	0.281	
ASA grade	1.235	0.476 to 1.994	0.002	0. 304	
postoperative complication grade	1.055	0.607 to 1.502	<0.001	0.465	
preoperative rh-EPO injection dose	-0.539	-0.957 to -0.122	0.012	-0.250	
Size of renal tumor	-0.145	-0.269 to -0.021	0.022	-0.221	
Total hospital fee					0.811
history of targeted drug therapy	-2.077	-3.615 to -0.539	0.009	-0.165	
the last preoperative Hb concentration	-0.040	-0.086 to 0.007	0.096	-0.106	
postoperative rh-EPO injection dose	0.629	0.064 to 1.194	0.030	0. 142	
postoperative complication grade	1.649	0.621 to 2.676	0.002	0.246	
days stay in ICU	1.763	1.338 to 2.188	<0.001	0. 596	
IVC thrombus classification	1.245	-0.0408 to 2.531	0.057	0. 142	
CCI	-1.481	-2.977 to 0.015	0.052	-0.123	

Conclusions

In conclusion, we found that preoperative Hb concentration in RTs patients underwent RAL-IVCTE were relatively low and preoperative anemia was not uncommon among them. Patients with lower Hb levels were associated with increased demand of intraoperative and postoperative RBC transfusion. More preoperative, rather than postoperative rh-EPO administration was related to shorter ICU stay. The perioperative rh-EPO treatment was not significantly associated with more RBC transfusion demand and higher grade of postoperative complications.

Limitations

However, our study has several limitations. On the one hand, we have a relatively small number of samples, which may be related to the relatively low incidence of RTs with IVC tumor thrombus. On the other hand, we retrospective analysis the postoperative complications during hospitalization, but not analysis the long-term complications and death rate of patients. Larger sample size or prospective studies are needed to further verify our conclusion.

Declarations

Acknowledgment: This work was supported by the Bethune Charitable Foundation (BQE-2018-SX-01) of China. Thanks to the Bethune Charitable Foundation for funding this research. We completed the study, including data collection, analysis and interpretation. We were grateful for patient's informed consent and the data provided by the hospital. We declare that there are no conflicts of interest. Our research was approved by the ethics

committee of Chinese PLA General Hospital

Funding: This work was supported by the Bethune Charitable Foundation (BQE-2018-SX-01) of China.

Conflict of interest: The authors declare no conflict of interest.

Data availability statement: The data of this study are available by email of acada_ljting@sina.com.

References

1. Wotkowicz C, Wszolek MF, Libertino JA. Resection of renal tumors invading the vena cava. Urol Clin North Am. 2008; 35: 657-671.
2. Marshall FF, Dietrick DD, Baumgartner WA, Reitz BA. Surgical management of renal cell carcinoma with intracaval neoplastic extension above the hepatic veins. J Urol. 1988; 139: 1166-1172.
3. Hatcher PA, Anderson EE, Paulson DF, Carson CC, Robertson JE. Surgical management and prognosis of renal cell carcinoma invading the vena cava. J Urol. 1991; 145: 20-23.
4. Bansal RK, Tu HY, Drachenberg D, Shayegan B, Matsumoto E, et al. Laparoscopic management of advanced renal cell carcinoma with renal vein and inferior vena cava thrombus. Urology. 2014; 83: 812-816.
5. Chopra S, Simone G, Metcalfe C, de Castro Abreu AL, Nabhani J, et al. Robot-assisted Level II-III Inferior Vena Cava Tumor Thrombectomy: Step-by-Step Technique and 1-Year Outcomes. Eur Urol. 2017; 72: 267-274.
6. Wang B, Huang Q, Liu K, Fan Y, Peng C, et al. Robot-assisted Level III-IV Inferior Vena Cava Thrombectomy: Initial Series with Step-by-step Procedures and 1-yr Outcomes. Eur Urol. 2020; 78: 77-86.
7. Bedair H, Yang J, Dwyer MK, McCarthy JC. Preoperative erythropoietin alpha reduces postoperative transfusions in THA and TKA but may not be cost-effective. Clin Orthop Relat Res. 2015; 473: 590-596.
8. Weltert L, Rondinelli B, Bello R, Falco M, Bellisario A, et al. A single dose of erythropoietin reduces perioperative transfusions in cardiac surgery: results of a prospective single-blind randomized controlled trial. Transfusion. 2015; 55: 1644-1654.
9. Corwin HL, Gettinger A, Fabian TC, May A, Pearl RG, et al. Efficacy and safety of epoetin alfa in critically ill patients. N Engl J Med. 2007. 357(10): 965-76.
10. Stowell CP, Jones SC, Enny C, Langholff W, Leitz G. An open-label, randomized, parallel-group study of perioperative epoetin alfa versus standard of care for blood conservation in major elective spinal surgery: safety analysis. Spine (Phila Pa 1976). 2009; 34: 2479-2485.
11. Mueller MM, Van Remoortel H, Meybohm P, Aranko K, Aubron C, et al. Patient Blood Management: Recommendations From the 2018 Frankfurt Consensus Conference. JAMA. 2019; 321: 983-997.
12. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004; 240: 205-213.
13. Reese AC, Whitson JM, Meng MV. Natural history of untreated renal cell carcinoma with venous tumor thrombus. Urol Oncol. 2013; 31: 1305-1309.
14. Whitson JM, Reese AC, Meng MV. Population based analysis of survival in patients with renal cell carcinoma and venous tumor thrombus. Urol Oncol. 2013; 31: 259-263.
15. Gu L, Ma X, Gao Y, Li H, Li X, et al. Robotic versus Open Level I-II Inferior Vena Cava Thrombectomy: A Matched Group Comparative Analysis. J Urol. 2017; 198: 1241-1246.
16. Kundavaram C, Abreu AL, Chopra S, Simone G, Sotelo R,et al. Advances in Robotic Vena Cava Tumor Thrombectomy: Intracaval Balloon Occlusion, Patch Grafting, and Vena Cavoscopy. Eur Urol. 2016; 70: 884-890.
17. Kettelhack C, Hönes C, Messinger D, Schlag PM. Randomized multicentre trial of the influence of recombinant human erythropoietin on intraoperative and postoperative transfusion need in anaemic patients undergoing right hemicolectomy for carcinoma. Br J Surg. 1998; 85: 63-67.
18. Duh MS, Lefebvre P, Fastenau J, Piech CT, Waltzman RJ. Assessing the clinical benefits of erythropoietic agents using area under the hemoglobin change curve. Oncologist. 2005; 10: 438-448.
19. Lefebvre P, Vekeman F, Sarokhan B, Enny C, Provenzano R, Cremieux PY. Relationship between hemoglobin level and quality of life in anemic patients with chronic kidney disease receiving epoetin alfa. Curr Med Res Opin. 2006; 22: 1929-1937.
20. Stull DE, Vernon MK, Legg JC, Viswanathan HN, Fairclough D, Revicki DA. Use of latent growth curve models for assessing the effects of darbepoetin alfa on hemoglobin and fatigue. Contemp Clin Trials. 2010; 31: 172-179.
21. Shasha D, Cremieux P, Harrison L. Relationship between hemoglobin levels and quality of life during radiation therapy plus concomitant or sequential chemotherapy in patients with cancer and anemia treated with epoetin alfa. J Natl Compr Canc Netw. 2004; 2: 509-517.
22. Albers P, Heicappell R, Schwaibold H, Wolff J. Erythropoietin in urologic oncology. Eur Urol. 2001; 39: 1-8.
23. Singh AK, Szczech L, Tang KL, Barnhart H, Sapp S, et al. Correction of anemia with epoetin alfa in chronic kidney disease. N Engl J Med. 2006; 355: 2085-2098.
24. Pfeffer MA, Burdmann EA, Chen CY, Cooper ME, de Zeeuw D, et al. A trial of darbepoetin alfa in type 2 diabetes and chronic kidney disease. N Engl J Med. 2009; 361: 2019-2032.
25. Penny-Dimri JC, Cochrane AD, Perry LA, Smith JA. Characterising the Role of Perioperative Erythropoietin for Preventing Acute Kidney Injury after Cardiac Surgery: Systematic Review and Meta-Analysis. Heart Lung Circ. 2016; 25: 1067-1076.
26. Oh SW, Chin HJ, Chae DW, Na KY. Erythropoietin improves long-term outcomes in patients with acute kidney injury after coronary artery bypass grafting. J Korean Med Sci. 2012; 27: 506-511.
27. Sowade O, Ziemer S, Sowade B, Franke W, Messinger D, et al. The effect of preoperative recombinant human erythropoietin therapy on platelets and hemostasis in patients undergoing cardiac surgery. J Lab Clin Med. 1997; 129: 376-383.
28. Spahn DR, Schoenrath F, Spahn GH, Seifert B, Stein P, et al. Effect of ultra-short-term treatment of patients with iron deficiency or anaemia undergoing cardiac surgery: a prospective randomised trial. Lancet. 2019; 393: 2201-2212.
29. Abdelsattar ZM, Hendren S, Wong SL, Campbell DA Jr, Henke P. Variation in Transfusion Practices and the Effect on Outcomes After Noncardiac Surgery. Ann Surg. 2015; 262: 1-6.

30. Goel R, Patel EU, Cushing MM, Frank SM, Ness PM, et al. Association of Perioperative Red Blood Cell Transfusions With Venous Thromboembolism in a North American Registry. JAMA Surg. 2018; 153: 826-833.

31. Shapiro GS, Boachie-Adjei O, Dhawlikar SH, Maier LS. The use of Epoetin alfa in complex spine deformity surgery. Spine (Phila Pa 1976). 2002; 27: 2067-2071.

32. Shin HJ, Ko E, Jun I, Kim HJ, Lim CH. Effects of perioperative erythropoietin administration on acute kidney injury and red blood cell transfusion in patients undergoing cardiac surgery: A systematic review and meta-analysis. Medicine (Baltimore). 2022; 101: e28920.

33. Brines ML, Ghezzi P, Keenan S, Agnello D, de Lanerolle NC, et al. Erythropoietin crosses the blood-brain barrier to protect against experimental brain injury. Proc Natl Acad Sci U S A. 2000; 97: 10526-10531.

34. Coleman T, Brines M. Science review: recombinant human erythropoietin in critical illness: a role beyond anemia. Crit Care. 2004; 8: 337-341.

35. Wurnig C, Schatz K, Noske H, et al. Subcutaneous low-dose epoetin beta for the avoidance of transfusion in patients scheduled for elective surgery not eligible for autologous blood donation. Eur Surg Res. 2001; 33: 303-310.

36. Weber EW, Slappendel R, Hémon Y, Mähler S, Dalén T,et al. Effects of epoetin alfa on blood transfusions and postoperative recovery in orthopaedic surgery: the European Epoetin Alfa Surgery Trial (EEST). Eur J Anaesthesiol. 2005; 22: 249-257.

37. Kosmadakis N, Messaris E, Maris A, Katsaragakis S, Leandros E, et al. Perioperative erythropoietin administration in patients with gastrointestinal tract cancer: prospective randomized double-blind study. Ann Surg. 2003; 237: 417-421.

38. Goldberg MA, McCutchen JW, Jove M, Di Cesare P, Friedman RJ, et al. A safety and efficacy comparison study of two dosing regimens of epoetin alfa in patients undergoing major orthopedic surgery. Am J Orthop (Belle Mead NJ). 1996; 25: 544-552.