·临床研究·

补充10%及20%浓度人血白蛋白对心肺转流术后患者肾功能的影响

徐猛[1,2],陆璇[1],李程浩[1],孟文晴[1],潘正慧[1],赵文静[1,2*]
([1]徐州医科大学附属医院重症医学科,徐州 221002;[2]徐州医科大学麻醉学院麻醉系,徐州 221004)

【摘 要】 **目的** 探讨10%及20%的人血白蛋白(HSA)对心肺转流(CPB)心脏手术患者术后肾功能的影响。**方法** 选取徐州医科大学附属医院重症医学科2016年3月至2016年12月接受CPB心脏手术后低蛋白血症患者100例,按随机数字表法将患者分为接受10% HSA组及20% HSA组,每组各50例。2组患者给予对应浓度HSA,至白蛋白(ALB)水平>35 g/L。记录并比较2组患者术后临床相关指标、肾功能、HSA使用量、药物使用情况、尿量及ICU停留时间、术后住院时间等差异。应用SPSS 21.0软件进行统计分析。根据数据类型,组间比较采用非配对t检验或χ^2检验,组内比较采用单因素方差分析。**结果** 2组患者术后当天ALB均较术前明显下降,补充HSA后第1、2天ALB水平有所上升但仍低于术前水平($P<0.05$);术后当天2组患者血肌酐(SCr)水平升高不明显,但术后第1、2天较术前明显升高($P<0.05$);2组患者尿素氮(BUN)水平在手术当天、第1、2天呈上升趋势,但第1、2天水平显著高于手术前($P<0.05$);手术当天2组患者血红蛋白(Hb)显著低于手术前,术后第1、2天有不同程度升高,但仍低于术前水平($P<0.05$);术前及术后2组患者各时间点ALB、SCr、BUN、尿酸(UA)、Hb比较,差异均无统计学意义($P>0.05$)。与10% HSA组比较,20% HSA组HSA用量降低[(21.20±8.81) *vs* (30.00±10.41)g, $P<0.01$],术后第2天尿量明显增多,差异有统计学意义[(2.62±0.67) *vs* (2.13±0.82)ml/(kg·h), $P<0.05$]。其他相关指标在2组间差异均无统计学意义($P>0.05$)。**结论** 10%及20%浓度的HSA对CPB心脏手术后低蛋白血症患者肾功能无明显不同影响,但20%的HSA使用总量少,且在增加术后尿量方面效果较好。

【关键词】 心肺转流;白蛋白;肾功能;尿量
【中图分类号】 R541;R592 【文献标志码】 A 【DOI】 10.11915/j.issn.1671-5403.2018.07.112

Effects of 10% and 20% human serum albumin on renal functions of patients after cardiopulmonary bypass

XU Meng[1,2], LU Xuan[1], LI Cheng-Hao[1], MENG Wen-Qing[1], PAN Zheng-Hui[1], ZHAO Wen-Jing[1,2*]
([1]Department of Intensive Medcine, Affiliated Hospital of Xuzhou Medical University, Xuzhou 221002, China; [2]Faculty of Anesthesia, School of Anesthesiology, Xuzhou Medical University, Xuzhou 221004, China)

【**Abstract**】 **Objective** To explore the different effects of 10% and 20% human serum albumin (HSA) solutions on the renal functions of the patients after cardiopulmonary bypass (CPB). **Methods** Totally 100 patients with hypoalbuminemia were enrolled in this study who received CPB from March 2016 to December 2016 in our department. The patients were randomly divided into 2 groups (20% HSA and 10% HSA, $n=50$). HAS were administered in all patients until the albumin (ALB) concentration was >35 g/L. The two groups were compared postoperatively in the aspects of relevant clinical indicators, the renal functions, the amount of HAS administered, drug usage, urine output, length of stay in the ICU, and postoperative hospital stay. SPSS statistics 21.0 was used for statistical analysis. Non-paired t test and Chi-square test was adopted for comparison between groups according to the data types, and univariate analysis of variance was used for intragroup comparison. **Results** ALB in the 2 groups decreased significantly on the day of operation compared with before operation, and in the first and second day after CPB, the level of ALB had some increases, but still lower than that before operation ($P<0.05$). The increase of serum creatinine (SCr) level in 2 groups was not obvious immediately after the operation compared with before operation, but in the first and second day, SCr were significantly higher ($P<0.05$). Blood urea nitrogen (BUN) in the 2 groups showed an upward trend in the day of operation, the first and second day after the operation, and BUN in the first and second day were significantly higher than that before operation($P<0.05$); hemoglobin (Hb) level in the 2 groups in the day of operation were obviously lower than that before operation, and there were some different increases in the first and second day after operation, but still lower than that before operation($P<0.05$). There was no significant difference at the same time point between the

收稿日期:2018-02-22;**修回日期**:2018-03-12
基金项目:六大人才高峰省级D类资助项目(2009059);徐州市科技厅课题(KC16SY150)
通信作者:赵文静,E-mail:zhaowj886@sina.com

2 groups before and after the operation, such as ALB, SCr, BUN, uric acid (UA) and Hb ($P>0.05$). A smaller amount of HSA were administered in the patients in 20% HSA group than those in 10% HSA group [(21.20 ± 8.81) *vs* (30.00 ± 10.41) g, $P<0.01$]. Besides, compared with 10% HSA group, the postoperative urine output on the second day was higher in 20% HSA group [(2.62 ± 0.67) *vs* (2.13 ± 0.82) ml/(kg · h), $P<0.05$]. No significant differences were found in other relevant indices between groups ($P>0.05$). **Conclusion** There is no significant difference between two HSA solutions (10% and 20%) in their effects on the renal function in the patients with hypoalbuminemia who had undergone CPB. However, administration of 20% HSA can significantly reduce the amount of albumin used to treat hypoproteinemia. In terms of increased postoperative urine output, 20% HSA is superior to 10% HSA.

【Key words】 cardiopulmonary bypass; albumin; renal function; urine output

This work was supported by theProject of Six Major Talents Summit of Jiangsu Province, Level D (2009059) *and the Projects Funded by the Bureau of Science and Technology of Xuzhou Municipality* (KC16SY150).

Corresponding author: *ZHAO Wen-Jing*, *E-mail*: *zhaowj886@sina.com*

心肺转流(cardiopulmonary bypass,CPB)术由于血液稀释、出血、血管内皮损伤、术后引流多、应激等因素,会引起体内白蛋白(albumin,ALB)大量丢失、消耗及合成减少,导致患者术后产生低蛋白血症[1,2]。心脏手术后低蛋白血症患者发生急性肾损伤(acute kidney injury,AKI)的风险较大[3,4],且住院时间和ICU停留时间延长,不良转归的发生率以及感染的发生率亦会显著升高[5-7]。因此,术后补充人血白蛋白(human serum albumin,HSA)尤为重要。研究表明,不同浓度HSA应用于肝脏、胰腺手术以及脑出血后,患者住院时间、HSA及血浆使用量等存在明显差异[8-10],且CPB中不同浓度HSA预冲液可对患者术后尿量及利尿剂用量产生影响[11]。当前国内不合理应用HSA的现象普遍存在,导致HSA资源短缺;心脏手术后HSA制剂的使用方案不统一,缺少相关研究及规范。为此,本研究拟比较10%及20%两种临床常用浓度的HSA对CPB心脏手术术后患者肾功能的影响,以期为CPB术后低蛋白血症患者治疗提供参考。

1 对象与方法

1.1 研究对象

选取2016年3月至2016年12月徐州医科大学附属医院重症医学科CPB术后血浆ALB <30 g/L的患者100例,男性47例,女性53例,美国麻醉医师协会(American Society of Anesthesiologist, ASA)分级Ⅱ~Ⅲ级,心功能Ⅱ~Ⅲ级[12],年龄50~70(59.3 ± 6.0)岁。排除标准:(1)对HSA过敏;(2)术前存在低蛋白血症(血浆总蛋白 <60 g/L或ALB <35 g/L);(3)贫血、肝肾功能异常;(4)需要二次开胸手术。入选患者按照随机数字表法分为20% HSA组和10% HSA组,每组各50例。手术当天根据患者入ICU复查ALB水平予补充HSA,2组患者均补充至ALB水平 >35 g/L。本研究获得医院伦理委员会批准(xyfylw2013002)并得到患者或家属知情同意签字。

1.2 观察指标

(1)收集患者年龄、性别、ASA分级、纽约心脏病学会(New York Heart Association,NYHA)分级、左室射血分数(left ventricular ejection fraction,LVEF)、体质量指数(body mass index,BMI)、合并基础疾病情况及术中CPB时间、主动脉阻断时间(aortic cross clamp,ACC)、CPB期间平均动脉压(mean arterial pressure,MAP)等一般资料。(2)生化指标。记录患者术前(T_0)、手术当天(T_1)、术后第1天(T_2)、第2天(T_3)的ALB、血肌酐(serum creatinine,SCr)、尿素氮(blood urea nitrogen,BUN)、尿酸(uric acid,UA)、血红蛋白(hemoglobin,Hb)水平。(3)记录手术后患者HSA使用量、利尿剂用量(呋塞米、托拉塞米)、多巴胺用量、术后第1、2天尿量、患者ICU停留时间、术后住院时间。血常规使用SYSMEXXN-2000血常规分析仪测定,肝肾功能使用Cobas 8000全自动生化分析仪测定。

1.3 统计学处理

应用SPSS 21.0软件进行统计分析。计量资料以均数 ± 标准差($\bar{x} \pm s$)表示,组间比较采用非配对t检验,组内比较采用单因素方差分析。计数资料以例数(百分率)表示,组间比较采用χ^2检验。$P<0.05$为差异具有统计学意义。

2 结 果

2.1 2组患者一般资料比较

2组患者年龄、性别、BMI、LVEF、ASA分级、NYHA分级、高血压、糖尿病、CPB时间、ACC时间、术中MAP比较,差异均无统计学意义($P>0.05$;表1),具有可比性。

2.2 2组患者生化指标变化比较

2组患者手术当天ALB均较术前明显下降,补充HSA后第1、2天ALB水平仍低于术前($P<0.05$);手术当天2组患者SCr水平升高不明显,但术后第1天、第2天较术前明显升高($P<0.05$);2组患者BUN水平在手术当天、第1、2天呈上升趋势,但第1、2天水平显著高于手术前($P<0.05$);手术当天2组患者Hb显著低于手术前,术后第1、2天有不同程度升高,但仍低于术前水平($P<0.05$)。组间比较:术前及术后2组患者各时间点ALB、SCr、BUN、UA、Hb比较,差异均无统计学意义($P>0.05$;表2)。

2.3 2组患者术后情况比较

20% HSA组患者术后HSA使用总量明显低于10% HSA组,差异有统计学意义($P=0.002$);2组患者呋塞米、托拉塞米、多巴胺用量比较差异无统计学意义($P>0.05$);术后第1天2组患者尿量差异不明显,但第2天20% HSA组明显多于10% HSA组($P=0.024$)。2组患者ICU停留时间、住院时间及需要进行临床肾脏替代治疗的比例差异无统计学意义($P>0.05$;表3)。

表1 2组患者一般情况比较

Table 1 Comparison of baseline data between two groups ($n=50$)

Item	20% HSA group	10% HSA group	*P* value
Age(years, $\bar{x}\pm s$)	59.6±6.4	59.0±5.6	0.726
Gender(male/female, *n*)	24/26	23/27	0.323
BMI(kg/m^2, $\bar{x}\pm s$)	26.35±3.12	26.48±3.21	0.674
LVEF(%, $\bar{x}\pm s$)	58.36±7.48	57.84±4.88	0.772
ASA grade(Ⅱ/Ⅲ, *n*)	23/27	19/31	0.272
NYHA grade(Ⅱ/Ⅲ, *n*)	21/29	16/34	0.204
Hypertension[*n*(%)]	13(26.00)	16(32.00)	0.330
Diabetes mellitus[*n*(%)]	9(18.00)	7(14.00)	0.393
CPB time(min, $\bar{x}\pm s$)	80.92±25.00	80.40±30.01	0.947
ACC time(min, $\bar{x}\pm s$)	50.04±19.29	51.80±26.13	0.788
MAP (mmHg, $\bar{x}\pm s$)	66.46±11.37	69.27±9.70	0.353

HSA: human serum albumin; BMI: body mass index; LVEF: left ventricular ejection fraction; ASA: American Society of Anesthesiologist; NYHA: New York Heart Association; CPB: cardiopulmonary bypass; ACC: aortic cross clamp; MAP: mean arterial pressure. 1 mmHg=0.133 kPa

表2 2组患者临床指标比较

Table 2 Comparison of clinical indices between two groups ($n=50$, $\bar{x}\pm s$)

Item	20% HSA group				10% HSA group			
	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
ALB(g/L)	42.4±2.8	21.5±3.3*	36.6±3.5*	39.2±3.3*	43.2±3.6	21.2±2.8*	36.7±5.4*	39.0±3.8*
SCr(mmol/L)	66.6±10.5	69.5±18.3	78.4±13.5*	84.2±20.8*	66.6±12.9	72.2±13.7	78.2±17.4*	85.4±24.9*
BUN(mmol/L)	6.0±1.6	6.6±1.6	9.1±2.2*	12.0±4.5*	5.6±1.9	6.0±1.6	8.6±2.1*	12.1±2.9*
UA(μmol/L)	291.4±75.1	298.6±76.4	301.6±97.5	317.0±93.4	305.8±101.5	290.2±70.6	274.9±84.5	295.4±79.9
Hb(g/L)	135.1±24.6	94.3±7.0*	100.1±6.6*	105.6±5.7*	137.4±12.4	96.1±9.6*	102.6±12.3*	105.4±10.4*

T_0: before operation; T_1: operation day; T_2: 1st day after operation; T_3: 2nd day after operation; HSA: human serum albumin; ALB: albumin; SCr: serum creatinine; BUN: blood urea nitrogen; UA: uric acid; Hb: hemoglobin. Compared with T_0, *$P<0.05$

表3 2组患者术后情况比较

Table 3 Comparison of postoperative status between two groups ($n=50$)

Item	20% HSA group	10% HSA group	*P* value
HSA usage(g, $\bar{x}\pm s$)	21.20±8.81	30.00±10.41	0.002
Furosemide(mg, $\bar{x}\pm s$)	48.56±38.79	50.12±38.92	0.888
Torasemide(mg, $\bar{x}\pm s$)	22.40±12.17	20.20±17.10	0.603
Dopamine(mg, $\bar{x}\pm s$)	168.60±142.33	178.20±133.33	0.807
Urine in day 1 after operation[ml/(kg·h), $\bar{x}\pm s$]	2.59±0.78	2.78±0.87	0.409
Urine in day 2 after operation[ml/(kg·h), $\bar{x}\pm s$]	2.62±0.67	2.13±0.82	0.024
CRRT[*n*(%)]	1(2)	1(2)	0.753
ICU stay(h, $\bar{x}\pm s$)	37.48±4.69	39.04±5.01	0.262
Postoperative hospital stay(d, $\bar{x}\pm s$)	10.28±2.32	10.64±1.93	0.554

HSA: human serum albumin; CRRT: clinical renal replacement therapy; ICU: intensive care unit

3 讨 论

ALB 有协调维持血管内皮完整性、维持胶体渗透压、调节凝血功能、作为氮源为损伤组织修复提供营养等作用[13]，自应用于临床以来，在纠正危重症、外科术后及创伤患者低 ALB 血症等方面使用愈加广泛。CPB 心脏手术因大量补液、手术时间长等原因导致 ALB 水平下降较一般手术更加明显。CPB 术后患者的临床结局与 ALB 水平关系十分密切，即使术前患者营养状态良好、ALB 水平正常，术后低蛋白血症患者发生感染、病情恶化的概率要比 ALB 无明显降低的患者大。而心脏手术后补充 HSA 能迅速有效纠正低蛋白血症，减少术后并发症的发生风险[4]。

目前市场上使用 ALB 规格众多，主要有 5%、10%、20%、25% 以上 4 种，当前国内并无 CPB 术后 HSA 的使用指南，不同医院间亦未形成统一标准。Lee 等[4]研究显示，对于心脏手术前血清 ALB 水平低于 40 g/L 的患者，补充 20% HSA 可增加血浆胶体渗透压，将液体从第三间隙吸入循环，促进液体有效重吸收从而增加有效循环血量，增加肾脏血流量及尿量，并降低手术后发生急性肾损伤的风险，具有肾功能保护作用。CPB 心脏手术患者肾功能损伤较重[14,15]，我们考虑不同浓度 ALB 因为胶体渗透压的不同可能对肾功能产生不同影响，从而产生不同的治疗效果。研究结果显示，2 组 SCr、BUN 差异无统计学意义，这可能是由于 10% 及 20% 的 HSA 虽然血浆胶体渗透压不同，但均能清除和限制活性氧的产生，发挥抗氧化作用，与 NO 反应形成 S－亚硝基白蛋白，促进肾血管舒张以维持正常肾灌注和肾小球滤过，且 HSA 给药可以改善微循环血流量并减少炎症反应[4]，从而发挥肾脏保护作用，且未对肾功能产生不同影响。然而术后第 2 天使用 20% HAS 组患者较 10% HAS 组尿量增多，这可能是由于 20% HAS胶体渗透压较 10% HSA 高，能快速将第三间隙液体转移到血管中[4]，增加了血容量及肾脏血流量，加之配合利尿剂的使用从而使尿量增加，而尿量是反映组织灌注、体液平衡最为常用的参数，是判断心功能、循环容量、肾功能的重要指标[16]，提示 20% HSA 在改善术后尿量上有一定优势。

另一个研究结果显示，20% HAS 使用量明显少于 10% HSA，前者渗透压为后者 2 倍，血浆渗透压为 5 倍，因此可在快速提高胶体渗透压的同时短时间内增加循环血容量[4]，同时使用利尿剂可将过多液体迅速以尿液形式排出，减轻心脏负荷，提升 ALB 水平，从而体现出较高浓度 ALB 在心脏手术后应用的优势。

本研究比较 2 种浓度 HSA 对肾功能的影响，仅对比 SCr 及 BUN 这 2 种常用指标。最近研究表明，中性粒细胞明胶酶相关脂质运载蛋白、肾损伤分子 1（kidney injury molecule 1，KIM-1）等在心脏手术中预测急性肾损伤灵敏度较高[17,18]，因此在接下来的研究中可考虑检测以上指标，以得到更准确的效果。

综上，CPB 心脏手术后低蛋白血症患者中，10% 及 20% HSA 对患者肾功能无明显不同影响，但 20% HSA 用量较少，可减轻患者经济负担，减少 HSA 制品的浪费，且在增加术后尿量方面有一定优势。

【参考文献】

[1] 姜思源，张锦. 手术应激后低蛋白血症启因及治疗的最新进展[J]. 中华危重病急救医学，2017，29(3)：284－288. DOI：10.3760/cma.j.issn.2095-4352.2017.03.020.
Jiang SY, Zhang J. Recent advances in the pathogenesis and treatment of hypoproteinemia after surgical stress[J]. Chin Crit Care Med, 2017, 29(3): 284－288. DOI: 10.3760/cma.j.issn.2095-4352.2017.03.020.

[2] Fleck A, Raines G, Hawker F, *et al*. Increased vascular permeability: a major cause of hypoalbuminaemia in disease and injury[J]. Lancet, 1985, 1(8432): 781－784.

[3] 李雪，杨静，聂晓璐，等. 老年心脏手术患者术后急性肾损伤的发生率与预测因素研究[J]. 中华老年多器官疾病杂志，2016，15(5)：367－372. DOI：10.11915/j.issn.1671-5403.2016.05.087.
Li X, Yang J, Nie XL, *et al*. Incidence and predictive factors of acute kidney injury in elderly patients after cardiac surgery[J]. Chin J Mult Organ Dis Elderly, 2016, 15(5): 367－372. DOI: 10.11915/j.issn.1671-5403.2016.05.087.

[4] Lee EH, Kim WJ, Kim JY, *et al*. Effect of exogenous albumin on the incidence of postoperative acute kidney injury in patients undergoing off-pump coronary artery bypass surgery with a preoperative albumin level of less than 4.0 g/dl[J]. Anesthesiology, 2016, 124(5): 1001－1011. DOI: 10.1097/ALN.0000000000001051.

[5] Cruz KI, Bakaeen FG, Wang XL, *et al*. Hypoalbuminemia and long-term survival after coronary artery bypass: a propensity score analysis[J]. Ann Thorac Surg, 2011, 91(3): 671－675. DOI: 10.1016/j.athoracsur.2010.09.004.

[6] 夏萌，王文美，郝佳音，等. 心脏瓣膜患者术后临床结局与血浆白蛋白关系的研究[J]. 心肺血管病杂志，2011，30(4)：316－318，350. DOI：10.3969/j.issn.1007-5062.2011.04.015.
Xia M, Wang WM, Hao JY, *et al*. Relationship between serum albumin level and clinical outcome in patient with heart valve operation[J]. J Cardiovasc Pulm Dis, 2011, 30(4): 316－318, 350. DOI: 10.3969/j.issn.1007-5062.2011.04.015.

[7] Karas PL, Goh SL, Dhital K. Is low serum albumin associated with postoperative complications in patients undergoing cardiac surgery? [J]. Interact Cardiovasc Thorac Surg, 2015, 21(6): 777-786. DOI: 10.1093/icvts/ivv247.

[8] 赫嵘, 蒋力, 张珂, 等. 肝癌合并肝硬化患者术后人血白蛋白应用方案的临床研究[J]. 中华肝胆外科杂志, 2014, 20(1): 11-14. DOI: 10.3760/cma.j.issn.1007-8118.2014.01.004.
He R, Jiang L, Zhang K, *et al*. The role of human serum albumin therapy in the post-operative management of patients with hepatoeellular carcinoma associated with cirrhosis [J]. Chin J Hepatobiliary Surg, 2014, 20(1): 11-14. DOI: 10.3760/cma.j.issn.1007-8118.2014.01.004.

[9] 邓侠兴, 沈柏用, 吕文杰, 等. 百特5%及25%人血白蛋白在肝脏、胰腺手术围手术期应用的疗效和安全性[J]. 中华肝胆外科杂志, 2009, 15(3): 192-195. DOI: 10.3760/cma.j.issn.1007-8118.2009.03.012.
Deng XX, Shen BY, Lyu WJ, *et al*. The clinical research of 5% and 25% human serum albumin (ALB) in postoperative recovery of patients after liver resection or pancreatic operation[J]. Chin J Hepatobiliary Surg, 2009, 15(3): 192-195. DOI: 10.3760/cma.j.issn.1007-8118.2009.03.012.

[10] 时扣荣, 陈伟成, 李洁, 等. 5%与25%的人血白蛋白对老年脑出血危重患者血肿和神经功能缺损的影响[J]. 中国老年学杂志, 2017, 37: 4256-4258. DOI: 103969/j.issn.1005-9202.2017.17.041.
Shi KR, Chen WC, Li J, *et al*. Effects of 5% and 25% concentration of human serum albumin on hematoma and neurological deficit in elderly critical patients with cerebral hemorrhage[J]. Chin Med Gerontol, 2017, 37: 4256-4258. DOI: 103969/j.issn.1005-9202.2017.17.041.

[11] Yu K, Liu Y, Hei F, *et al*. Effect of different albumin concentrations in extracorporeal circuit prime on perioperative fluid status in young children[J]. ASAIO J, 2008, 54(5): 463-466. DOI: 10.1097/MAT.0b013e3181878631.

[12] 韩国锋, 张金元, 陆石, 等. 心脏术后发生急性肾功能衰竭的危险因素[J]. 中华急诊医学杂志, 2006, 15(7): 625-628. DOI: 10.3760/j.issn:1671-0282.2006.07.012.
Han GF, Zhang JY, Lu S, *et al*. Risk factor associated with acute renal failure (ARF) in patients after cardiac surgery[J]. Chin J Emerg Med, 2006, 15(7): 625-628. DOI: 10.3760/j.issn: 1671-0282.2006.07.012.

[13] 杨敏, 宁红, 叶琳燕, 等. 人血白蛋白的临床合理应用[J]. 中国药业, 2014, 23(6): 88-90.
Yang M, Ning H, Ye LY, *et al*. Clinical rational application of human serum albumin[J]. Chin Pharm, 2014, 23(6): 88-90.

[14] Wang Y, Bellomo R. Cardiac surgery-associated acute kidney injury: risk factors, pathophysiology and treatment[J]. Nat Rev Nephrol, 2017, 13(11): 697-711. DOI: 10.1038/nrneph.2017.119.

[15] Karim HM, Yunus M, Saikia MK, *et al*. Incidence and progression of cardiac surgery-associated acute kidney injury and its relationship with bypass and cross clamp time [J]. Ann Card Anaesth, 2017, 20(1): 22-27. DOI: 10.4103/0971-9784.197823.

[16] Song Y, Kim DW, Kwak YL, *et al*. Urine output during cardiopulmonary bypass predicts acute kidney injury after cardiac surgery: a single-center retrospective analysis[J]. Medicine (Baltimore), 2016, 95(22): e3757. DOI: 10.1097/MD.0000000000003757.

[17] de Geus HR, Ronco C, Haase M, *et al*. The cardiac surgery-associated neutrophil gelatinase-associated lipocalin (CSA-NGAL) score: a potential tool to monitor acute tubular damage[J]. J Thorac Cardiovasc Surg, 2016, 151(6): 1476-1481. DOI: 10.1016/j.jtcvs.2016.01.037.

[18] Vandenberghe W, De Loor J, Hoste EA. Diagnosis of cardiac surgery-associated acute kidney injury from functional to damage biomarkers[J]. Curr Opin Anaesthesiol, 2017, 30(1): 66-75. DOI: 10.1097/ACO.0000000000000419.

(编辑: 张美)