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Significance of Pcv-aCO_2 Combined with Collapse Index of Inferior Vena Cava Monitoring in Guiding Fluid Resuscitation in High-Risk Surgery Patients

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Abstract

Objective: To investigate the value of central venous-to-arterial carbon dioxide difference (Pcv-aCO_2) combined with collapse index of inferior vena cava (cIVC) monitoring in guiding fluid resuscitation in high-risk surgery patients. Methods: A total of 86 cases of high-risk postoperative patients with shock admitted to the ICU of Shandong Provincial Hospital from June 2018 to December 2019 were selected as the study objects, and were randomly divided into the Observation group and the Control group, with 43 cases in each group. The general indwelling central venous catheter was performed on the patients after their enrollment. Fluid resuscitation was initiated according to the early goal-directed therapy (EGDT) protocol for patients with shock. Fluid resuscitation in the control group was guided with the goal of Pcv-aCO_2. Fluid resuscitation in the observation group was guided with the goal of Pcv-aCO_2 combined with cIVC. The differences in HR, MAP, CVP, urine volume, ScvO_2, Pcv-aCO_2, Lac, LCR before and 6 h after fluid resuscitation, as well as EGDT compliance rate, postoperative complication rate and 28-day mortality were compared between the 2 groups. Results: After 6 h of fluid resuscitation, HR, MAP, CVP, ScvO_2, Pcv-aCO_2 and Lac in the 2 groups were significantly improved compared with those before resuscitation ($P < 0.05$). The CVP in the control group was significantly higher than that in the observation group ($P < 0.05$). The Lac level in the observation group was lower than that in the control group, and the LCR was significantly higher than that in the control group ($P < 0.05$). There were no significant differences in HR, MAP, ScvO_2, Pcv-aCO_2, urine volume, and EGDT compliance rate ($P > 0.05$). The incidence of postoperative complications in the observation group was significantly lower than that in the control group ($P < 0.05$), and the 28-day mortality rate was also lower than that in the control group, but there was no significant difference between the groups ($P > 0.05$). Conclusion: Pcv-aCO_2 combined with cIVC monitoring has a better application value in guiding fluid resuscitation in patients with high-risk surgery, which can effectively improve tissue perfusion, correct cell hypoxia, and avoid the aggravation of disease caused by excessive fluid infusion. Both comply with the requirement, with the highest lactate clearance rate and the lowest incidence of postoperative complications.

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Keywords

The High-Risk Surgery, Fluid Resuscitation, Central Venous-to-Arterial Carbon Dioxide Difference ($Pcv\text{-}aCO_2$), Collapse Index of Inferior Vena Cava (cIVC)

$Pcv\text{-}aCO_2$联合下腔静脉塌陷指数监测对高危手术患者液体复苏的指导意义

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摘　要

目的：探讨中心静脉－动脉二氧化碳分压差($Pcv\text{-}aCO_2$)联合下腔静脉塌陷指数(cIVC)监测对高危手术患者液体复苏的指导意义。方法：选取2018年06月~2019年12月山东省立医院ICU收治的86例高危外科术后合并休克的患者为研究对象，随机编入观察组与对照组。入组后常规留置中心静脉导管，按照早期目标导向治疗(EGDT)方案进行液体复苏，对照组以$Pcv\text{-}aCO_2$为目标指导液体复苏，观察组以$Pcv\text{-}aCO_2$联合cIVC为目标指导液体复苏。对比两组患者液体复苏前及复苏6 h后病人的HR、MAP、CVP、$ScvO_2$、$Pcv\text{-}aCO_2$、Lac及Lac清除率、尿量等监测指标变化，以及EGDT达标率、术后并发症发生率、28天死亡率差异。结果：液体复苏6 h后，两组患者HR、MAP、CVP、$ScvO_2$、$Pcv\text{-}aCO_2$、Lac较复苏前显著改善($P < 0.05$)，其中对照组CVP明显高于观察组($P < 0.05$)，而观察组的Lac水平较对照组更低，Lac清除率也明显高于对照组($P < 0.05$)，HR、MAP、$ScvO_2$、$Pcv\text{-}aCO_2$、尿量及EGDT达标率比较无显著差异($P > 0.05$)。观察组术后并发症的发生率较对照组显著下降($P < 0.05$)，28天死亡率也小于对照组，但两组间比较无显著差异($P > 0.05$)。结论：$Pcv\text{-}aCO_2$联合cIVC监测在指导高危手术患者液体复苏中有更好的应用价值，能更有效地改善患者组织灌注，纠正细胞缺氧，同时避免过度补液加重病情；两者均达标，乳酸清除率最高，术后并发症发生率最低。

关键词

高危手术，液体复苏，中心静脉－动脉二氧化碳分压差($Pcv\text{-}aCO_2$)，下腔静脉塌陷指数(cIVC)

1. 引言

高危手术患者是重症医学科的常见病人，出现术后并发症风险及死亡率均较高，组织缺氧是导致术

后预后不良的主要因素，早期准确识别容量不足，纠正器官低灌注和组织缺氧是治疗的关键[1] [2]。脓毒症休克早期目标导向治疗(EGDT)方案[3]，目前广泛应用于各种危重症及高危手术病人的液体复苏，可有效降低术后并发症和死亡率[2]。中心静脉－动脉二氧化碳分压($Pcv\text{-}aCO_2$)作为反映组织低灌注的指标，可以补充 EGDT 的不足，优化高危手术患者的容量管理[4]。床旁超声具有快速、准确、无创等技术特点，下腔静脉直径(IVCD)及塌陷指数(cIVC)可以评估患者的血容量状态及容量反应性[5] [6]，广泛应用于指导液体治疗。本研究探讨 $Pcv\text{-}aCO_2$ 与 cIVC 联合监测能否更好地指导高危手术患者的液体复苏治疗。

2. 资料与方法

2.1. 一般资料

选取 2018 年 09 月~2019 年 12 月收入山东省立医院 ICU 的 86 例有自主呼吸的高危外科术后合并休克的患者为研究对象，其中男 48 例，女 38 例，年龄 21~90 岁，平均(57.35 ± 14.23)岁，手术部位：口腔 28 例，腹部 47 例，其他 11 例。将上述患者随机编入观察组和对照组，每组 43 例。

2.1.1. 入选标准

1) 年龄 ≥ 18 周岁；2) 高危手术患者，包括年龄 ≥ 60 岁，存在心肺功能不全及其他基础疾病，手术创伤大、时间长(≥6 h)，术中失血量大，感染手术，急诊手术等[7] [12]；3) 合并休克，包括收缩压 < 90 mmHg 或收缩压降低 > 40 mmHg，心率 > 100 次/分，低灌注(乳酸 ≥ 2 mmol/L)等[8] [9]。

2.1.2. 排除标准

1) 中心静脉导管禁忌；2) 严重心肺功能障碍、肝肾功能不全；3) 腹内高压影响超声监测；4) 不可逆终末状态；5) 患者及家属拒绝有创操作。

本研究符合医学伦理学要求，并经我院伦理委员会审批同意，获得患者或家属的知情同意。

2.2. 研究方法

2.2.1. 治疗方法

患者入组后常规留置颈内或锁骨下中心静脉导管(ARROW 双腔，型号 CV-17702-E)，按照 EGDT 方案进行液体复苏，具体方案为[10]：每隔 30 min 给予 500 ml 晶体液，维持 CVP 8~12 mmHg；若收缩压 < 80 mmHg 或 MAP < 65 mmHg，应用血管活性药物；如果 $ScvO_2$ < 70%，输注红细胞使 HCT ≥ 30%，若 $ScvO_2$ 仍不达标，加用多巴酚丁胺，连续治疗 6 小时。在此基础上，对照组以 $Pcv\text{-}aCO_2$ 为目标进行液体复苏，每小时评估 1 次 $Pcv\text{-}aCO_2$ 值，若 $Pcv\text{-}aCO_2 \geq 6$ mmHg，继续给予液体治疗，以 $Pcv\text{-}aCO_2$ 2~5 mmHg 为复苏终点。观察组在对照组的基础上，每隔 1 小时测量下腔静脉直径(IVCD)，计算塌陷指数(cIVC)，若 cIVC ≥ 40%，则重新进行液体滴定式治疗，若 cIVC < 40%，则可能存在容量反应性不良，采取谨慎的补液措施，避免过度液体治疗。

2.2.2. IVCD 及 cIVC 的测量方法

由高年资主治医师使用美国西门子 ACUSON P300 型超声，采用剑突下长轴纵切面探及下腔静脉，选择下腔静脉距右心房入口 2~3 cm 处，测量 IVC 最大直径和 IVC 最小直径[8] [9]。cIVC= (IVCDmax − IVCDmin)/IVCDmax × 100%，重复测量 3 次，取其平均数[6]。

2.2.3. 数据采集

记录患者年龄、性别、手术部位、主要诊断等一般情况，采集液体复苏前和复苏 6 h 后的心率(HR)、平均动脉压(MAP)、中心静脉压(CVP)、尿量等指标。分别采集液体复苏前和复苏 6 h 的动脉血和中心静

脉血，使用 GEM Premier 4000 型血气生化分析仪行血气检查，记录动脉血乳酸(Lac)、中心静脉血氧饱和度($ScvO_2$)、动脉血二氧化碳分压($PaCO_2$)、中心静脉血二氧化碳分压($PcvCO_2$)，计算 Pcv-aCO_2。计算乳酸清除率(LCR)，LCR = (复苏前 Lac − 复苏 6 h Lac)/复苏前 Lac × 100% [11]。记录复苏 6 h EGDT 达标率、28 d 死亡率，以及术后 7 天内是否出现吻合口破裂、刀口不愈合、感染、器官功能障碍等并发症情况。EGDT 达标需满足液体复苏 6 h 内：CVP 8~12 mmHg，MAP 65~90 mmHg，尿量 ≥0.5 ml/(kg·h)，$ScvO_2$ ≥ 70%，任意一项不符合均视为 EGDT 未达标。

2.2.4. 观察指标

对比两组患者复苏前和复苏 6 h 后的 HR、MAP、CVP、$ScvO_2$、Pcv-aCO_2、Lac、尿量等检测指标的变化及 6 h EGDT 达标率、Lac 清除率、7 天内术后并发症发生率、28 天死亡率差异。

2.3. 统计学方法

采用统计软件 SPSS 22.0 进行数据分析。计量资料行正态分布检验，用均数 ± 标准差($\bar{x} \pm s$)表示，组间比较采用独立样本 t 检验，组内比较采用配对 t 检验；计数资料用计数和百分比表示，采用 χ^2 检验。以 $P < 0.05$ 为差异有统计学意义。

3. 结果

3.1. 一般资料

观察组(43 例，男 25/女 18)，平均年龄(59.98 ± 12.63)岁，手术部位：口腔 13 例(30.2%)、腹部 24 例(55.8%)、其他 6 例(14.0%)；对照组(43 例，男 23/女 20)，平均年龄(54.72 ± 15.38)岁，手术部位：口腔 15 例(34.9%)、腹部 23 例(53.5%)、其他 5 例(11.6%)。两组资料比较差异无统计学意义($P > 0.05$)。

3.2. 监测指标

液体复苏前两组 HR、MAP、CVP、$ScvO_2$、Pcv-aCO_2、Lac 比较差异无统计学意义($P > 0.05$)；液体复苏 6 h 后两组 HR、MAP、CVP、$ScvO_2$、Pcv-aCO_2、Lac 较复苏前明显改善($P < 0.05$)；对照组 CVP 明显高于观察组($P < 0.05$)，观察组 Lac 低于对照组，Lac 清除率高于对照组($P < 0.05$)，两组患者 HR、MAP、$ScvO_2$、Pcv-aCO_2、尿量、EGDT 达标率比较差异无统计学意义($P > 0.05$)。见表 1，表 2。

Table 1. Monitoring indexes before and after resuscitation in both groups ($\bar{x} \pm s$, $n = 43$)
表 1. 两组患者复苏前后监测指标比较($\bar{x} \pm s$，$n = 43$)

	治疗前				治疗后			
	观察组	对照组	*t* 值	*P* 值	观察组	对照组	*t* 值	P 值
HR (次/分)	107.07 ± 10.49	109.56 ± 11.60	−1.043	0.300	86.58 ± 8.14※	84.51 ± 8.24※	1.172	0.245
MAP (mmHg)	60.72 ± 5.64	60.42 ± 7.04	0.220	0.827	79.98 ± 9.28※	82.16 ± 8.30※	−1.151	0.253
CVP (mmHg)	5.02 ± 1.63	4.95 ± 1.65	0.198	0.844	10.67 ± 2.50※	13.67 ± 3.05※	−4.990	0.000
$ScvO_2$(%)	62.74 ± 7.78	61.52 ± 7.89	0.720	0.474	74.01 ± 6.42※	76.63 ± 7.24※	−1.780	0.079
Pcv-aCO_2 (mmHg)	9.19 ± 2.22	9.40 ± 2.42	−0.418	0.677	5.05 ± 1.70※	4.77 ± 1.77※	0.745	0.458
Lac (mmol/L)	4.37 ± 1.20	4.49 ± 1.46	−0.436	0.664	2.64 ± 0.87※	3.19 ± 1.28※	−2.312	0.023
LCR (%)					39.27 ± 9.70	29.96 ± 9.64	4.467	0.000
尿量(ml/kg·h)					0.77 ± 0.26	0.74 ± 0.29	0.511	0.610

注：※表示与液体复苏前比较，$P < 0.05$。

Table 2. Prognosis in both groups [*n*(%), *n* = 43]
表 2. 两组患者预后比较[*n*(%), *n* = 43]

	观察组	对照组	χ^2 值	*P* 值
EGDT 达标率	32 (74.4)	33 (76.7)	0.063	0.802
并发症发生率	7 (16.3)	15 (34.9)	3.909	0.048
28 天死亡率	4 (9.3)	7 (16.3)	0.938	0.333

3.3. 预后

观察组出现并发症为 7 例，其中切口感染(2 例)，肺部感染(2 例)，急性肾损伤(2 例)，心功能障碍(1 例)；对照组出现并发症 15 例，其中切口感染(3 例)，吻合口瘘(2 例)，肺部感染(3 例)，急性肾损伤(3 例)，心功能障碍(4 例)；两组患者并发症发生率为观察组(16.3%)比对照组(34.9%)，差异有统计学意义($P < 0.05$)。观察组 28 天内死亡 4 例，死亡原因为：失血性休克(1 例)，肺栓塞(1 例)，脓毒症休克多器官功能衰竭(2 例)；对照组死亡 7 例，死亡原因为：失血性休克(1 例)，急性心肌梗死(1 例)，充血性心力衰竭(2 例)，脓毒症休克多器官功能衰竭(3 例)；观察组 28 天死亡率(9.3%)小于对照组(16.3%)，但差异无统计学差异($P > 0.05$)。

4. 讨论

高危手术仅占外科手术的 12.5%，却占外科手术死亡的 80%，术后并发症的发生率也较高[2]。组织缺氧是术后预后不良的主要原因，术后并发症、器官衰竭和死亡的发生率与组织缺氧的严重程度和持续时间有关[1] [2]。因术中失血失液、手术应激、生理储备不足、需氧量增加等原因，导致有效循环血容量不足，细胞氧代谢障碍，若不及时纠正，会导致器官功能障碍甚至衰竭，而一旦出现器官衰竭，后续治疗往往效果很差，所以早期识别组织低灌注、及时液体复苏至关重要[12] [13]。但是若液体反应性不良，过度补液会增加心脏负荷及组织水肿，加重组织缺氧[14] [15]。因此，高危手术病人应在尽量完善的容量监测条件下，采取谨慎的液体治疗措施。

传统的血容量指标如 HR、MAP、CVP 等可靠性差，在其改变前就已经存在组织低灌注及 Lac 升高，不能准确识别容量状态[2] [17]，而有创血流动力学监测难以大范围普及。乳酸(Lac)是细胞无氧代谢的产物，常作为反映组织低灌注和缺氧的指标[19]，但肝功能不全、应激、高代谢或某些药物等原因也会引起乳酸升高，且乳酸升高有滞后性[17] [18]。乳酸清除率(LCR)反映乳酸水平的动态变化，较乳酸更能反映组织灌注的变化，早期乳酸清除增加有助于评估疗效及改善预后[18]。研究证实[19]，感染性休克液体复苏 6 h 内 LCR > 10%可提高生存率，也有学者发现[20]，6 h 内 LCR > 30%的患者预后优于 LCR 仅为 10%患者。

2001 年，Rivers 等[10]首次提出早期目标导向治疗(EGDT)指导脓毒症休克液体复苏，可明显降低死亡率，此后的国际指南[3]均推荐 EGDT 方案指导感染性休克的早期液体复苏。目前超过 70 项研究报告了 EGDT 后患者的预后明显改善[21] [22]，被广泛应用到各种危重症的早期液体复苏治疗之中[2] [3] [4] [12] [23]，但最新研究发现 EGDT 方案能否降低病死率存在争议，其指导液体复苏还存在某些不足，亟待不断完善发展[24] [25] [26]。二氧化碳是组织代谢终产物，组织灌注不足时 CO_2 清除力下降，Pcv-aCO_2 可反映微循环中是否有足够的血流带走组织产生的 CO_2。Pcv-aCO_2 正常范围是 2~5 mmHg，当 Pcv-a$CO_2 \geq$ 6 mmHg 时，提示组织灌注不足[27] [28] [29]。Robin 等[30]对 115 名高危手术患者的前瞻性研究发现，术后高 Pcv-aCO_2 与患者并发症增加显著相关，导致住院时间延长、器官功能衰竭甚至死亡。Helmy 等[31]研究发现，Pcv-aCO_2 可更敏感的反映组织灌注及心输出量(CO)变化，复苏 6 h 后高 Pcv-aCO_2 > 7.8 mmHg 与高死亡率有关。Guo 等[32]研究发现，感染性休克 $ScvO_2 \geq 70\%$的患者中，Pcv-aCO_2 与心脏指数(CI)呈

负相关。因此，Pcv-aCO_2是反映组织灌注和 CO 的良好指标，可有效评估高危手术患者的血容量变化及预后，可作为 EGDT 的补充，用来指导早期液体复苏。

床旁超声可快速、准确、动态的评估患者血容量及液体反应性，优化液体治疗，避免液体过负荷[33] [34] [35]。下腔静脉(IVC)是顺应性良好的容量血管，直接与右心房相连，其内径受呼吸运动影响[36]。下腔静脉塌陷指数(cIVC)表示自主呼吸时下腔静脉管径随呼吸变异的幅度，临床上最常用来评估患者血流动力学状态，在危重症患者的诊断、治疗及疗效评估中发挥了重要作用[35] [36]。国内外多项研究[8] [9] [37] [38]证实，自主呼吸状态下 cIVC 评估液体反应性的阈值为 40%，cIVC 升高考虑存在容量不足，应积极补液治疗，当 cIVC 降低时补液需谨慎。本研究利用 Pcv-aCO_2联合 cIVC 监测指导高危手术患者早期液体复苏治疗，期望达到更好的复苏效果及滴定式治疗的目的，减少术后并发症及死亡率。

本研究结果显示，液体复苏 6 h 后，两组患者 HR、MAP、CVP、$ScvO_2$、Pcv-aCO_2、Lac 较复苏前显著改善($P < 0.05$)，其中对照组 CVP 明显高于观察组($P < 0.05$)，提示对照组患者平均血容量多于观察组，但是两组患者 HR、MAP、$ScvO_2$、Pcv-aCO_2、尿量及 EGDT 达标率比较无显著差异($P > 0.05$)，而观察组 Lac 及 Lac 清除率优于对照组($P < 0.05$)，说明对照组可能存在液体过负荷现象加重病情，观察组液体复苏方案能更有效的提高患者乳酸清除率，改善组织器官灌注。本研究还发现，观察组术后并发症发生率较对照组显著下降($P < 0.05$)，考虑是因为对照组液体过负荷导致组织水肿从而加重缺氧，证明 Pcv-aCO_2与 cIVC 联合监测能有效的减少术后并发症的发生，在一定程度上改善预后；而观察组 28 天死亡率也小于对照组，但组间比较差异没有统计学意义，可能与本研究纳入样本量较少有关，尚不能证实 Pcv-aCO_2与 cIVC 联合监测能降低高危手术死亡率。而从并发症类型及死亡因素分析，对照组心血管事件的发生概率要高于观察组，提示了过度的补液治疗增加了心脏意外的风险，对高危手术患者的预后是不利的。

5. 结论

综上所述，Pcv-aCO_2与 cIVC 联合监测在指导高危手术患者液体复苏中有更好的应用价值，能更有效地改善患者组织灌注，纠正细胞缺氧，同时避免过度补液使组织缺氧加重，使病情恶化。此外，Pcv-aCO_2与 cIVC 联合监测还可以减少高危手术术后并发症的发生，对于能否降低术后死亡率还有待进一步研究。

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参考文献

[1] Ackland, G.L., Iqbal, S., Paredes, L.G., *et al*. (2015) Individualised Oxygen Delivery Targeted Haemodynamic Therapy in High-Risk Surgical Patients: A Multicentre, Randomised, Double-Blind, Controlled, Mechanistic Trial. *The Lancet Respiratory Medicine*, **3**, 33-41. https://doi.org/10.1016/S2213-2600(14)70205-X

[2] Parker, T., Brealey, D. and Dyson, A. (2019) Optimising Organ Perfusion in the High-Risk Surgical and Critical Care Patient: A Narrative Review. *British Journal of Anaesthesia*, **123**, 170-176. https://doi.org/10.1016/j.bja.2019.03.027

[3] Dellinger, R.P., Levy, M.M., Rhodes, A., *et al*. (2013) Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock: 2012. *Critical Care Medicine*, **41**, 580-637. https://doi.org/10.1097/CCM.0b013e31827e83af

[4] Futier, E., Robin, E., Jabaudon, M., *et al*. (2010) Central Venous O_2 Saturation and Venous-to-Arterial CO_2 Difference as Complementary Tools for Goal-Directed Therapy during High-Risk Surgery. *Critical Care*, **14**, R193. https://doi.org/10.1186/cc9310

[5] Lee, C.W. and Kory, P.D. (2016) Development of a Fluid Resuscitation Protocol Using Inferior Vena Cava and Lung Ultrasound. *Journal of Critical Care*, **31**, 96-100. https://doi.org/10.1016/j.jcrc.2015.09.016

[6] Preau, S., Bortolotti, P., Colling, D., *et al*. (2017) Diagnostic Accuracy of the Inferior Vena Cava Collapsibility to Predict Fluid Responsiveness in Spontaneously Breathing Patients with Sepsis and Acute Circulatory Failure. *Critical*

Care Medicine, **45**, e290-e297. https://doi.org/10.1097/CCM.0000000000002090

[7] Malbouisson, L.M.S., Silva, J.M., Carmona, M.J.C., *et al*. (2017) A Pragmatic Multi-Center Trial of Goal-Directed Fluid Management Based on Pulse Pressure Variation Monitoring during High-Risk Surgery. *BMC Anesthesiology*, **17**, 70. https://doi.org/10.1186/s12871-017-0356-9

[8] Airapetian, N., Maizel, J., Alyamani, O., *et al*. (2015) Does Inferior Vena Cava Respiratory Variability Predict Fluid Responsiveness in Spontaneously Breathing Patients? *Critical Care*, **19**, 400. https://doi.org/10.1186/s13054-015-1100-9

[9] Muller, L., Bobbia, X., Toumi, M., *et al*. (2012) Respiratory Variations of Inferior Vena Cava Diameter to Predict Fluid Responsiveness in Spontaneously Breathing Patients with Acute Circulatory Failure: Need for a Cautious Use. *Critical Care*, **16**, R188. https://doi.org/10.1186/cc11672

[10] Rivers, E., Nguyen, B., Havstad, S., *et al*. (2001) Early Goal-Directed Therapy in the Treatment of Severe Sepsis and Septic Shock. *The New England Journal of Medicine*, **345**, 1368-1377. https://doi.org/10.1056/NEJMoa010307

[11] Londoño, J., Niño, C., Díaz, J., *et al*. (2018) Association of Clinical Hypoperfusion Variables with Lactate Clearance and Hospital Mortality. *Shock*, **50**, 286-292. https://doi.org/10.1097/SHK.0000000000001066

[12] Lees, N. and Hamilton, M. (2009) Clinical Review: Goal-Directed Therapy in High Risk Surgical Patients. *Critical Care*, 13, 231. https://doi.org/10.1186/cc8039

[13] Daviaud, F., Grimaldi, D., Dechartres, A., *et al*. (2015) Timing and Causes of Death in Septic Shock. *Annals of Intensive Care*, **5**, 16. https://doi.org/10.1186/s13613-015-0058-8

[14] Bednarczyk, J.M., Fridfinnson, J.A., Kumar, A., *et al*. (2017) Incorporating Dynamic Assessment of Fluid Responsiveness into Goal-Directed Therapy: A Systematic Review and Meta-Analysis. *Critical Care Medicine*, **45**, 1538-1545. https://doi.org/10.1097/CCM.0000000000002554

[15] Wu, J., Wang, Z., Wang, T., *et al*. (2018) Evaluation of the Fluid Responsiveness in Patients with Septic Shock by Ultrasound plus the Passive Leg Raising Test. *Journal of Surgical Research*, **224**, 207-214. https://doi.org/10.1016/j.jss.2017.12.014

[16] Cecconi, M., De Backer, D., Antonelli, M., *et al*. (2014) Consensus on Circulatory Shock and Hemodynamic Monitoring. Task Force of the European Society of Intensive Care Medicine. *Intensive Care Medicine*, **40**, 1795-1815. https://doi.org/10.1007/s00134-014-3525-z

[17] 肖岳, 王洪桥, 赵同礼, 牛柳卉, 朱玉. 感染性休克患者预后与早期血乳酸清除率的关系[J]. 内科急危重症杂志, 2016, 22(2): 127-128+143.

[18] Zollo, A.M., Ayoob, A.L., Prittie, J.E., *et al*. (2019) Utility of Admission Lactate Concentration, Lactate Variables, and Shock Index in Outcome Assessment in Dogs Diagnosed with Shock. *Journal of Veterinary Emergency and Critical Care*, **29**, 505-513. https://doi.org/10.1111/vec.12868

[19] Bolvardi, E., Malmir, J., Reihani, H., *et al*. (2016) The Role of Lactate Clearance as a Predictor of Organ Dysfunction and Mortality in Patients with Severe Sepsis. *Materia Socio Medica*, **28**, 57-60. https://doi.org/10.5455/msm.2016.28.57-60

[20] Zhou, X., Liu, D., Su, L., *et al*. (2017) Use of Stepwise Lactate Kinetics-Oriented Hemodynamic Therapy Could Improve the Clinical Outcomes of Patients with Sepsis-Associated Hyperlactatemia. *Critical Care*, **21**, 33. https://doi.org/10.1186/s13054-017-1617-1

[21] Nguyen, H.B., Jaehne, A.K., Jayaprakash, N., *et al*. (2016) Early Goal-Directed Therapy in Severe Sepsis and Septic Shock: Insights and Comparisons to Process, Promise, and Arise. *Critical Care*, **20**, 160. https://doi.org/10.1186/s13054-016-1288-3

[22] Lu, Y., Zhang, H., Teng, F., *et al*. (2018) Early Goal-Directed Therapy in Severe Sepsis and Septic Shock: A Meta-Analysis and Trial Sequential Analysis of Randomized Controlled Trials. *Journal of Intensive Care Medicine*, **33**, 296-309. https://doi.org/10.1177/0885066616671710

[23] Chen, Z.H., Jin, C.D., Chen, S., *et al*. (2017) The Application of Early Goal Directed Therapy in Patients during Burn Shock Stage. *International Journal of Burns and Trauma*, **7**, 27-33.

[24] Protti, A., Masson, S., Latini, R., *et al*. (2018) Persistence of Central Venous Oxygen Desaturation During Early Sepsis Is Associated with Higher Mortality: A Retrospective Analysis of the ALBIOS Trial. *Chest*, **154**, 1291-1300. https://doi.org/10.1016/j.chest.2018.04.043

[25] Wittayachamnankul, B., Chentanakij, B. and Sruamsiri, K. (2016) The Role of Central Venous Oxygen Saturation, Blood Lactate, and Central Venous-to-Arterial Carbon Dioxide Partial Pressure Difference as a Goal and Prognosis of Sepsis Treatment. *Journal of Critical Care*, **36**, 223-229. https://doi.org/10.1016/j.jcrc.2016.08.002

[26] Araujo, D.T., Felice, V.B. and Meregalli, A.F. (2019) Value of Central Venous to Arterial CO Difference after Early Goal-directed Therapy in Septic Shock Patients. *Indian Journal of Critical Care Medicine*, **23**, 449-453.

https://doi.org/10.5005/jp-journals-10071-23262

[27] Muller, G., Mercier, E., Vignon, P., *et al*. (2017) Prognostic Significance of Central Venous-to-Arterial Carbon Dioxide Difference during the First 24 Hours of Septic Shock in Patients with and without Impaired Cardiac Function. *British Journal of Anaesthesia*, **119**, 239-248. https://doi.org/10.1093/bja/aex131

[28] Gao, W., Zhang, Y., Ni, H., *et al*. (2018) Prognostic Value of Difference between Peripheral Venous and Arterial Partial Pressure of Carbon Dioxide in Patients with Septic Shock: A Pilot Study. *Journal of Southern Medical University*, **38**, 1312-1317.

[29] 霍丽坤, 李培军. 中心静脉-动脉血二氧化碳分压差的临床应用进展[J]. 中华危重病急救医学, 2016, 28(11): 1048-1052.

[30] Robin, E., Futier, E., Pires, O., *et al*. (2015) Central Venous-to-Arterial Carbon Dioxide Difference as a Prognostic Tool in High-Risk Surgical Patients. *Critical Care*, **19**, 227. https://doi.org/10.1186/s13054-015-0917-6

[31] Helmy, T.A. and El-Reweny, E.M. (2017) Prognostic Value of Venous to Arterial Carbon Dioxide Difference during Early Resuscitation in Critically Ill Patients with Septic Shock. *Indian Journal of Critical Care Medicine*, **21**, 589-593. https://doi.org/10.4103/ijccm.IJCCM_64_16

[32] Guo, Z., Yin, M., Kong, J., *et al*. (2019) Relationship Analysis of Central Venous-to-Arterial Carbon Dioxide Difference and Cardiac Index for Septic Shock. *Scientific Reports*, **9**, 8822. https://doi.org/10.1038/s41598-019-45252-6

[33] Zhu, W., Wan, L., Wan, X., *et al*. (2016) Measurement of Brachial Artery Velocity Variation and Inferior Vena Cava Variability to Estimate Fluid Responsiveness. *Chinese Critical Care Medicine*, **28**, 713-717.

[34] Thanakitcharu, P. and Charoenwut, M. (2013) Inferior Vena Cava Diameter and Collapsibility Index: A Practical Non-Invasive Evaluation of Intravascular Fluid Volume in Critically-Ill Patients. *Journal of the Medical Association of Thailand*, **96**, S14-S22.

[35] 王小亭, 刘大为, 于凯江, 管向东, 马晓春, 严静, 康焰, 艾宇航, 胡振杰. 中国重症超声专家共识[J]. 中华内科杂志, 2016, 55(11): 900-912.

[36] Çelebi Yamanoğlu, N.G., Yamanoğlu, A., Parlak, İ., *et al*. (2015) The Role of Inferior Vena Cava Diameter in Volume Status Monitoring, the Best Sonographic Measurement Method? *American Journal of Emergency Medicine*, **33**, 433-438. https://doi.org/10.1016/j.ajem.2014.12.014

[37] 何志权, 伍伟光. 下腔静脉塌陷指数(cIVC)与循环衰竭患者的容量反应相关性[J]. 生物医学工程学进展, 2016, 37(2): 75-77.

[38] 麦叶, 黄钰财, 贺志飚, 李瑞. 下腔静脉塌陷指数预测循环衰竭患者的容量反应性[J]. 医学综述, 2015(13): 2438-2440.