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Original Article

Target-directed management strategy reduces complications in high-risk subjects undergoing cardiac and major vascular surgery

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Abstract: *Background and Objective*: Early goal-directed therapy (EGDT) has been proved to decrease mortality in severe sepsis and septic shock, which have begun to impact the care of all critically ill subjects. The aim of this study was to evaluate the effect of postoperative target-directed management strategy on the incidence of complications and outcomes in subjects undergoing cardiac and major vascular surgery. *Materials and Methods:* We performed a retrospective analysis on the adult subjects undergoing cardiac major vascular surgery. The 12-month baseline (1 July 2011 to 30 June 2012) is considered to be the pre-EGDT period, where subjects received usual care after operation. While 12 months from 1 October 2012 to 30 September 2013 is considered the EGDT period, where subjects were treated according to target-directed management strategy. Targets of EGDT protocol were CVP 10-12 mmHg, CI ≥ 2.4 litre·min^{-1}·m^{-2}, Lactate <4 mmol litre^{-1} and SvO_2 >65 mmHg. *Results:* There were 101 subjects in the usual care group and 131 in the protocol group. Subjects in the protocol group received more fluid (P<0.001) and shorter duration of mechanical ventilation (P=0.017). Statistically significant difference was noted with regard to CI (P=0.006), SvO_2 (P=0.014), DO_2I (P=0.03) and SOFA score (P=0.005) between the protocol and the usual care group. *Conclusion:* Our study showed that target-directed management strategy significantly reduced the occurrence of postoperative complications in subjects with high risk for adverse outcome after cardiac and major vascular surgery.

Keywords: Target-directed management strategy, cardiac and major vascular surgery, complications

Introduction

With the improvement of surgical strategies and the supportive technologies, it has now become possible to conduct cardiac and vascular surgery in high-risk subjects [1]. However, subjects coexisting with previous cardiac surgery, extra cardiac arteriopathy, chronic lung disease, hypertension and diabetes have high incidence of organ dysfunction or multiple organ failure with prolonged postoperative care and high mortality after surgery. Estimated mortality after cardiac surgery in the subjects with EuroSCORE ≥ 6 is higher than 10% [2].

Early goal-directed therapy (EGDT) has been proved to decrease mortality and morbidity worldwide in severe sepsis and septic shock [3, 4]. EGDT is used to describe the use of cardiac output or similar parameters to guide intravenous fluid and inotropic therapy [5]. The ultimate goal of EGDT protocol is to enhance oxygen delivery and utilization ability. Hypovolemia and low cardiac output are mainly responsible for global tissue hypoxia after cardiac and vascular surgery. Blood lactate level and mixed venous oxygen saturation (SvO_2) have been shown to be surrogates for the balance between systemic oxygen delivery and consumption during treatment of critically ill subjects [6]. It has been demonstrated that the use of early goal-directed haemodynamic therapy helps to improve the outcomes in non-cardiac surgery in several randomized controlled trials [7-9]. Goal-directed therapy in cardiac or major vascular surgery has not been investigated to the same extent.

We have found that majority of high-risk subjects presents an increased blood lactate level

and decreased SvO_2 early after cardiac and major vascular surgery. Since July 2012, we applied target-directed management strategy for quality improvement in postoperative management. The aim of this study was to evaluate the effect of postoperative target-directed management strategy on the incidence of complications and outcomes in subjects undergoing cardiac and major vascular surgery.

Subjects and methods

Ethics statement

The EGDT protocol for quality improvement in postoperative management was approved in July 2012 by the Ethics Committee of Sir Run Run Shaw Hospital affiliated to College of Medicine of Zhejiang University, China.

Study subjects

Adult subjects (age ≥ 18 years) undergoing cardiac or vascular or mixed surgery with cardiopulmonary bypass (CPB) and deemed to be at high risk of postoperative mortality (EuroSCORE ≥ 6 points) were enrolled. Subjects with contradiction to pulmonary artery cannulation were excluded. Subjects requiring any of the following therapies before surgery were excluded: mechanical ventilation, intra-aortic balloon pump (IABP). Subjects who were re-operated early after surgery were excluded.

Establishment of EGDT protocol

The 12-month baseline (July 1, 2011 to June 30, 2012) is considered to be the pre-EGDT period, while duration of 12 months from October 1, 2012 to September 30, 2013 is considered to be the EGDT period. July 1, 2012 to September 30, 2012 is considered to be the run-in period, since staff education and monitor of compliance were conducted by ICU directors in the 3 months.

Subjects during the pre-EGDT period were administered crystal solution intravenously at the rate of 60-80 mL per hour till initiating oral feeding after extubation. Adjustment of inotropic agents (dopamine, adrenaline, noradrenaline and milrinone) and extra intravenous fluid administration was decided by experience according to hemodynamic parameters, aim to maintaining MAP between 65 and 100 mmHg. Hematocrit value was maintained at or above 30% with packed cell transfusions, if necessary.

Subjects during the EGDT period received standard care as our institutional protocol. Central venous catheter (CVC) and pulmonary artery catheter (PAC) were inserted before surgery in operation room. Heart rate (HR), mean arterial pressure (MAP), blood oxygen saturation (SpO_2), central venous pressure (CVP), pulmonary arterial pressure (PAP) and core temperature were monitored continuously. Pain score, urine output, blood loss and net fluid balance were monitored at hourly basis. SvO_2, electrolyte, arterial blood gas (ABG) and lactate were measured at 0 (T0), 4 (T1), 8 (T2), 12 (T3) and 24 (T4) hours after patients are transferred to ICU. Cardiac output was measured in triplicate and the mean value was used for calculations at T0, T1 and T3. Cardiac index (CI) and systemic vascular resistance index (SVRI) were calculated simultaneously. Oxygen delivery index (DO_2I) was calculated according to standard formula, multiplying the thermodilution cardiac output with arterial oxygen content and indexed to body surface area. The biochemical abnormalities were corrected as necessary.

During the EGDT period, subjects with lactate ≥ 4 mmol/L or SvO_2 <65% after transferred to ICU were treated followed by EGDT protocol. Fluid management was performed as a priority of postoperative treatment. If CVP was less than 10 mmHg or pulmonary arterial wedge pressure (PAWP) less than 12 mmHg, 250 mL aliquots of crystal solution were given within 15-30 minutes till the target CVP and PAWP levels were achieved or increased CVP >3 mmHg. During the EGDT period, background fluid administration at the rate of 60-80 mL per hour as given during pre-EGDT period was cancelled. When CVP reached the target levels, inotropic agents and vasodilators were adjusted to maintain the hemodynamic parameters within the target values. The choice of inotropic agents was determined by HR, MAP, CI, SV and SVRI. Adrenaline was given at a rate of 0.03 μg/kg/min if CI was lower than 2.2 $L/min/m^2$ and MAP lower than 65 mmHg. Noradrenaline was administrated to increase SVRI. Milrinone or vasodilators was selected when SVRI was higher than 2000 dyn $s/cm^5/m^2$.

Table 1. Baseline characteristics of both groups

Characteristics	Pre-EGDT group (*n*=101)	EGDT group (*n*=131)	*P* value
Age (yr)[a]	59.3 ± 17.1	59.7 ± 11.1	0.830
Male gender (n, %)	65 (51.1%)	76 (49.7%)	0.199
Weight (kg)[a]	60.1 ± 10.4	61.4 ± 9.7	0.328
Height (cm)[a]	165 ± 9.5	163 ± 10.3	0.131
EuroSCORE II (points)[a]	10.5 ± 6.9	11.0 ± 9.7	0.661
Type of surgery			
Valve replacement (n, %)	45 (44.6%)	48 (36.6%)	
Valve replacement and MAZE (n, %)	6 (5.9%)	17 (13.0%)	
Coronary artery bypass grafting (n, %)	10 (9.9%)	10 (7.6%)	
Valve replacement and CABG (n, %)	8 (7.9%)	10 (7.6%)	
Vascular surgery (n, %)	9 (8.9%)	13 (9.9%)	
Cardiac and vascular surgery (n, %)	16 (15.8%)	19 (14.5%)	
Others (n, %)	7 (6.9%)	14 (10.7%)	
Cardiopulmonary bypass (min)[a]	115.3 ± 47.5	120 ± 50.2	0.470
Aortic cross clamp (min)[a]	82.7 ± 39.9	86.2 ± 41.9	0.520

[a]Data were shown as mean ± SD.

During the EGDT period, fluid management was optimized as a priority aiming to maintaining PAWP at 12-15 mmHg or CVP at 10-12 mmHg. Inotropic agents were administrated to achieve the CI at 2.4-4.0 L/min/m^2. The targets of EGDT protocol were S_VO_2 >65% and lactate <4 mmol/L within 12 hours after cardiac or vascular or mixed surgery with CPB, in addition to the goals in the standard care such as HR at 60-100 beat/min, MAP at 65-100 mmHg, ABG analysis values (pH 7.35-45, PaO_2 more than 80 mmHg and $PaCO_2$ 35-45 mmHg), SpO_2 more than 95%, hematocrit value more than 30% and urine output more than 1 mL/kg/h.

Removing ventilator was considered when the subject achieved all of the following: 1. Awake and powerful cough; 2. Normal skeletal muscle power; 3. Hemodynamically stable with or without low dosage of inotropic agents (adrenaline or noradrenaline <0.04 μg/kg/min); 4. HR at 60-100 beats/min and no ventricular arrhythmia; 5. ABG values within the normal range; 6. Core temperature more than 36°C; 7. Drainage less than 50 mL/h; 8. Urine output more than 1 mL/kg/h.

Spontaneous breathing test for 30 minutes was performed before extubation. Subjects were reassessed every two hours in the event of failure of removing ventilator. All of the high-risk subjects were scheduled to be transferred from the ICU on the morning of the day after extubation, unless the use of inotropic or vasodilator drugs, IABP and CRRT were necessary or severe arrhythmia was not resolved.

Outcome measure

The primary outcome measure was the incidence of postoperative complications. The secondary outcome measure included length of stay in the ICU, duration of hospital stay and in-hospital mortality. The duration of ventilation (hours), duration of use of inotropic agents (days), the amount of fluid balance (mL) and sequential organ failure assessment (SOFA) score at T4 were noted. The data were collected from hospital electronic medical records and nursing record sheets. The retrospective charts were done by two ICU doctors and one nurse.

Statistics analysis

The results were analyzed using SPSS software (IBM SPSS Statistics, version 21). Data were presented as mean ± standard deviation. Data were checked for normal distribution by means of the Kolmogorov-Smirnov's test. Student's t test was used for comparisons between groups. Two-way ANOVA test was used to analyze the data within the same group at various time intervals. Discrete data were analyzed by two-side Chi-square test or Fisher's exact test. For all tests, a *P* value <0.05 was considered as significant difference.

Results

Population characteristics

There were 290 subjects undergoing cardiac and major vascular surgery with EuroSCORE ≥ 6 between July 1, 2011 and September 30, 2013. After excluding 26 subjects that were not

Table 2. Fluid management and use of diuretics between pre-EGDT group and EGDT group within 12 hours after surgery

Variable	Pre-EGDT group (*n*=101) T0-T3	EGDT group (*n*=131) T0-T3	*P* value
Fluid requirement	1652.2 ± 912.7	2641.1 ± 1140.3	<0.001
Colloid (mL)	120.8 ± 95.2	641.2 ± 556.5	<0.001
Crystalloid (mL)	1245.4 ± 895.2	1835.1 ± 1039.7	<0.001
Blood transfusion (mL)	152.4 ± 201.3	164.1 ± 180.6	0.642
Blood loss (mL)	481.3 ± 354.2	509.2 ± 368.5	0.562
Positive Fluid balance >200 mL (n, %)	31 (30.7%)	83 (63.4%)	<0.001
Diuretics			
Furosemide (mg)	1.3 ± 4.1	1.4 ± 4.7	0.865
Torasemide (mg)	0.3 ± 1.6	0.4 ± 2.0	0.681

Data were shown as mean ± SD.

congruent, 264 subjects were analyzed, of which 101 cases were in the pre-EGDT group and 131 were in the EGDT group, and 32 subjects were in the run-in period for education of medical staff. The pre-EGDT group and EGDT group were well matched for demographic characteristics, EuroSCORE, duration of CPB and aortic cross clamping, fluid requirement in operation and type of surgery (**Table 1**).

Parametric changes in the groups

Fluid balance within 12 hours after surgery was compared between the two groups, as shown in **Table 2**. Fluid requirement including colloid (641.2 ± 556.5 *vs*. 120.8 ± 95.2 mL, *P*<0.001) and crystalloid (1835.1 ± 1039.7 *vs*. 1245.4 ± 895.2 mL, *P*<0.001) in the EGDT group was more than that in the pre-EGDT group. More subjects developed positive fluid balance >200 mL within 12 hours after surgery in the EGDT group (83/131 *vs*. 31/101, *P*<0.001) with statistically significant difference.

CI, SVRI, DO_2I, SvO_2 and lactate levels at various time intervals were compared between the two groups within 24 hours after surgery (**Table 3**). Statistically significant difference was noted with CI at T3 (3.2 ± 0.5 *vs*. 3.0 ± 0.6 L/min/m^2, *P*=0.006), SVRI at T1 (2510.8 ± 660.5 *vs*. 2687.6 ± 612.1 dyns/cm^5/m^2, *P*=0.038) and T3 (2323.7 ± 554.4 *vs*. 2498.2 ± 476.5 dyns/cm^5/m^2, *P*=0.012) between the EGDT and pre-EGDT groups, respectively. DO_2I at T3 was much higher in the EGDT group than that in the pre-EGDT group (397.4 ± 81.2 *vs*. 375.2 ± 70.6 mL/min/m^2, *P*=0.03), although it was lower than physiological value. SvO_2 was significantly higher in the EGDT group at T3 than in the pre-EGDT group (61.2 ± 7.5% *vs*. 58.8 ± 7.1%, *P*=0.014). Lactate levels increased in both groups postoperatively, and it was significantly lower at T2 and T3 in the EGDT group than in the pre-EGDT group (T2: 5.3 ± 2.5 vs. 6.1 ± 2.8, *P*=0.023; T3: 3.2 ± 1.4 *vs*. 3.8 ± 1.3, *P*=0.001), respectively.

Table 4 provides the summary of the subjects meeting the goals (CVP 10-12 mmHg, CI ≥ 2.4 L/min/m^2, Lactate <4 mmol/L and SvO_2 >65 mmHg) at 12 hours after surgery among the pre-EGDT group, run-in period and the EGDT group. In run-in period, 78.1% of subjects meet the CVP goal, which was significantly higher than the pre-EGDT group. More subjects meet all of the four goals in the EGDT group than those in the pre-EGDT group (90% *vs*. 54.5%, *P*<0.001; 89.3% *vs*. 70.3%, *P*<0.001; 64.9% *vs*. 45.5%, *P*<0.001; 51.1% *vs*. 34.7%, *P*<0.001), respectively.

Complications and outcomes analysis

Complications and outcomes were presented in **Table 5**. The duration of mechanical ventilation (9.1 ± 5.4 *vs*. 13.2 ± 5.6 h, *P*=0.017) was statistically significantly less in the EGDT group. 40.5% of the subjects in the EGDT group and 54.5% in the pre-EGDT group experienced respiratory insufficiency with PaO_2/FiO_2 ratio <200 mmHg in ICU stay. Subjects in the EGDT group had acute kidney injury were less than those in the pre-EGDT group (24.4% vs. 37.6%, *P*=0.032). SOFA score at 24 hours after surgery in the EGDT group was lower than that in the pre-EGDT group (6.0 ± 3.4 *vs*. 7.5 ± 4.6, *P*=0.005). There was no difference in ventricular arrhythmia, gastrointestinal bleed and other parameters.

Discussion

The high-risk subjects undergoing cardiac and vascular surgery are at higher risks of morbidity and mortality. It has been proved that inade-

Table 3. Parametric changes at various time points within 24 hours after surgery in the two groups

Parameter	T0	T1	T2	T3	T4
CI (L/min/m^2)					
Pre-EGDT group	2.7 ± 0.6	2.6 ± 0.9	-	3.0 ± 0.6	-
EGDT group	2.6 ± 0.7	2.7 ± 0.4	-	3.2 ± 0.5	-
P value	0.253	0.258	-	0.006*	-
SVRI (dyn s/cm^5/m^2)					
Pre-EGDT group	2706.3 ± 676.8	2687.6 ± 612.1	-	2498.2 ± 476.5	-
EGDT group	2695.1 ± 701.5	2510.8 ± 660.5	-	2323.7 ± 554.4	-
P value	0.903	0.038*	-	0.012*	-
DO_2I (mL/min/m^2)					
Pre-EGDT group	364.9 ± 86.2	357.6 ± 82.4	-	375.2 ± 70.6	-
EGDT group	366.1 ± 82.6	364.7 ± 78.1	-	397.4 ± 81.2	-
P value	0.914	0.503	-	0.03*	-
S_VO_2 (%)					
Pre-EGDT group	59.3 ± 8.1	59.1 ± 8.8	58.9 ± 8.2	58.8 ± 7.1	-
EGDT group	59.1 ± 7.9	59.0 ± 7.1	60.1 ± 6.3	61.2 ± 7.5	-
P value	0.850	0.924	0.209	0.014*	-
Lac (mmol/L)					
Pre-EGDT group	3.6 ± 2.2	6.0 ± 2.3	6.1 ± 2.8	3.8 ± 1.3	2.3 ± 1.5
EGDT group	3.5 ± 2.4	5.7 ± 2.1	5.3 ± 2.5	3.2 ± 1.4	2.2 ± 1.7
P value	0.745	0.302	0.023*	0.001*	0.641

Data were shown as mean ± SD. *Significant difference.

Table 4. Comparisons on the number of subjects meeting the goals at T3 among the three groups

Parameters	Pre-EGDT group (*n*=101)	Run-in period* (*n*=32)	EGDT group** (*n*=131)	*P* value*	*P* value**
CVP (n, %)	55 (54.5%)	25 (78.1%)	118 (90.0%)	0.022	<0.001
CI (n, %)	71 (70.3%)	26 (81.3%)	117 (89.3%)	0.261	<0.001
Lactate (n, %)	46 (45.5%)	18 (56.3%)	85 (64.9%)	0.297	0.003
SvO_2 (n, %)	35 (34.7%)	15 (46.9%)	67 (51.1%)	0.218	0.016

P value*: between pre-EGDT group and run-in period. *P* value**: between pre-EGDT group and EGDT group.

quate oxygen delivery and higher oxygen extraction in the first 24 hours after surgery are associated with prolonged intensive care unit (ICU) stay [10]. Impaired oxygen metabolism may cause the consequence of global tissue hypoxia postoperatively.

The chief aim of EGDT in this study was CVP, CI, SvO_2 and blood lactate. HR, MAP, ABG and urine output were managed to maintain the physiological limits in the early postoperative period by active interventions. EuroSCORE is a simple and objective system for assessing heart surgery [11]. Subjects in the high-risk group have the tendency to increase morbidity and mortality rates, and may benefit from early intensive interventions postoperatively. In this study, we applied and evaluated the EGDT protocol in subjects with EuroSCORE ≥ 6 points (high risk).

Based on the theory of Frank-Starling curve [12], preload was optimized as a priority through volume resuscitation guided by HR, MAP, CVP and PAWP. Volume responsiveness was evaluated by fluid loading or passive leg raising test. Fluid requirement in the EGDT group, either colloid or crystalloid, was more than that in the pre-EGDT group. To alleviate hypovolemia through more fluid administration and blood transfusion, companied by the use of inotropic or vasoactive agents, may effectively increase cardiac output and DO_2. Similar findings have been reported in several studies in other major surgery [13]. SVRI at T2 and T3 in the EGDT group was lower than that in the pre-EGDT group, which might be

Table 5. Comparisons of complications and outcomes after operation between pre-EGDT group and EGDT group

Parameters	Pre-EGDT group (*n*=101)	EGDT group (*n*=131)	*P* value
Duration of mechanical ventilation (h)[a]	13.2 ± 15.6	9.1 ± 10.4	0.017*
Duration of inotropic/vasopressor support (h)[a]	14.8 ± 13.3	10.1 ± 9.2	0.002
Atrial fibrillation requiring treatment	30 (29.7%)	31 (23.6%)	0.367
Ventricular arrhythmia	3 (3.0%)	4 (3.1%)	1.000
PaO_2/FiO_2 ratio <200 mmHg	55 (54.5%)	53 (40.5%)	0.046*
Acute kidney injury	38 (37.6%)	32 (24.4%)	0.032*
Acute hepatic injury	24 (23.8%)	29 (22.1%)	0.875
Sternal wound infection	1 (1.0%)	1 (0.4%)	1.000
Gastrointestinal bleed	1 (1.0%)	0 (0%)	0.435
Cerebral vascular accident	1 (0.8%)	1 (0.7%)	1.000
SOFA score at T4 (points)[a]	7.5 ± 4.6	6.0 ± 3.4	0.005*
Length of ICU stay (h)[a]	86.5 ± 66.7	83.0 ± 57.2	0.668
Length of hospital stay (d)[a]	19.1 ± 12.3	18.5 ± 13.1	0.723

[a]Data were shown as mean ± SD. *Significant difference.

another consequence of volume resuscitation and helpful for improving cardiac output.

Decreased SvO_2 with concomitant hyperlactacidemia, as consequences of tissue oxygen debt caused in the inoperative and postoperative period, was common in both groups of subjects. The central venous oxygen saturation ($ScvO_2$) has been reported correlates well with SvO_2 in subjects with myocardial infarction and sepsis [14, 15]. However, a study of 9267 pairs of measurements concluded that the measure of $ScvO_2$ should not replace the measure of SvO_2 with PAC for the management of subjects undergoing cardiac surgery with cardiopulmonary bypass because of the large interindividual variability in the difference between SvO_2 and $ScvO_2$ [16-18]. Considering of potential complication of PAC, it is reasonable to apply PAC in high-risk subjects of cardiac and major vascular surgery. In this study, SvO_2 values below the normal range may be interpreted as a condition of decreased oxygen delivery and increased oxygen-extraction rate. That SvO_2 value at T3 in the EGDT group higher than in the pre-EGDT group might attribute to improving DO_2 benefited from optimal hemodynamic management of EGDT, although nearly half of the subjects in the EGDT group failed to achieve the target (SvO_2 >65%).

The use of lactates has been established as a marker of global tissue hypoxia in circulatory shock by various studies [19, 20]. Blood lactate concentration depends on the balance between production and elimination (by the liver). However, the kinetics of lactates clearance depends mainly on the production rate, because hepatic clearance appears to be preserved even during cardiogenic shock. Hyperlactatemia coupled with low S_VO_2 may attribute to impaired tissue oxygenation rather than inability of the peripheral tissues to use oxygen. In this study, the presence of peak lactate was earlier in the EGDT group, while blood lactate level was lower at T2 and T3 than in the pre-EGDT group. It might be interpreted as a condition of reduction of lactate production benefited from improving DO_2 and paying back the tissue oxygen debt in the early postoperative period.

Subjects in the EGDT had shorter duration of inotropic and/or vasopressor usage. This shows that by active volume resuscitation to optimize the preload in the early recovery period, hemodynamic parameters can be improved quickly and the duration of use of inotropic agents and/or vasopressors can be reduced. Similarly, shorter duration of mechanical ventilation in the EGDT group showed quick recovery benefited from active intensive management in the early postoperative period.

The SOFA score is used to track a subject's status during the stay in ICU. Both the mean and highest SOFA scores have been proved to be predictors of outcomes [21]. In this study, SOFA score at 24 hours after surgery was significantly lower in the EGDT group than in the pre-EGDT group. Morbidity of respiratory dysfunction (PaO_2/FiO_2 ratio <200 mmHg) and acute kidney injury were significantly lower than in the pre-EGDT group. EGDT protocol has significantly reduced the occurrence of postoperative complications. Similar conclusions

have been found in some studies [22]. Preventing or paying back soon after tissue oxygen debt has been shown to reduce postoperative complications. In cardiac surgical subjects, the number of subjects with postoperative complications may be significantly reduced in both intra-(off-pump procedures) and postoperative (on-pump) EGDT groups [23]. However, in previous studies including subjects undergoing vascular surgery, EGDT did not reduce the mortality and occurrence of postoperative complications. A recent review demonstrated that higher the subject risk, higher the benefit of EGDT [24]. From this point of view, enrolling high risk subjects undergoing either cardiac or major vascular surgery might be an explanation of EGDT on benefit on reduction of occurrence of postoperative complications. No benefit of EGDT protocol on length of ICU stay, length of hospital stay and mortality has showed in our study.

In modern medical practice, adoption of EGDT protocol is part of increasing acceptance of "time is tissue" and related early treatment. An important goal of perioperative hemodynamic therapy is to maintain cardiac function and organ perfusion, optimizing the balance between oxygen delivery and consumption. The essences of EGDT might be "early", "sufficient" and "individuation". In an early stage of the disease process of the systemic inflammatory response syndrome, it is possible to prevent or overcome peripheral defects in oxygen delivery.

The meta-analysis by Heyland and colleagues found no overall benefit from maximizing oxygen delivery with the aim of improving outcome [25]. There is no benefit to keep CI and DO_2I at supranormal values. Therefore, we set the goals of CI >2.4 L/min/m^2. In this study, DO_2I at 12 hours after surgery in the EGDT group was around 400 mL/min/m^2.

We measured cardiac output, oxygen delivery and mixed venous oxygen saturation intermittently rather than continuously monitor. Some subjects have been extended the length of ICU stay due to occupation of ordinary floor. The study is a single center trial and could not be prospective and blinded. The number of subjects involved in the study is considerably small. Therefore, no benefit of EGDT protocol on length of ICU stay, length of hospital stay and mortality has showed in our study. Larger cohorts in multicenter trials are required to validate our data.

PAC guided postoperative EGDT, aiming to optimize hemodynamics and oxygen delivery through volume and cardiac output management, may be a useful strategy in subjects with high risk for adverse outcome after cardiac and major vascular surgery. EGDT contributes to reduce the occurrence of postoperative complication, which is worthy of clinical application.

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Disclosure of conflict of interest

None.

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