GOAL DIRECTED THERAPY IN CARDIAC SURGERY

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Definition

- Goal-directed ***Hemodynamic & Fluid*** therapy (GDT)
  - ***Standardized algorithmic approach*** *to achieve predefined hemodynamic end points through the provision of*
    - Fluid
    - Vasopressors
    - Inotropes
  - *Guided by advanced monitoring w/*
    - Invasive arterial
    - Central venous
    - Pulmonary artery catheters (selected high-risk patients)

Definition

- Goal-directed *Hemodynamic* & *Fluid* therapy (GDT)
  - *Quantified goals*
    - Blood pressure
    - Cardiac index
    - Systemic venous oxygen saturation
    - Urine output

    (+)
    - Oxygen consumption
    - Oxygen debt
    - Lactate levels..

    ➔ Targeting normal or supra-normal ***Oxygen Delivery*** to the tissue (**DO_2**)

    ➔ Augment therapeutic tactics!

Definition

- Corner-stone of GDT
  - ***Patients who are responsive to fluid administration*** *be identified*
    - Thorough dynamic tests including
      - *SVV or PPV*
      - *CO or SV responsiveness*

    ➔ Establishing a protocol for appropriate resuscitation interventions

    “Guide to Targeted Resuscitation”

Guidelines

JAMA Surgery | Special Communication

Guidelines for Perioperative Care in Cardiac Surgery
Enhanced Recovery After Surgery Society Recommendations

JAMA Surg. 2019;154(8):755-766.

- Goal-directed fluid therapy (GDT) recommended to reduce postoperative complications
  - *Class I, Level B-R*

Guidelines

Ann Thorac Surg 2024;117:669-89

- Summary Statement
  - Goal-directed fluid & hemodynamic therapy can guide perioperative resuscitation and prevent postoperative organ injury.
    - *Quantity of Evidence: Moderate*

Evidences

- Trials consistently demonstrate reduced organ injury, medical complications rates & hospital length of stay in
  - *Surgery overall*
  - *Specifically in Cardiac Surgery*

- Not universal, inconsistent results
  - *High degrees of clinical heterogeneity*
  - *Varying algorithms, monitoring techniques, and study design*

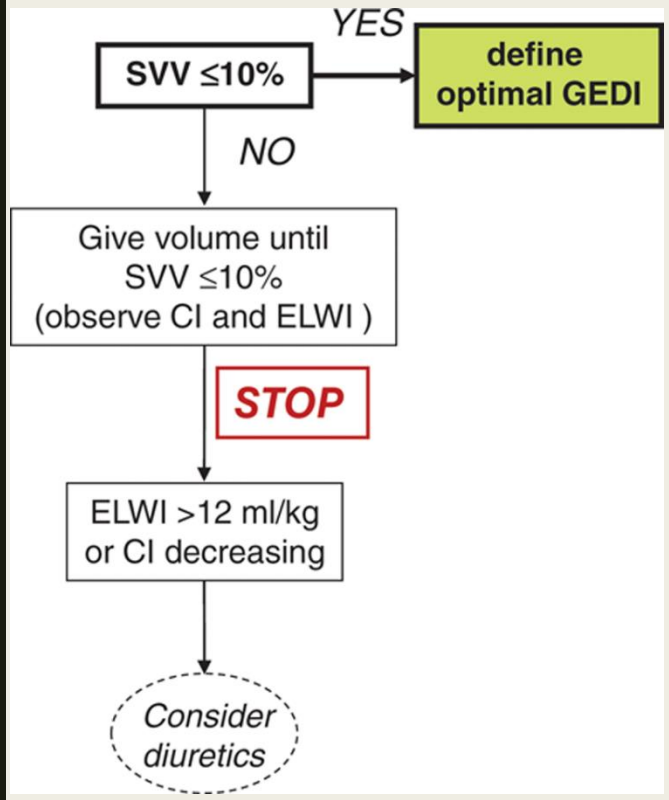
- **What are the ideal monitoring indicators & algorithm?**
  - *Additional study is necessary*

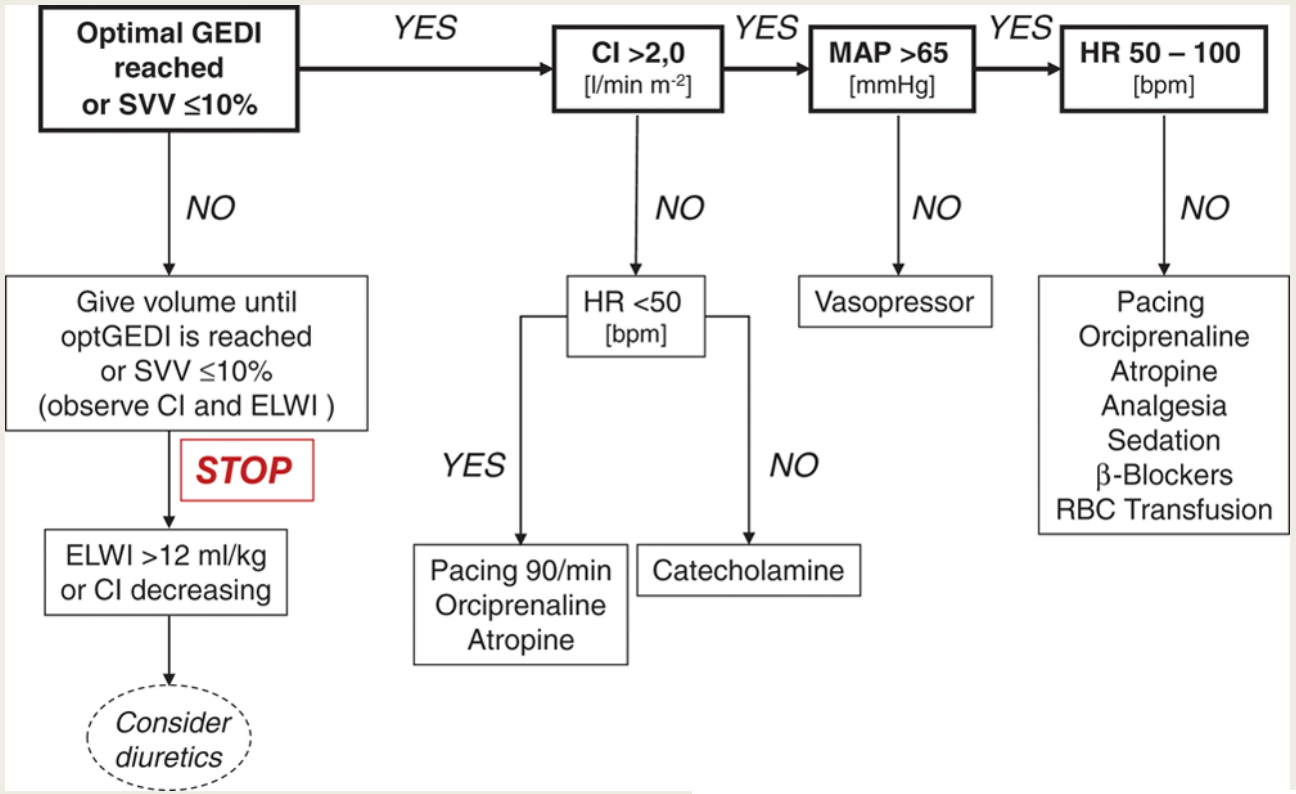
ANESTHESIOLOGY
Trusted Evidence: Discovery to Practice®

Individually Optimized Hemodynamic Therapy Reduces Complications and Length of Stay in the Intensive Care Unit

A Prospective, Randomized Controlled Trial

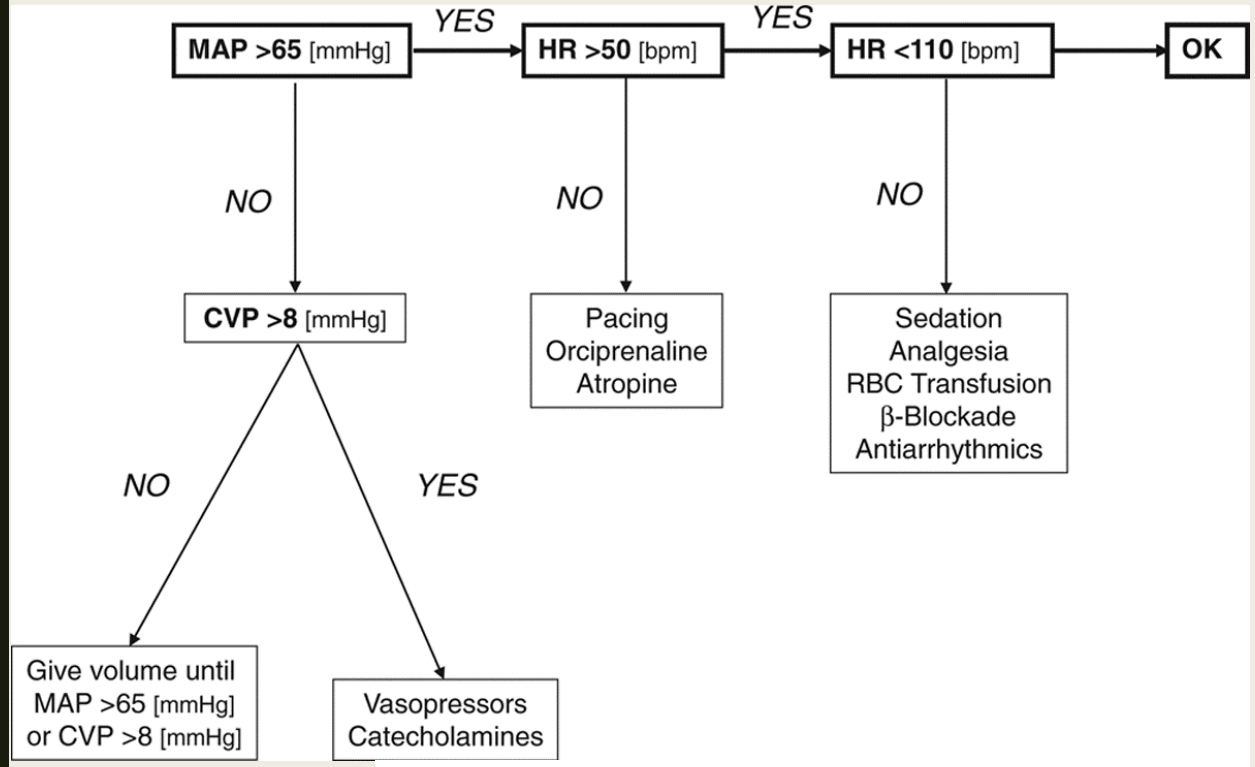
Anesthesiology. 2013 Oct;119(4):824-36.





Hemodynamic algorithm for patients of the study group.

- CABG and/or AVR patients, n=100
- Study group: hemodynamic therapy guided by SVV, optimized GEDI, MAP, CI



Hemodynamic algorithm for patients of the study group.

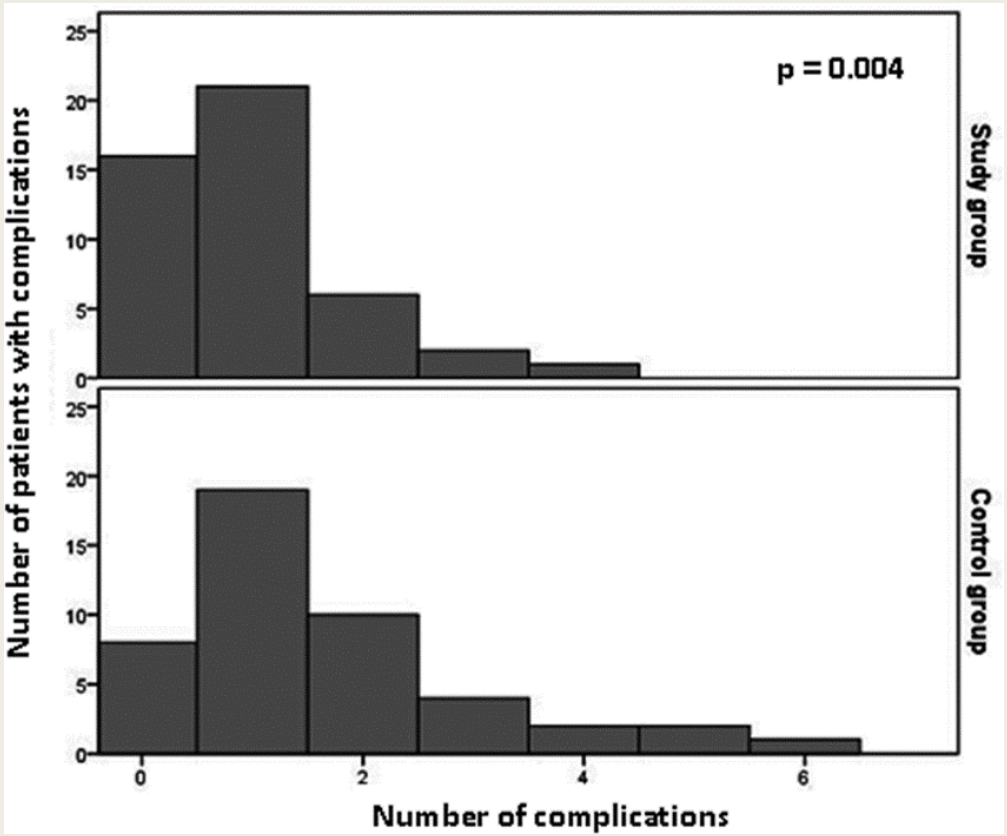
- Control group: hemodynamic therapy guided by MAP & CVP
- Therapy started immediately after induction of anesthesia & continued until ICU discharge criteria

Anesthesiology. 2013 Oct;119(4):824-36.

Variables	Group	After Induction of Anesthesia Baseline	After Induction of Anesthesia Optimized	Before Starting CPB	Directly after CPB	ICU Admission	6 h after EOS	12 h after EOS	24 h after EOS	36 h after EOS
MAP, mmHg	SG	66 ± 11.7 [67]	71 ± 9.6 [68]	76 ± 11.6 [76]	71 ± 7.7 [70]	81 ± 13.0 [78]	77 ± 11.0 [75]	79 ± 10.5 [77]	80 ± 10.8 [79]	80 ± 13.0 [78]
	CG	68 ± 10.4 [68]	70 ± 7.7 [69]	76 ± 10.4 [72]	70 ± 7.0 [68]	81 ± 13.8 [77]	78 ± 12.1 [76]	78 ± 8.5 [76]	83 ± 9.8 [84]	82 ± 11.1 [83]
	P Value	0.176*	0.594†	0.777*	0.388†	0.956†	0.770†	0.622†	0.549*	0.685*
HR, beats/min	SG	60 ± 9.4 [60]	59 ± 8.5 [60]	66 ± 14.0 [65]	88 ± 6.2 [88]	86 ± 10.0 [87]	84 ± 12.0 [87]	83 ± 12.1 [83]	82 ± 10.2 [84]	83 ± 10.0 [84]
	CG	58 ± 11.4 [57]	59 ± 11.2 [57]	66 ± 13.8 [62]	90 ± 5.4 [90]	90 ± 9.5 [88]	89 ± 9.8 [90]	87 ± 9.6 [89]	84 ± 12.8 [81]	85 ± 12.3 [83]
	P Value	0.386*	0.950*	0.940*	0.109†	0.212†	0.024†	0.089*	0.665*	0.895*
CVP, mmHg	SG	9.1 ± 3.3 [8.0]	9.8 ± 3.3 [9.5]	9.2 ± 3.7 [9.0]	8.7 ± 2.8 [8.0]	11.7 ± 3.1 [12.0]	10.9 ± 3.2 [11.0]	10.2 ± 3.5 [10.0]	8.9 ± 4.7 [8.0]	7.9 ± 1.2 [8.0]
	CG	8.5 ± 2.7 [9.0]	9.2 ± 1.7 [9.0]	9.2 ± 2.4 [9.0]	9.4 ± 1.9 [9.0]	10.3 ± 2.3 [10.0]	10.1 ± 2.6 [10.0]	8.9 ± 2.7 [9.0]	9.8 ± 3.1 [9.5]	10.8 ± 2.7 [12.0]
	P Value	0.340*	0.816†	0.947†	0.173†	0.011*	0.195*	0.041†	0.505*	0.015*
SVV, %	SG	9.5 ± 4.7 [8.5]	6.6 ± 2.2 [7.0]	7.3 ± 2.7 [7.0]	8.2 ± 2.4 [8.0]	8.4 ± 2.1 [9.0]	n.d.	n.d.	n.d.	n.d.
	CG	10.6 ± 5.7 [9.0]	9.8 ± 4.7 [9.0]	11.5 ± 6.1 [10.0]	11.3 ± 4.0 [11.0]	14.6 ± 4.9 [14.0]				
	P Value	0.500†	<0.001†	<0.001†	<0.001†	<0.001†				
GEDI, ml/m^2	SG	650 ± 123 [637]	673 ± 112 [650]	667 ± 122 [631]	656 ± 118 [600]	701 ± 137 [682]	711 ± 144 [679]	734 ± 130 [762]	807 ± 137 [789]	920 ± 179 [887]
	CG	661 ± 156 [620]	668 ± 155 [621]	638 ± 137 [616]	658 ± 133 [656]	663 ± 134 [641]	683 ± 133 [672]	725 ± 120 [728]	726 ± 133 [741]	828 ± 178 [740]
	P Value	0.818†	0.545†	0.210†	0.960†	0.186*	0.337*	0.757*	0.060*	0.459†
ELWI, ml/kg	SG	7.3 ± 2.0 [7.0]	7.3 ± 2.1 [7.0]	7.2 ± 2.2 [7.0]	7.3 ± 1.6 [7.0]	7.2 ± 1.7 [7.0]	6.2 ± 1.5 [6.0]	6.1 ± 1.7 [6.0]	6.6 ± 1.7 [6.0]	7.9 ± 1.7 [9.0]
	CG	7.0 ± 2.1 [7.0]	7.0 ± 2.1 [7.0]	6.9 ± 2.0 [7.0]	7.6 ± 2.1 [7.0]	7.2 ± 2.1 [7.0]	6.2 ± 1.7 [6.0]	6.6 ± 1.8 [6.0]	6.7 ± 1.7 [6.0]	7.5 ± 1.2 [7.5]
	P Value	0.586†	0.691†	0.649†	0.791†	0.740†	0.796†	0.293†	0.928†	0.597*
CI, l·min^{-1}·m^{-2}	SG	2.3 ± 0.4 [2.3]	2.5 ± 0.3 [2.5]	2.8 ± 0.5 [2.8]	3.2 ± 0.6 [3.1]	3.1 ± 0.7 [3.0]	3.2 ± 0.6 [3.1]	3.3 ± 0.6 [3.2]	3.6 ± 0.5 [3.6]	3.9 ± 1.0 [3.7]
	CG	2.2 ± 0.5 [2.1]	2.2 ± 0.5 [2.1]	2.5 ± 0.5 [2.4]	3.2 ± 0.6 [3.1]	2.9 ± 0.7 [2.8]	3.0 ± 0.5 [3.1]	3.2 ± 0.6 [3.2]	2.9 ± 0.6 [2.9]	3.1 ± 0.5 [3.1]
	P Value	0.106*	<0.001†	0.003*	0.669*	0.186†	0.363*	0.230*	<0.001*	0.046*
SVI, ml/m	SG	39.3 ± 8.9 [38.9]	43.7 ± 7.8 [42.9]	43.2 ± 8.6 [42.9]	36.1 ± 7.2 [34.4]	35.9 ± 7.2 [34.0]	38.0 ± 7.6 [36.1]	40.6 ± 8.4 [41.4]	43.9 ± 5.0 [43.6]	46.6 ± 8.1 [48.3]
	CG	38.1 ± 10.2 [37.3]	38.9 ± 9.9 [37.8]	38.0 ± 8.3 [37.4]	36.0 ± 7.1 [36.1]	32.5 ± 7.6 [32.2]	34.5 ± 6.3 [34.6]	36.7 ± 6.8 [37.5]	35.0 ± 6.6 [35.6]	37.8 ± 9.6 [35.8]
	P Value	0.559*	0.005†	0.004*	0.941*	0.027*	0.020*	0.041†	<0.001*	0.046*
$ScvO_2$, %	SG	n.d.	82.3 ± 6.1 [82.3]	85.3 ± 4.8 [85.5]	85.8 ± 6.2 [85.9]	71.2 ± 9.0 [71.9]	67.6 ± 7.3 [69.5]	70.0 ± 8.5 [70.5]	66.9 ± 6.3 [67.0]	72.7 ± 10.8 [70.9]
	CG		80.5 ± 5.9 [81.0]	81.6 ± 6.7 [82.4]	83.9 ± 7.1 [84.3]	71.1 ± 8.4 [71.8]	66.2 ± 6.8 [66.1]	69.9 ± 5.4 [70.7]	68.1 ± 8.5 [67.1]	69.3 ± 16.7 [69.1]
	P Value		0.144*	0.004*	0.173*	0.954*	0.317*	0.880†	0.593*	0.668*
Norepinephrine, µg/kg	SG	n.d.	n.d.	2.5 ± 2.6 [1.7]	6.9 ± 6.4 [5.5]	9.0 ± 7.6 [7.7]	12.0 ± 9.8 [9.8]	13.6 ± 11.9 [9.8]	14.0 ± 12.2 [10.2]	14.1 ± 12.4 [10.2]
	CG			5.0 ± 3.2 [4.7]	11.0 ± 8.7 [8.6]	14.9 ± 11.1 [13.2]	19.2 ± 14.2 [15.9]	21.3 ± 16.9 [16.5]	21.6 ± 17.8 [16.5]	21.7 ± 17.8 [16.5]
	P Value			<0.001†	0.004†	0.002†	0.005†	0.012†	0.017†	0.018†
Epinephrine, µg/kg	SG	n.d.	n.d.	0.2 ± 0.6 [0.0]	0.2 ± 0.7 [0.0]	0.3 ± 0.8 [0.0]	0.4 ± 1.0 [0.0]	0.4 ± 1.0 [0.0]	0.4 ± 1.0 [0.0]	0.4 ± 1.0 [0.0]
	CG			0.0 ± 0.1 [0.0]	0.1 ± 0.5 [0.0]	0.4 ± 1.6 [0.0]	0.9 ± 4.9 [0.0]	1.0 ± 5.0 [0.0]	1.0 ± 5.0 [0.0]	1.0 ± 5.0 [0.0]
	P Value			0.086†	0.448†	0.770†	0.469†	0.469†	0.469†	0.469†

Complications	Study Group	Control Group	*P* Value
Total	43	75	0.004
Arrhythmias	18	22	0.41
Hemorrhagic	7	8	1.0
Respiratory	2	3	1.0
Neurological	3	9	0.12
PMD	5	10	0.26
I/R damage	1	7	0.06
Infection	2	6	0.27
ICU readmission	2	2	1.0
Acute kidney injury	3	8	0.2

ICU = intensive care unit; I/R damage = ischemia/reperfusion damage; PMD = postoperative myocardial damage.



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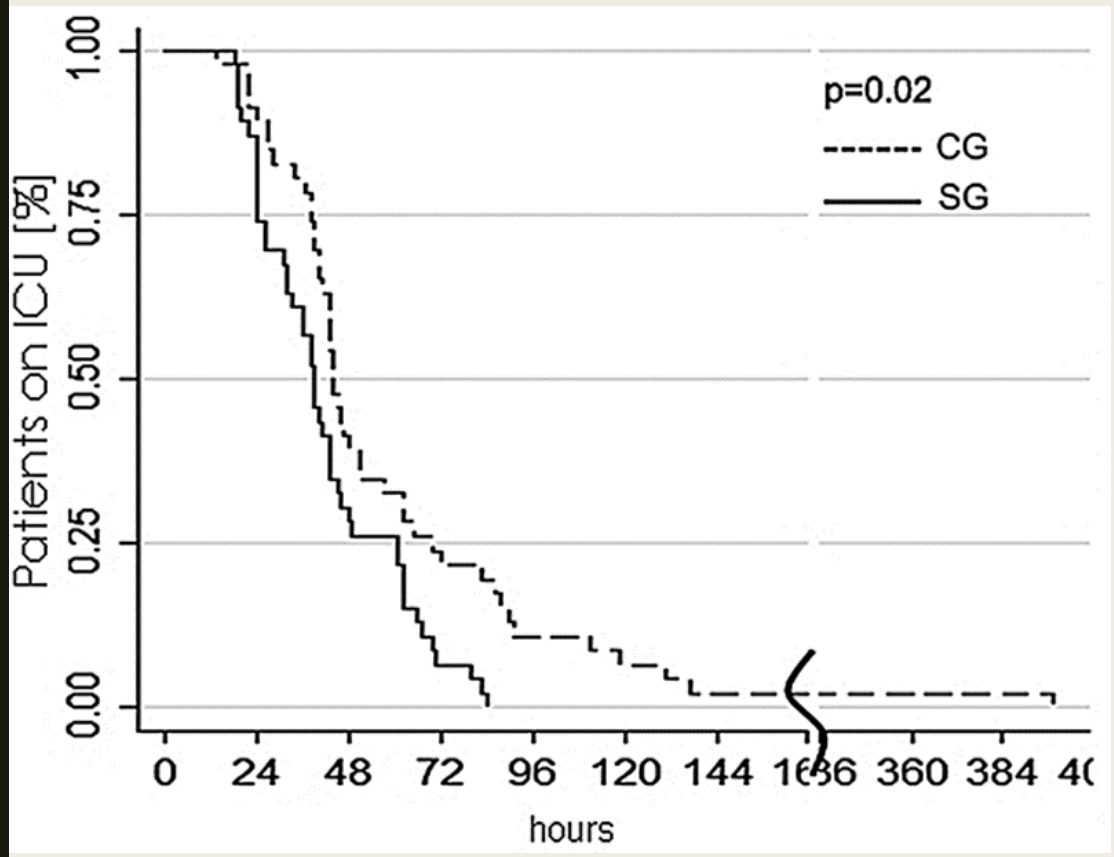

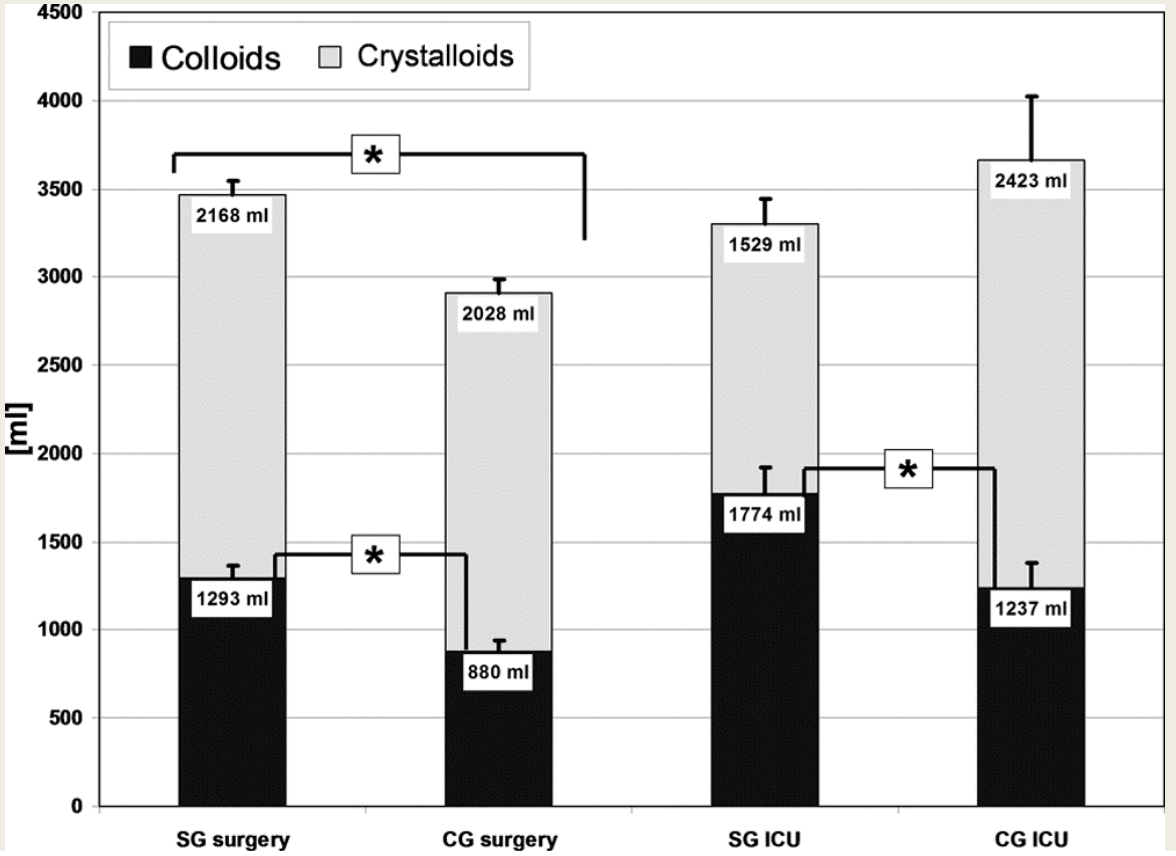

Fig. 4. Cumulative, algorithm-driven crystalloid and colloid infusion during surgery (excluding cardiopulmonary bypass) and intensive care unit (ICU) treatment. Data are presented as mean + standard error of the mean. CG = control group; SG = study group. *$P < 0.001$.

Critical Care Medicine
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Crit Care Med. 2016 Apr;44(4):724-33.

CLINICAL INVESTIGATIONS

Effect of Perioperative Goal-Directed Hemodynamic Resuscitation Therapy on Outcomes Following Cardiac Surgery

A Randomized Clinical Trial and Systematic Review

- High-risk patients undergoing CABG or valve repair (n=126)
- GDT group (n=62)
  - *Target CI >3L/min2*
  - *IV fluids, inotropes, RBC transfusion*
  - *Starting from CBP weaning*
  - *Ending 8hrs after ICU admission*
- Control group (n=64)
  - *Usual care*

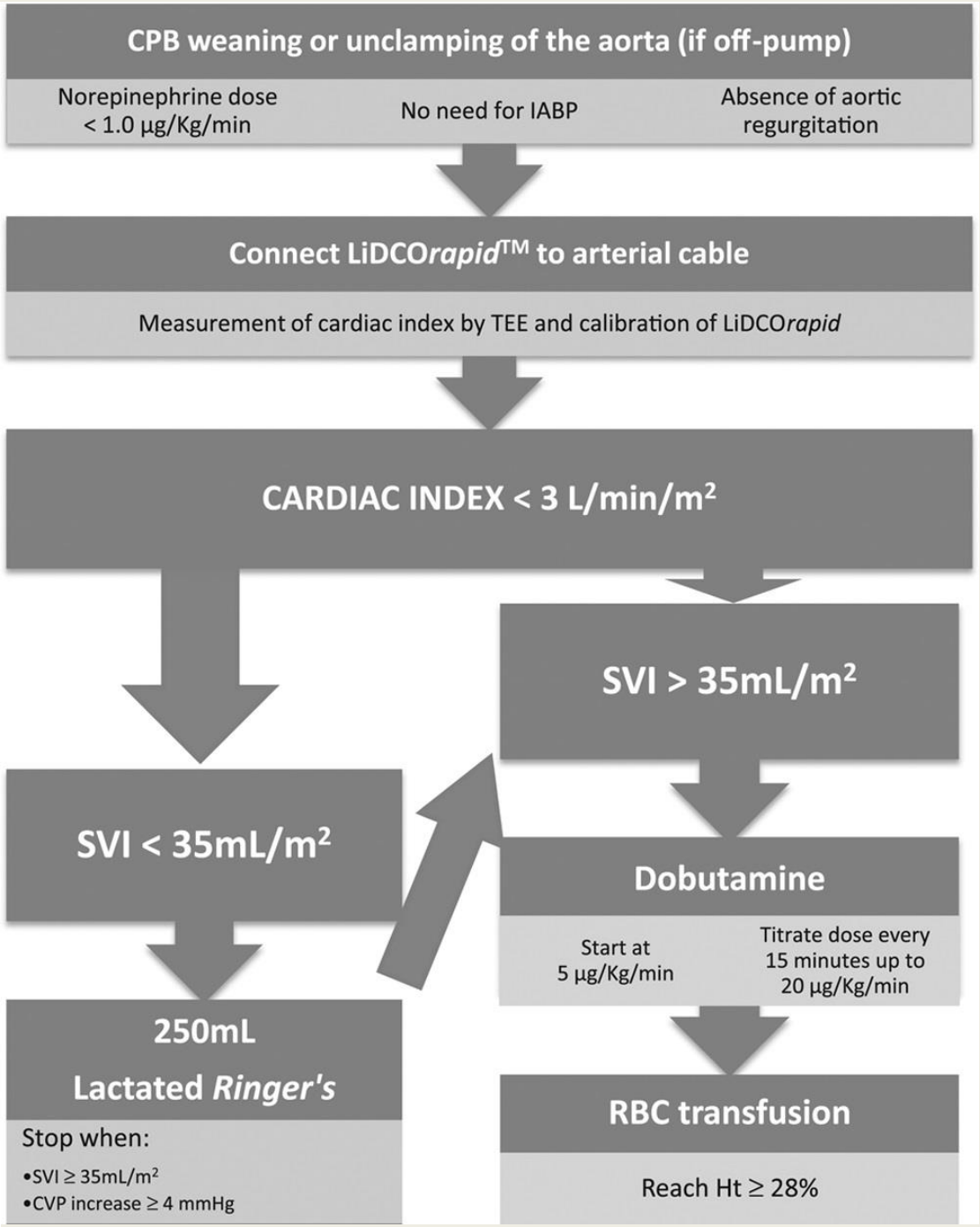


Figure 1. Algorithm of the goal-directed therapy (GDT) group. CPB = cardiopulmonary bypass, CVP = central venous pressure, Ht = hematocrit, IABP = intraaortic balloon pump, SVI = stroke volume index, TEE = transesophageal echocardiogram.

Crit Care Med. 2016 Apr;44(4):724-33.

TABLE 2. Hemodynamic Interventions During the Study

Variable	Goal-Direct Therapy ($n = 62$)	Usual Care ($n = 64$)	p
Fluid *bolus* (mL), median (IQR)	1,000 (625–1,500)	500 (500–1,000)	< 0.001
Total fluid input (mL), median (IQR)	1,056 (257–1,568)	894 (229–1,595)	0.85
No. of patients given dobutamine, *n* (%)	61 (98.4)	61 (95.3)	0.62
Cummulative dosage of dobutamine (μg/kg)	4 (3–5)	4 (3–6)	0.22
RBC transfusion (U), *n* (%)	0 (0)	1 (1.6)	0.32

IQR = interquartile range.

- Primary outcome

: Composite endpoint of 30-day mortality & major postoperative complications

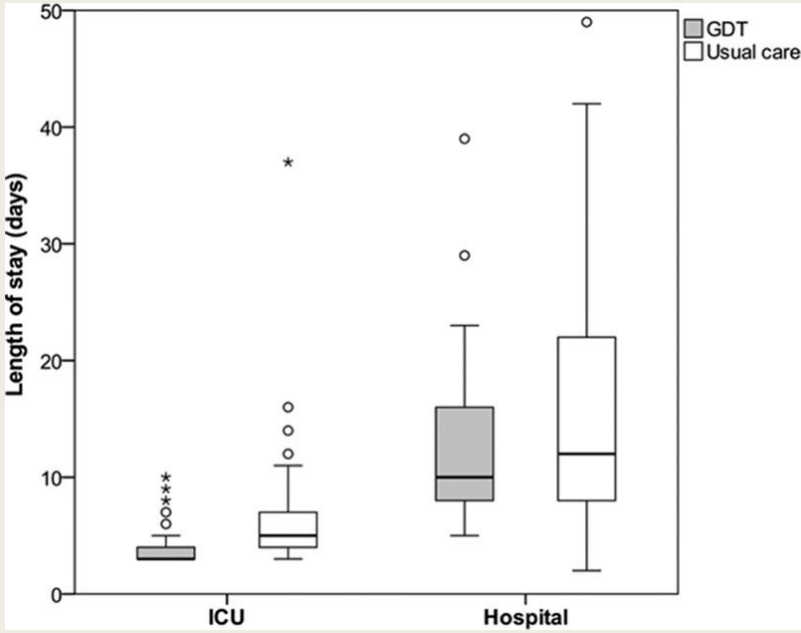
TABLE 3. Study Outcomes Following Goal-Directed Therapy for High-Risk Cardiac Surgery

Variable	Goal-Directed Therapy Group ($n = 62$)s	Usual Care Group ($n = 64$)	p
Primary outcome, *n* (%)			
Composite endpoint	17 (27.4)	29 (45.3)	0.04
Infection	8 (12.9)	19 (29.7)	0.022
Pneumonia	2 (3.2)	5 (7.8)	
Sternal wound infection/ osteomyelitis	5 (8.1)	14 (21.8)	
Catheter related infection	1 (1.6)	0	
Low cardiac output syndrome	4 (6.5)	17 (26.6)	0.002
Death	3 (4.8)	6 (9.4)	0.49
Stroke	0	5 (7.8)	0.06
Myocardial ischemia	5 (8.1)	4 (6.3)	0.74
Reoperation	3 (4.8)	1 (1.6)	0.36
Dialysis	2 (3.2)	0	0.24

TABLE 3. Study Outcomes Following Goal-Directed Therapy for High-Risk Cardiac Surgery

Variable	Goal-Directed Therapy Group ($n = 62$)s	Usual Care Group ($n = 64$)	p
Secondary outcomes, *n* (%)			
Acute kidney injury			
0	40 (64.5)	38 (59.4)	0.82
1	14 (22.6)	17 (26.6)	
2	6 (9.7)	8 (12.5)	
3	2 (3.2)	1 (1.6)	
Bradyarrhythmia	1 (1.6)	3 (4.7)	0.62
Tachyarrhythmia	12 (19.4)	21 (32.8)	0.09
Seizure	1 (1.6)	1 (1.6)	1.00
Delirium	6 (9.7)	9 (14.1)	0.45
Venous thromboembolism	0 (0)	2 (3.1)	0.50
Duration of mechanical ventilation (hr)	7.25 (5.5–9)	8.2 (6.6–11.5)	0.09
Use of dobutamine during ICU stay			
Cumulative dosage (mg/kg)	12 (6–22)	19 (11–31)	0.003
Duration of use (hr)	54 (49–80)	76 (56–111)	0.001
Use of norepinephrine during ICU stay			
Cumulative dosage (μg/kg)	0 (0–231)	369 (0–1,051)	< 0.001
Length of use (hr)	0 (0–65)	78 (0–112)	0.001
Length of ICU stay (d)	3 (3–4)	5 (4–7)	< 0.001
Length of hospital stay (d)	9 (8–16)	12 (9–22)	0.049

Data presented as either *n* (%) or median (interquartile range).



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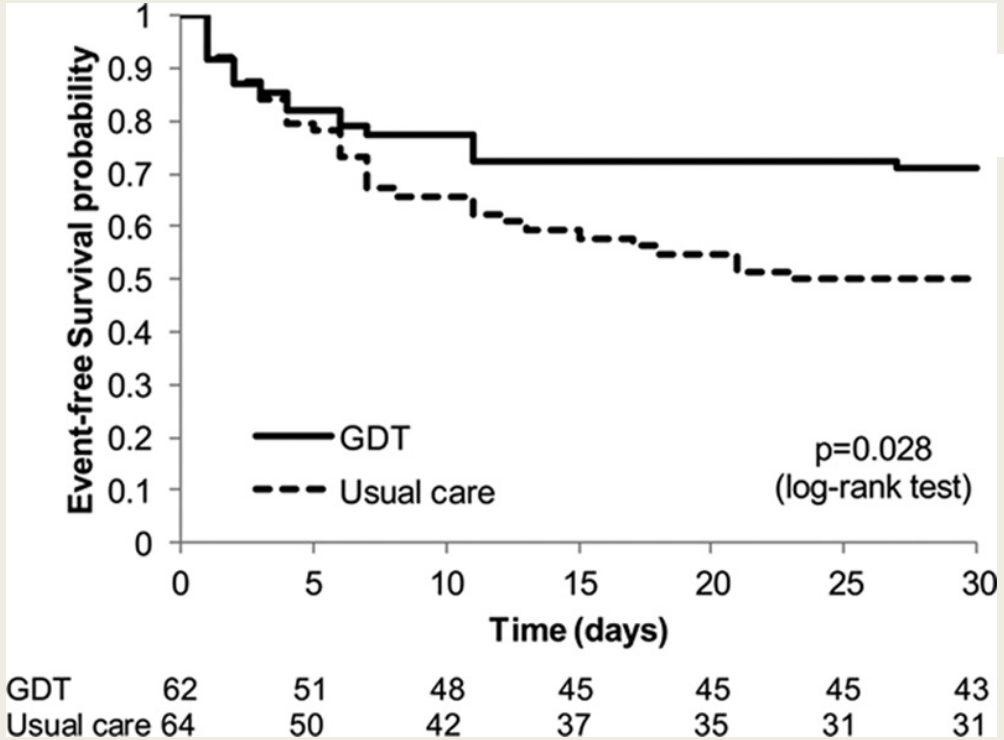
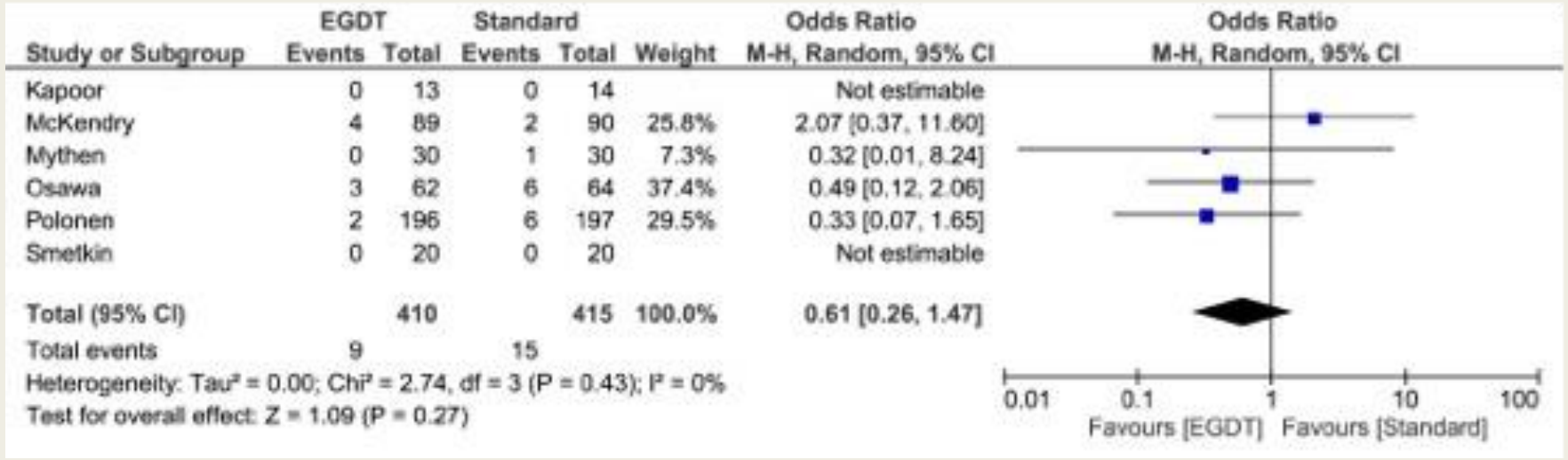


Figure 3. Kaplan-Meier event-free survival probability during 30 days after surgery. GDT = goal-directed therapy.

No difference in 30-day mortality rates
(4.8% vs 9.4, P=0.492)

Forest plot showing the effect of early goal-directed therapy (EGDT) on mortality

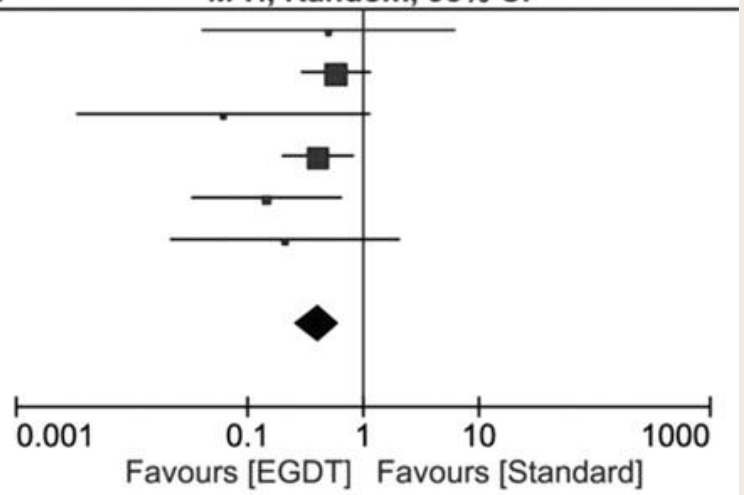


Crit Care Med. 2016 Apr;44(4):724-33.

Forest plot showing the effect of early goal-directed therapy (EGDT) on postoperative complications.

Study or Subgroup	EGDT Events	EGDT Total	Standard Events	Standard Total	Weight	Odds Ratio M-H, Random, 95% CI
Kapoor	1	13	2	14	3.2%	0.50 [0.04, 6.28]
McKendry	17	89	26	90	41.9%	0.58 [0.29, 1.17]
Mythen	0	30	6	30	2.4%	0.06 [0.00, 1.15]
Osawa	26	62	41	64	39.6%	0.41 [0.20, 0.83]
Polonen	2	196	13	197	9.0%	0.15 [0.03, 0.66]
Smetkin	1	20	4	20	3.9%	0.21 [0.02, 2.08]
Total (95% CI)		**410**		**415**	**100.0%**	**0.40 [0.26, 0.63]**
Total events	47		92			

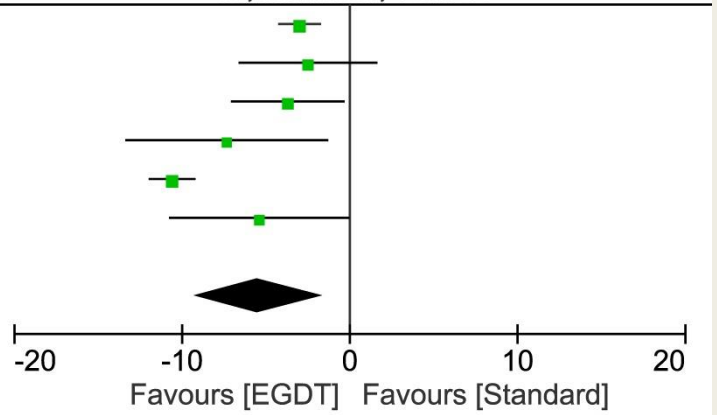
Heterogeneity: Tau² = 0.00; Chi² = 4.87, df = 5 (P = 0.43); I² = 0%
Test for overall effect: Z = 3.94 (P < 0.0001)



Forest plot showing the effect of early goal-directed therapy (EGDT) on hospital stay

Study or Subgroup	EGDT Mean	EGDT SD	EGDT Total	Standard Mean	Standard SD	Standard Total	Weight	Mean Difference IV, Random, 95% CI
Kapoor	5.8	1.2	13	8.8	2.1	14	19.5%	-3.00 [-4.28, -1.72]
McKendry	11.4	13.2	89	13.9	15	90	16.2%	-2.50 [-6.64, 1.64]
Mythen	6.4	1.1	30	10.1	9.4	30	17.3%	-3.70 [-7.09, -0.31]
Osawa	13.95	12.24	62	21.29	21.34	64	13.3%	-7.34 [-13.39, -1.29]
Polonen	7.3	6.6	196	17.9	7.5	197	19.4%	-10.60 [-12.00, -9.20]
Smetkin	14	7.1	20	19.4	10	20	14.3%	-5.40 [-10.77, -0.03]
Total (95% CI)			**410**			**415**	**100.0%**	**-5.44 [-9.28, -1.60]**

Heterogeneity: Tau² = 19.29; Chi² = 67.51, df = 5 (P < 0.00001); I² = 93%
Test for overall effect: Z = 2.77 (P = 0.006)



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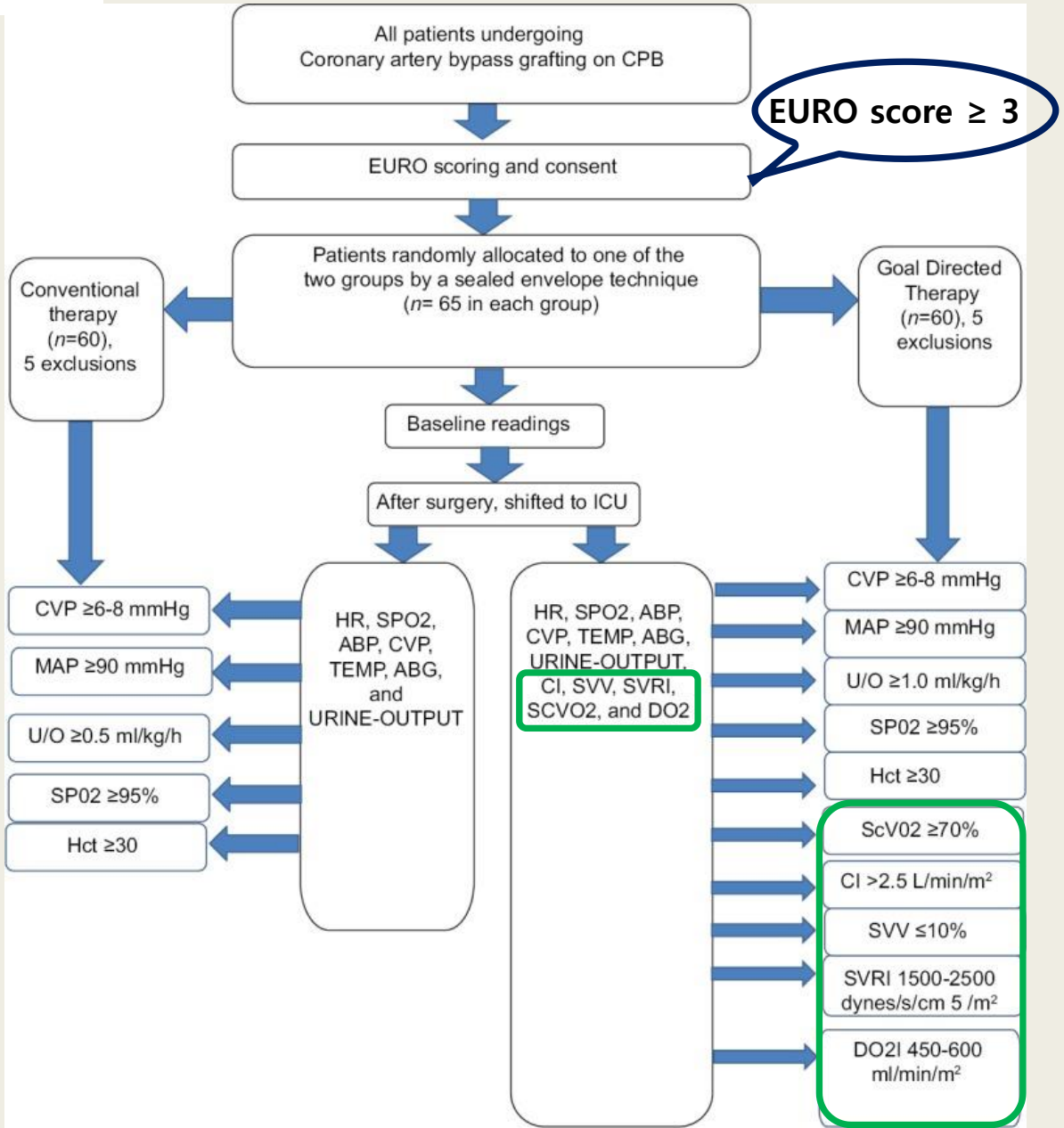
Perioperative utility of goal-directed therapy in high-risk cardiac patients undergoing coronary artery bypass grafting: "A clinical outcome and biomarker-based study"

Ann Card Anaesth. 2016 Oct-Dec;19(4):638-682.



➔ Monitoring gradually withdrawn after 24h

Table 2: Heart rate, mean arterial pressure, and central venous pressure in the two groups

Parameter	Time	Control group (*n*=60)	GDT group (*n*=60)	*P*
Heart rate	T_1	69.42±5.02*	68.17±6.85*	0.257
	T_2	92.18±7.24*	93.75±6.51	0.215
	T_3	99.75±8.29*	100.45±7.69*	0.633
	T_4	99.95±8.30*	102.37±6.13*	0.072
	T_5	101.95±8.60*	103.33±6.10*	0.312
	T_6	100.00±6.81*	100.92±7.11*	0.473
MAP	T_1	89.33±6.98*	91.57±7.17*	0.087
	T_2	94.20±6.54*	94.78±6.85*	0.634
	T_3	96.07±6.06*	97.82±4.16*	0.068
	T_4	94.73±6.37*	96.78±5.65*	0.065
	T_5	94.98±5.39*	97.02±5.91*	0.052
	T_6	98.30±6.38*	100.45±5.59*	0.052
CVP	T_1	6.50±0.93*	6.08±1.09*	0.117
	T_2	6.42±0.56*	6.45±0.77*	0.753
	T_3	6.22±0.49*	6.35±0.58*	0.175
	T_4	6.17±0.46*	6.3±0.80*	0.182
	T_5	6.37±0.48*	6.4±0.58*	0.736
	T_6	6.28±0.52*	6.53±0.87*	0.059

*Standard deviation, *P*<0.05 is considered significant. T_1 (baseline), T_2 (sternal closure), T_3 (0), T_4 (6), T_5 (12), T_6 (24) h in ICU. ICU: Intensive Care Unit, MAP: Mean arterial pressure, CVP: Central venous pressure, GDT: Goal-directed therapy

Table 3: Comparison of the outcomes between the control and the goal-directed therapy group

Parameter	Control group	GDT group	*P*
Average extra volume added	343.33±62.02*	376.33±55.23*	0.003
Number of times inotropes adjusted	2.77±0.91*	3.12±0.80*	0.029
Duration of ventilation (h)	19.89±3.96*	18.05±4.53*	0.025
Duration of inotrope usage (days)	3.09±0.59*	2.81±0.94*	0.063
Length of ICU stay (days)	3.74±0.59*	3.41±0.75*	0.012
Length of hospital stay (days)	7.94±1.64*	7.17±1.93*	0.025
Mortality	6/60	2/60	0.272

*Standard deviation, *P*<0.05 is considered significant. Apart from the first two parameters, the *n* for the outcome measures for the control group was 54 and 58 for the GDT group in view of the mortality. GDT: Goal-directed therapy, ICU: Intensive Care Unit

Ann Card Anaesth. 2016 Oct-Dec;19(4):638-682.

Table 4: Comparison of biomarkers between the two groups

Biomarker	Time	Control group (*n*=60)	GDT group (*n*=60)	*P*
BNP (pg/mL)	T_1	152.27±11.60*	153.72±9.41*	0.454
	T_4	187.85±13.34*	184.20±10.24*	0.095
	T_6	207.70±28.44*	198.98±9.33*	0.026
NGAL (ng/mL)	T_1	77.45±12.86*	81.25±11.29*	0.088
	T_4	116.95±16.76*	112.62±9.79*	0.086
	T_6	127.45±13.52*	122.18±8.85*	0.013
Lactate (mmol/L)	T_1	1.00±0.30*	1.01±0.29*	0.752
	T_2	2.00±0.60*	2.03±0.59*	0.752
	T_3	2.52±0.40*	2.38±0.47*	0.015
	T_4	4.72±0.43*	4.51±0.53*	0.024
	T_5	5.22±0.64*	4.14±0.55*	<0.001
	T_6	3.77±0.31*	3.23±0.41*	<0.001

*Standard deviation, *P*<0.05 is considered significant). T_1 (baseline), T_2 (sternal closure), T_3 (0), T_4 (6), T_5 (12), T_6 (24) h in ICU. ICU: Intensive Care Unit, GDT: Goal-directed therapy, BNP: Brain natriuretic peptide, NGAL: Neutrophil gelatinase-associated lipocalin

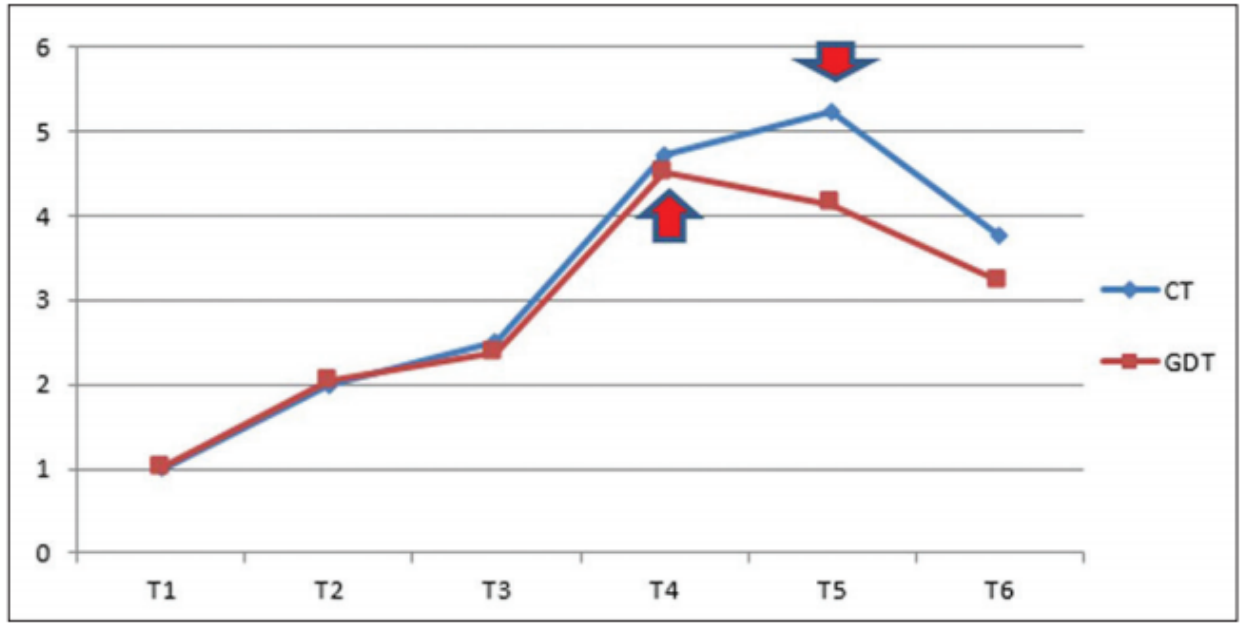


Figure 2: The lactate at T_1 (baseline), T_2 (sternal closure), T_3 (0), T_4 (6), T_5 (12), and T_6 (24) h in Intensive Care Unit. The arrow shows the peak in the groups

Ann Card Anaesth. 2016 Oct-Dec;19(4):638-682.

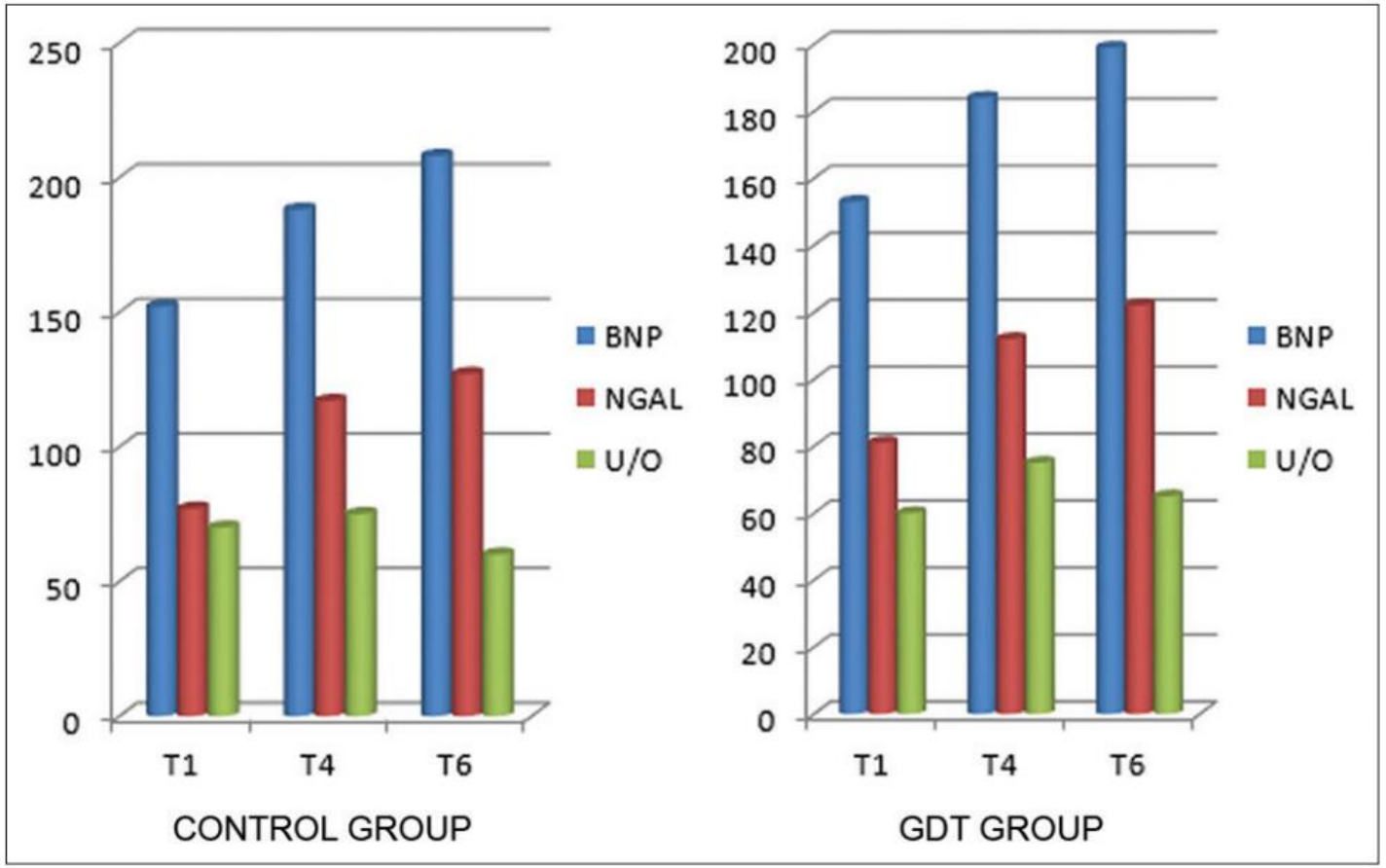


Figure 3: The brain natriuretic peptide, neutrophil gelatinase-associated lipocalin, average hourly urine output at T_1, T_4, T_6, where the rise in brain natriuretic peptide/neutrophil gelatinase-associated lipocalin is clear at T_6

Ann Card Anaesth. 2016 Oct-Dec;19(4):638-682.

Journal of Critical Care

Goal-directed therapy after cardiac surgery and the incidence of acute kidney injury

J Crit Care. 2014 Dec;29(6):997-1000.

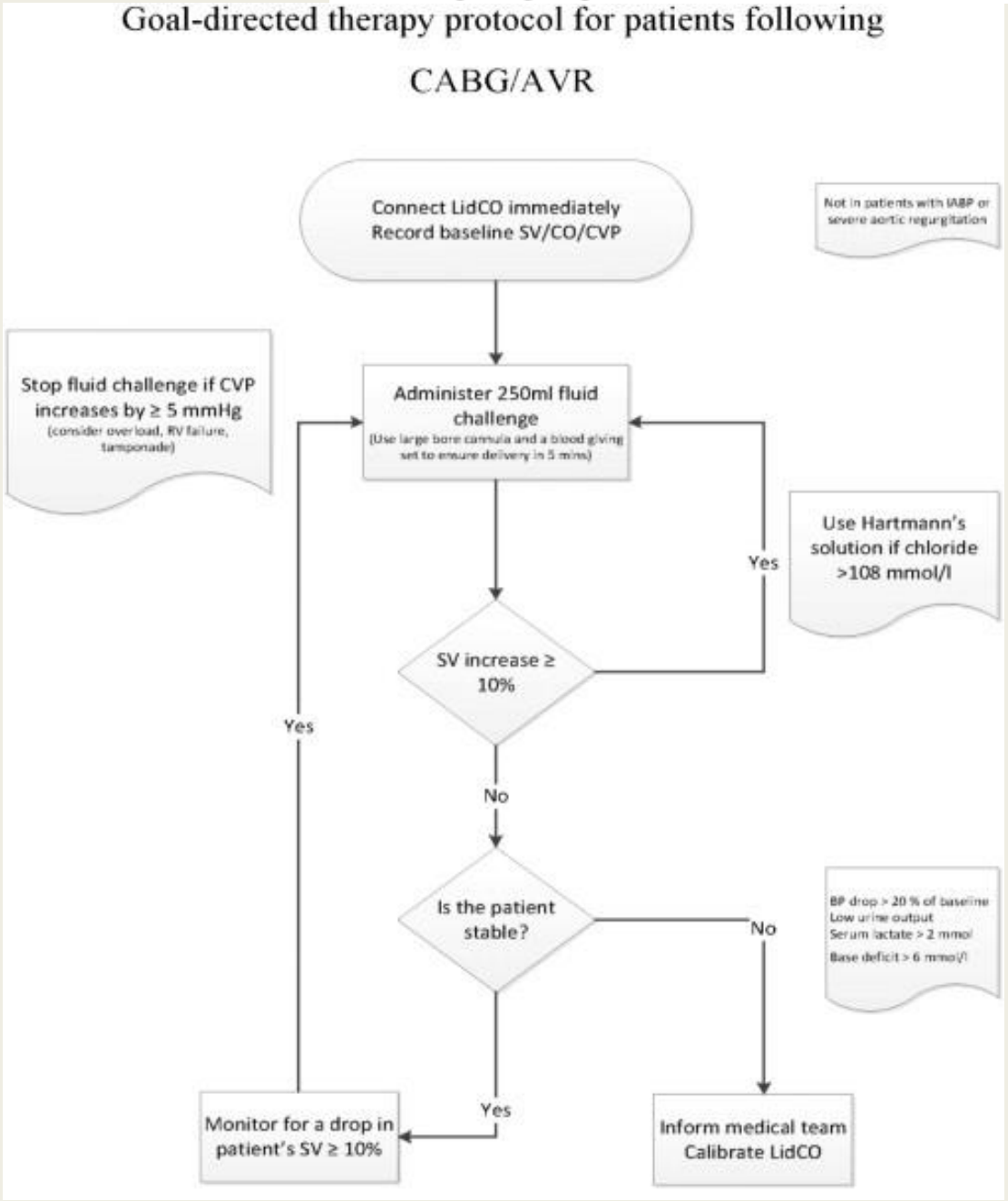


Fig. 1. Algorithm for SV maximization.

Table 1
Characteristics

			ST, n = 141	GDT, n = 123	*P*
Age	Mean (SD)	Years	69.8 (9.8)	69 (10.9)	.51
Sex		F:M	1: 3.03	1:3.24	.81
Surgery	CABG total		99	90	.85
(Off pump)			(2)	(2)	
(MIDCAB)			(2)	(2)	
	AVR		18	15	
	CABG & AVR		24	18	
Height	Mean (SD)	cm	169 (9)	171 (9)	.23
Weight	Mean (SD)	kg	80 (18)	84 (16)	.05
BMI	Mean (SD)	kg/m^{-2}	27.77 (4.98)	28.84 (4.80)	.08
Ethnicity	White British		95 (67.4%)	99 (80.5%)	.01
	Asian		19 (13.5%)	15 (12.2%)	
	White other		21 (14.9%)	4 (3.3%)	
	Afro-Caribbean		2 (1.4%)	3 (2.4%)	
	Other		4 (2.8%)	2 (1.6%)	
Euroscore	median (IQR)		4.78 [5.87]	4.83 [5.98]	.57
Baseline creatinine	median (IQR)	$\mu mol/L^{-1}$	85 [29]	91 [29]	.32
Creatinine clearance (Cockroft-Gault) median (IQR)		mL/min^{-1}	73 [40]	76 [49]	.50

BMI indicates body mass index; MIDCAB, minimally invasive direct coronary artery bypass.

Table 2
Results

			ST, n = 141	GDT, n = 123	*P*
Surgical drain loss median (IQR)		mL	500 [440]	520 [360]	.48
Total fluids received	Median (IQR)	mLs	2704 [1393]	2905 [1367]	.09
Creatinine clearance (day 3) median (IQR)		mL/min^{-1}	73 [49]	79 [51]	.048
AKI (day 3)		n	28 (19.9%)	8 (6.5%)	.002
RRT		n	15 (10.6%)	4 (3.3%)	.021
Readmission		n	13 (9.2%)	4 (3.3%)	.049
Time to readiness to discharge from ICU	Median (IQR)	Hours	24 [25]	20 [6]	<.001
Duration of hospital stay	Median (IQR)	Days	7 [8]	6 [4]	.004
Mortality		n	2 (1.4%)	2 (1.6%)	.89

J Crit Care. 2014 Dec;29(6):997-1000.

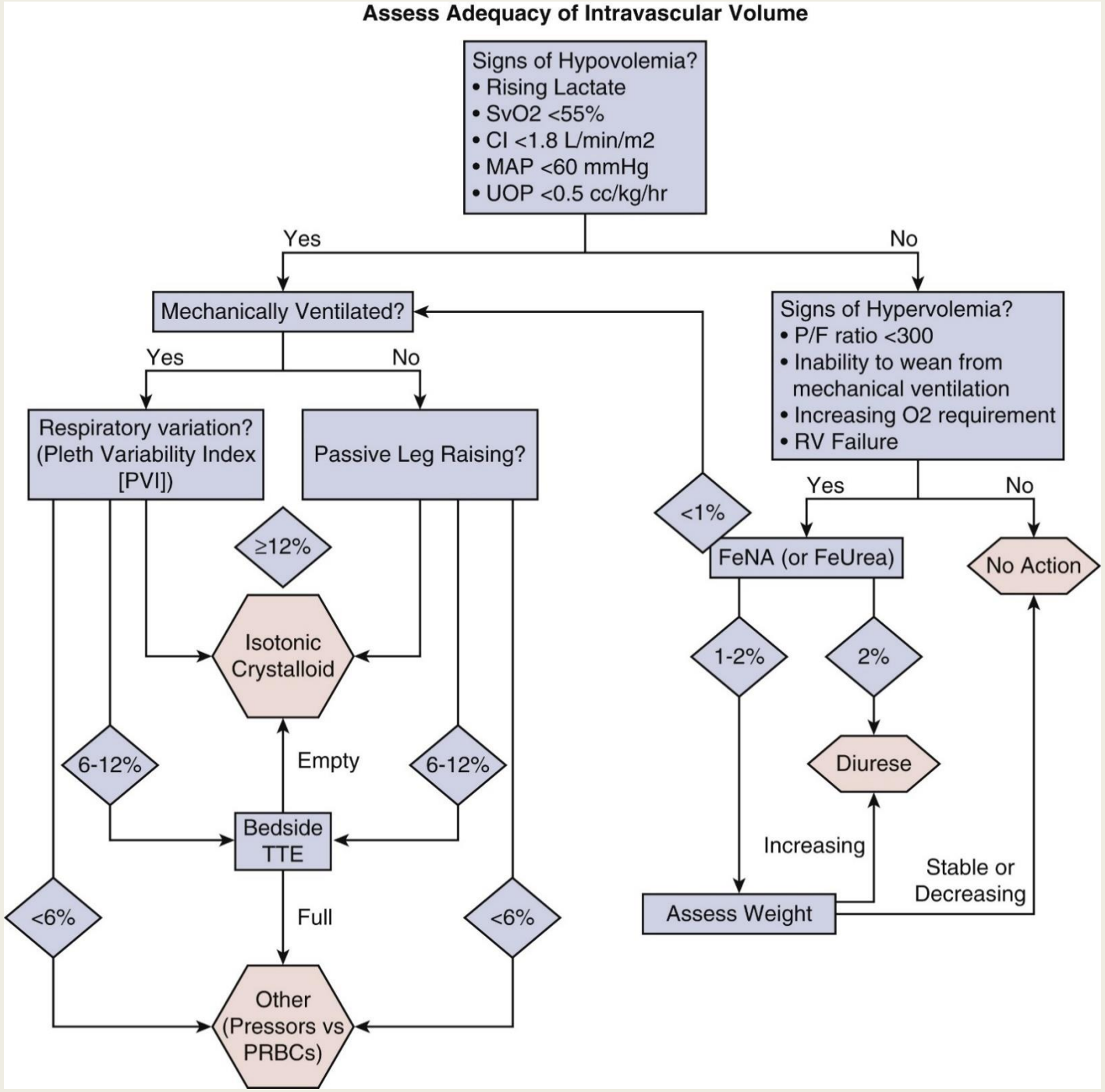
The Journal of Thoracic and Cardiovascular Surgery
Volume 159, Issue 5, May 2020, Pages 1868-1877.e1

Adult: Perioperative Management

Goal-directed resuscitation following cardiac surgery reduces acute kidney injury: A quality initiative pre–post analysis

J Thorac Cardiovasc Surg. 2020 May;159(5):1868-1877.

- Formalize assessment of volume status
- Quantifiable physiologic goals
  - *CI > 2.5L/min/m$_2$*
  - *MAP > 65mmHg*
- Classification of patients as fluid responders vs non-responders
  - *PPV*
  - *PLR*



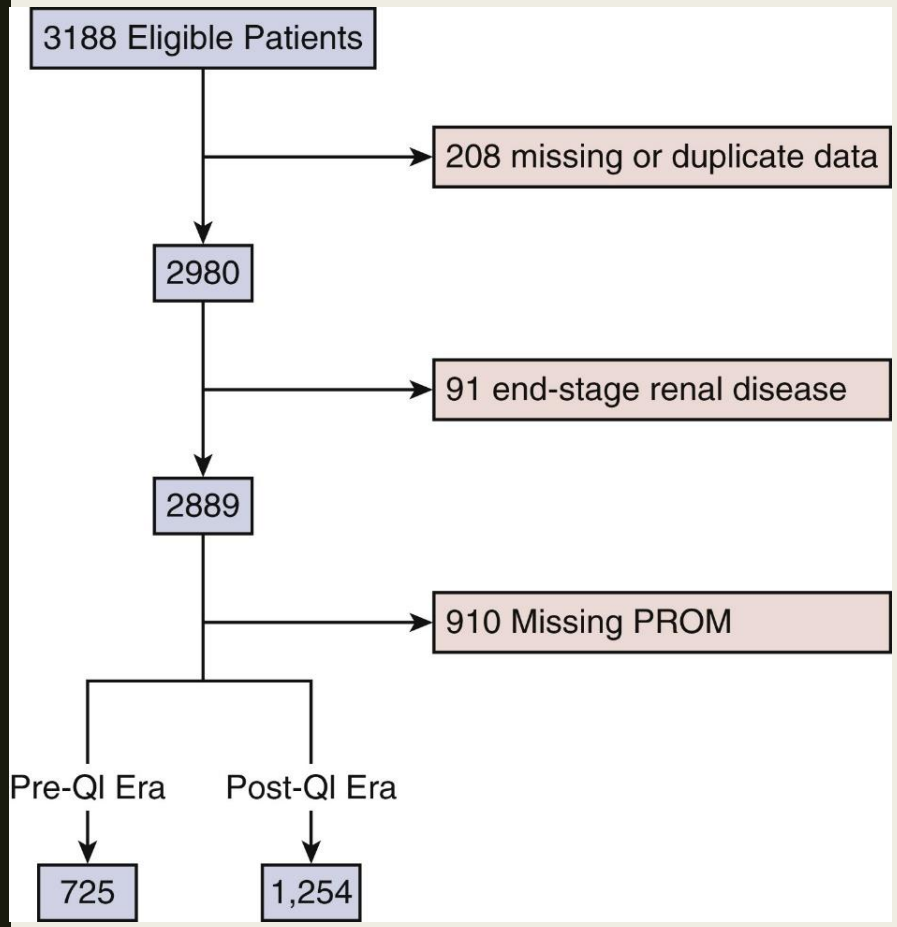


TABLE 3. Short-term complications by quality improvement (QI) era

Outcomes	Pre-QI (n = 725)	Post-QI (n = 1254)	*P* value
Operative mortality	14 (1.9)	23 (1.8)	.88
STS major morbidity	96 (13.2)	150 (12.0)	.41
Prolonged ventilation	48 (6.6)	96 (7.7)	.39
Reoperation	31 (4.3)	52 (4.1)	.89
Permanent stroke	14 (1.9)	16 (1.3)	.25

Values are presented as n (%). *QI*, Quality improvement; *STS*, Society of Thoracic Surgeons.

J Thorac Cardiovasc Surg. 2020 May;159(5):1868-1877.

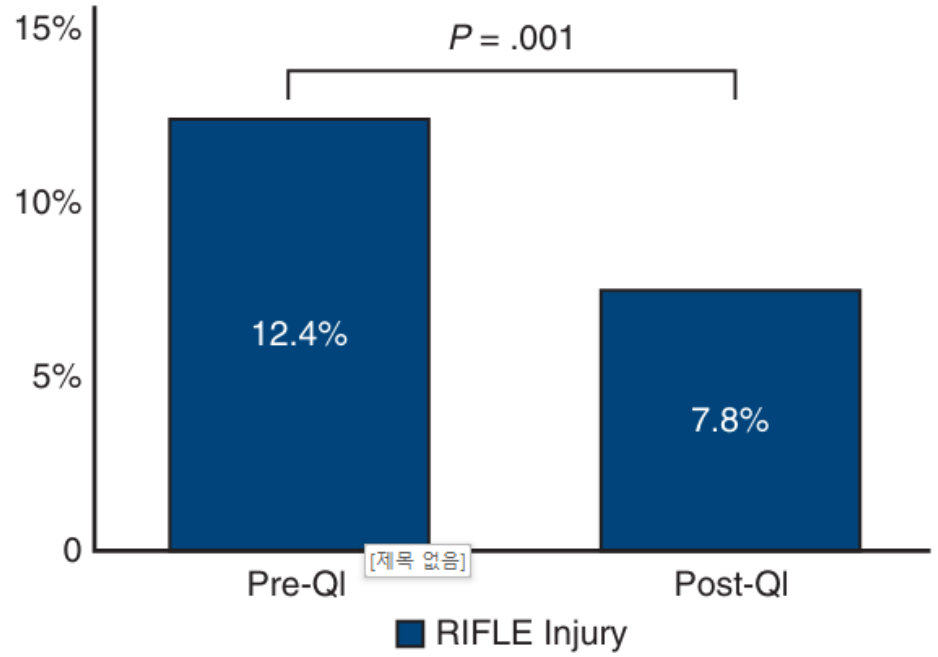


FIGURE 3. Risk, Injury, Failure, Loss of Kidney Function, and End-stage Kidney Disease (*RIFLE*) injury or failure in the pre-quality improvement (*QI*) versus post-QI groups. RIFLE injury or failure is significantly reduced in the post- compared with the pre-QI cohorts from 12.4% to 7.8% ($P = .001$).

TABLE 2. Renal outcomes by quality improvement (QI) era

Outcome	Pre-QI (n = 725)	Post-QI (n = 1254)	*P* value
Minimum GFR (mL/min/1.73 m^2)	58.7 (41.3-75.7)	62.0 (45.9-78.1)	.016
RIFLE classification			.002
No injury	428 (59.0)	818 (65.2)	
Risk	207 (28.6)	338 (27.0)	
Injury	59 (8.1)	58 (4.6)	
Failure	31 (4.3)	40 (3.2)	
Renal injury or failure	90 (12.4)	98 (7.8)	.001
Temporary or permanent postoperative dialysis	17 (2.3)	26 (2.1)	.69

Values are presented as median (interquartile range) for continuous variables or n (%). *QI*, Quality improvement; *GFR*, glomerular filtration rate; *RIFLE*, Risk, Injury, Failure, Loss of Kidney Function, and End-stage Kidney Disease classification criteria.

J Thorac Cardiovasc Surg. 2020 May;159(5):1868-1877.

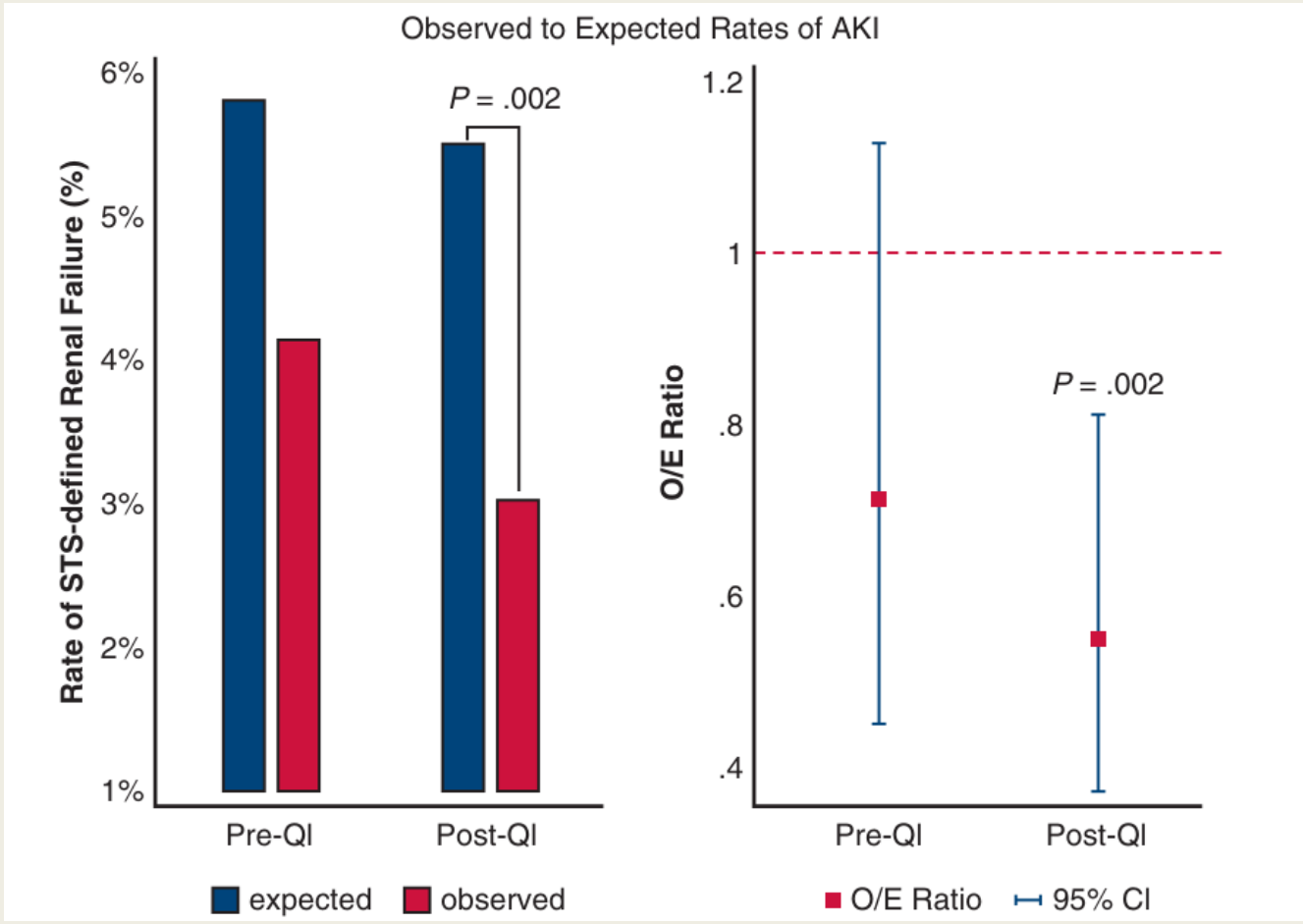


FIGURE 4. Observed to expected rates (*O/E*) of acute kidney injury (*AKI*) based on Society of Thoracic Surgeons (*STS*) definitions and risk models. The left panel depicts the rates of expected and observed cases of kidney injury, with expected cases based on the STS risk model. The right panel transforms these observed and expected cases into the O/E ratio depicted by the orange square and the bars represent the 95% confidence intervals (*CIs*). The O/E with confidence interval is significantly < 1 in the post-quality improvement (*QI*), but not the pre-QI, group.

TABLE 4. Multivariable model for renal injury or failure by Risk, Injury, Failure, Loss of Kidney Function, and End-Stage Kidney Disease (RIFLE) classification criteria

Variable	Logistic only		IPTW adjusted	
	Odds ratio (95% Confidence interval)	*P* value	Odds ratio (95% Confidence interval)	*P* value
Quality improvement era	0.63 (0.43-0.90)	.012	0.66 (0.44-0.97)	.037
STS predicted risk of morbidity or mortality score	31.7 (9.0-111.6)	<.0001	20.2 (3.8-106)	<.001
Last preoperative hematocrit	0.93 (0.90-0.96)	<.0001	0.93 (0.90-0.97)	.001
Intraoperative blood products	1.15 (0.78-1.70)	.5	1.09 (0.65-1.81)	.8
MELD score	1.04 (0.99-1.10)	.1	1.03 (0.96-1.09)	.4
ACE inhibitor or ARB	0.744 (0.41-1.34)	.3	0.79 (0.39-1.58)	.5
Last preoperative HbA1c	1.10 (0.98-1.22)	.1	1.02 (0.89-1.17)	.7
Family history of cardiac disease	0.94 (0.74-1.19)	.6	0.88 (0.45-1.73)	.7
Obstructive sleep apnea	0.89 (0.70-1.14)	.4	0.62 (0.31-1.23)	.2
Dyslipidemia	1.17 (0.66-2.09)	.6	1.01 (0.47-2.17)	1.0
Endocarditis	0.92 (0.39-2.17)	.9	0.74 (0.28-1.90)	.5
Crossclamp time	1.20 (1.05-1.38)	.008	1.06 (0.87-1.28)	.6
Procedure vs isolated CABG				
Isolated AVR	0.74 (0.46-1.21)	.2	0.72 (0.38-1.33)	.3
AVR/CABG	0.65 (0.37-1.13)	.1	1.11 (0.52-2.38)	.8
Isolated MVR	0.54 (0.27-1.04)	.07	0.46 (0.21-1.00)	.05
MVR/CABG	0.60 (0.26-1.38)	.2	0.88 (0.33-2.36)	.8

IPTW, Inverse probability of treatment weighting; *STS*, Society of Thoracic Surgeons; *MELD*, Model for End-stage Liver Disease; *ACE*, angiotensin-converting enzyme; *ARB*, angiotensin II receptor blocker; *HbA1c*, glycated hemoglobin; *CABG*, coronary artery bypass graft; *AVR*, aortic valve replacement; *MVR*, mitral valve repair or replacement.

J Thorac Cardiovasc Surg. 2020 May;159(5):1868-1877.

British Journal of Anaesthesia
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Cardiac complications associated with goal-directed therapy in high-risk surgical patients: a meta-analysis

Br J Anaesth. 2014 Apr;112(4):648-59.

Table 1 Summary of included studies

Study	Year	Jadad score	Type of surgery	No. of patients in the GDT group	No. of patients in the control group	Type of monitor in the GDT group	Intervention type	Goals in the GDT group	Goals in the control group	CVS complications, GDT (%)	CVS complications, control (%)
Bender and colleagues	1997	1	Elective vascular/ aortic	51	53	PAC	Fluid and inotropes	CI≥2.8; PAWP 8–14; SVR<1100	Standard care	4 (7.8)	6 (11.3)
Benes and colleagues	2010	3	Elective abdominal	60	60	Flotrac	Fluid and inotropes	SVV<10%; CI≥2.5	MAP >65; HR<100; CVP 8–12	6 (10.0)	12 (20.0)
Berlauk and colleagues	1991	2	Peripheral vascular surgery	68	21	PAC	Fluid and inotropes	CI≥2.8; PAWP 8–14; SVR<1100	Standard care	5 (7.4)	5 (23.8)
Bonazzi and colleagues	2002	2	Elective vascular	50	50	PAC	Fluid and inotropes	CI >3.0; PWP 10–18; SVR<1450; DO_2I >600	Standard care	2 (4.0)	4 (8.0)
Boyd and colleagues	1993	1	Abdominal/ vascular	53	54	PAC	Fluid and inotropes	MAP 80–110; PAWP 12–14; S p_{O_2} >94%; Hb >12; UO> 0.5 ml kg h^{-1}; DO_2I >600	MAP 80–110; PAWP 12–14; S p_{O_2} >94%; Hb >12; UO >0.5 ml kg h^{-1}	5 (9.4)	14 (25.9)
Buettner and colleagues	2008	2	Major abdominal or gynaecological	40	40	PiCCO	Fluids	SPV <10%; HCt >23%; normal clotting	Standard care	0 (0.0)	0 (0.0)
Cecconi and colleagues	2011	4	Hip THR	20	20	Flotrac	Fluid and inotropes	SV change; DO_2I >600	Standard care	0 (0.0)	6 (30.0)
Donati and colleagues	2007	3	Elective major abdominal/aortic	68	67	CVC	Fluids	O_2ER <27%; MAP >80; UO> 0.5; CVP 8–12; Hb >10	MAP >80; UO >0.5; CVP 8–12; Hb >10	1 (1.5)	5 (7.5)
Forget and colleagues	2010	2	Major intra-abdominal	41	41	Masimo pulsoximeter	Fluids	PVI <13%	Standard care	4 (9.8)	8 (19.5)
Gan and colleagues	2002	5	Elective general, urological, gynaecological	50	50	OD	Fluids	FTc >0.35; SV change	Increase HR >20% baseline; sAP <90 or CVP <20% baseline	1 (2.0)	2 (4.0)
Jhanji and colleagues	2010	3	Major surgery	45	45	LiDCO	Fluids	SV	CVP standard care	6 (13.3)	4 (8.9)
Lobo and colleagues	2000	3	Major surgery	19	18	PAC	Fluid and inotropes	DO_2I >600	Standard care	0 (0.0)	4 (22.2)
Lopes and colleagues	2007	2	Major surgery	17	16	IBPplus; Dixtal	Fluids	ΔPP <10%	Standard care	3 (17.6)	8 (50.0)
Mayer and colleagues	2010	2	Major GI surgery	30	30	Flotrac	Fluid and inotropes	CI >2.5; SVV <12%	CVP-8–12; MAP >65; UO >0.5	2 (6.7)	7 (23.3)
Pearse and colleagues	2005	3	Major surgery	62	60	LiDCO	Fluid and inotropes	D02I >600	Sa_{O_2} ≥94%; Hb > 8; Temp>37°C; HR <100 or <20 above baseline; MAP 60–100; CI≥2.5	8 (12.9)	16 (26.7)

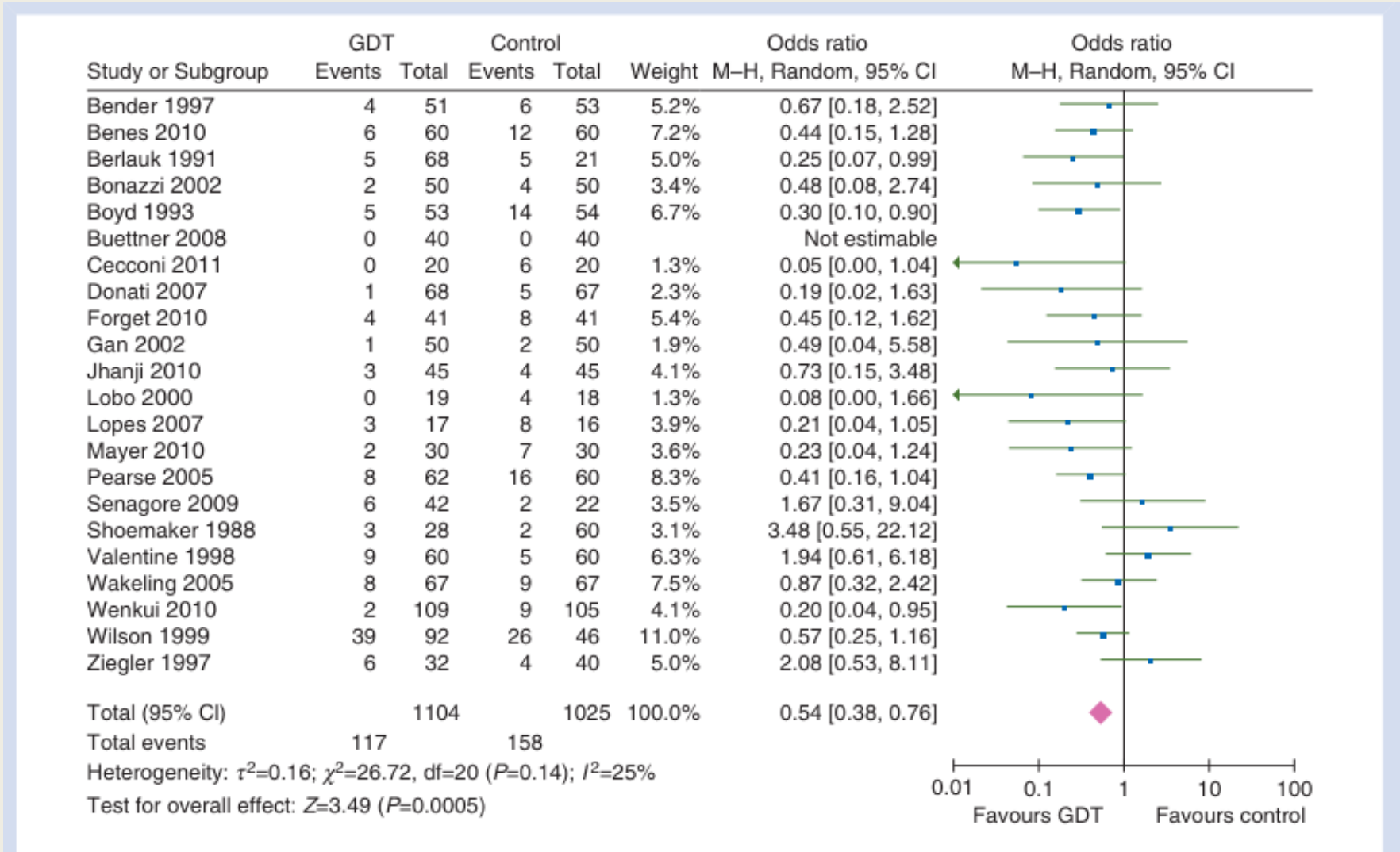

Fig 2 Effect of GDT in the protocol group *vs* control group on total cardiovascular events. M–H, Mantel–Haenszel.

Br J Anaesth. 2014 Apr;112(4):648-59.

Table 2 Cardiovascular complications. *$P < 0.05$

Total CVS events	No. of studies	No. of patients in the GDT group	CVS in the GDT group (%)	No. of patients in the control group	CVS in the control group (%)	Odds ratio	95% CI	*P*-value
Total	22	1104	117 (10.6)	1025	158 (15.4)	0.54	0.38–0.76	0.0005*
Fluid/inotropes								
Fluid	9	479	31 (6.4)	453	47 (10.3)	0.57	0.31–1.04	0.07
Fluid+inotrope	13	625	89 (14.2)	572	111 (19.4)	0.55	0.34–0.89	0.01*
Goal								
Supranormal	12	593	83 (13.9)	532	107 (20.1)	0.50	0.31–0.79	0.002*
Normal	10	511	37 (6.6)	493	51 (10.3)	0.61	0.35–1.06	0.08
Type of monitor								
PAC	9	453	73 (16.1)	402	70 (17.4)	0.70	0.38–1.29	0.25
Other	13	651	47 (7.2)	623	88 (14.1)	0.47	0.31–0.73	0.0008*
Arrhythmias	**No. of studies**	**No. of patients in the GDT group**	**Arrhythmia in the GDT group (%)**	**No. of patients in the control group**	**Arrhythmia in the control group (%)**	**Odds ratio**	**95% CI**	***P*-value**
Total	15	752	41 (5.4)	641	60 (9.3)	0.54	0.35–0.85	0.007*
Fluid/inotropes								
Fluid	4	208	8 (3.8)	183	16 (8.7)	0.38	0.11–1.26	0.11
Fluid+inotrope	11	544	33 (6.0)	458	44 (9.6)	0.58	0.35–0.96	0.03*
Goal								
Supranormal	9	452	29 (6.4)	358	39 (10.8)	0.55	0.32–0.94	0.03*
Normal	6	300	12 (4.0)	283	21 (7.4)	0.51	0.21–1.22	0.13
Type of monitor								
PAC	7	372	23 (6.2)	288	23 (8.0)	0.66	0.35–1.25	0.20
Other	8	380	18 (4.7)	353	37 (10.4)	0.45	0.24–0.83	0.01*

Br J Anaesth. 2014 Apr;112(4):648-59.

Acute pulmonary oedema	No. of studies	No. of patients in the GDT group	APO in the GDT group (%)	No. of patients in the control group	APO in the control group (%)	Odds ratio	95% CI	*P*-value
Total	15	773	39 (5.0)	695	44 (6.3)	0.69	0.43–1.10	0.12
Fluid/inotropes								
Fluid	3	168	0 (0.0)	143	3 (2.0)	0.23	0.02–2.13	0.19
Fluid+inotrope	12	605	39 (6.4)	552	41 (7.4)	0.72	0.44–1.18	0.19
Goal								
Supranormal	11	573	37 (6.4)	512	40 (7.8)	0.68	0.42–1.13	0.14
Normal	4	200	2 (1.0)	183	4 (2.1)	0.67	0.12–3.77	0.65
Type of monitor								
PAC	9	453	33 (7.2)	402	29 (7.2)	0.81	0.46–1.41	0.45

Acute myocardial ischaemia	No. of studies	No. of patients in the GDT group	CVS in the GDT group (%)	No. of patients in the control group	Mortality in the control group (%)	Odds ratio	95% CI	*P*-value
Total	16	793	22 (2.7)	715	27 (3.7)	0.70	0.38–1.28	0.25
Fluid/inotropes								
Fluid	3	168	3 (1.7)	143	0 (0)	2.84	0.31–26.2	0.36
Fluid+inotrope	13	625	18 (2.8)	572	23 (4.0)	0.62	0.33–1.17	0.14
Goal								
Supranormal	12	593	16 (2.6)	532	24 (4.5)	0.55	0.28–1.09	0.09
Normal	4	200	6 (3.0)	183	3 (1.6)	1.70	0.45–6.49	0.43
Type of monitor								
PAC	9	453	19 (4.1)	402	19 (4.7)	0.79	0.39–1.58	0.50
Other	7	340	3 (0.9)	313	8 (2.5)	0.46	0.13–1.65	0.23

Br J Anaesth. 2014 Apr;112(4):648-59.

British Journal of Anaesthesia
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Review Articles

Editor's choice

Goal-directed therapy in cardiac surgery: a systematic review and meta-analysis

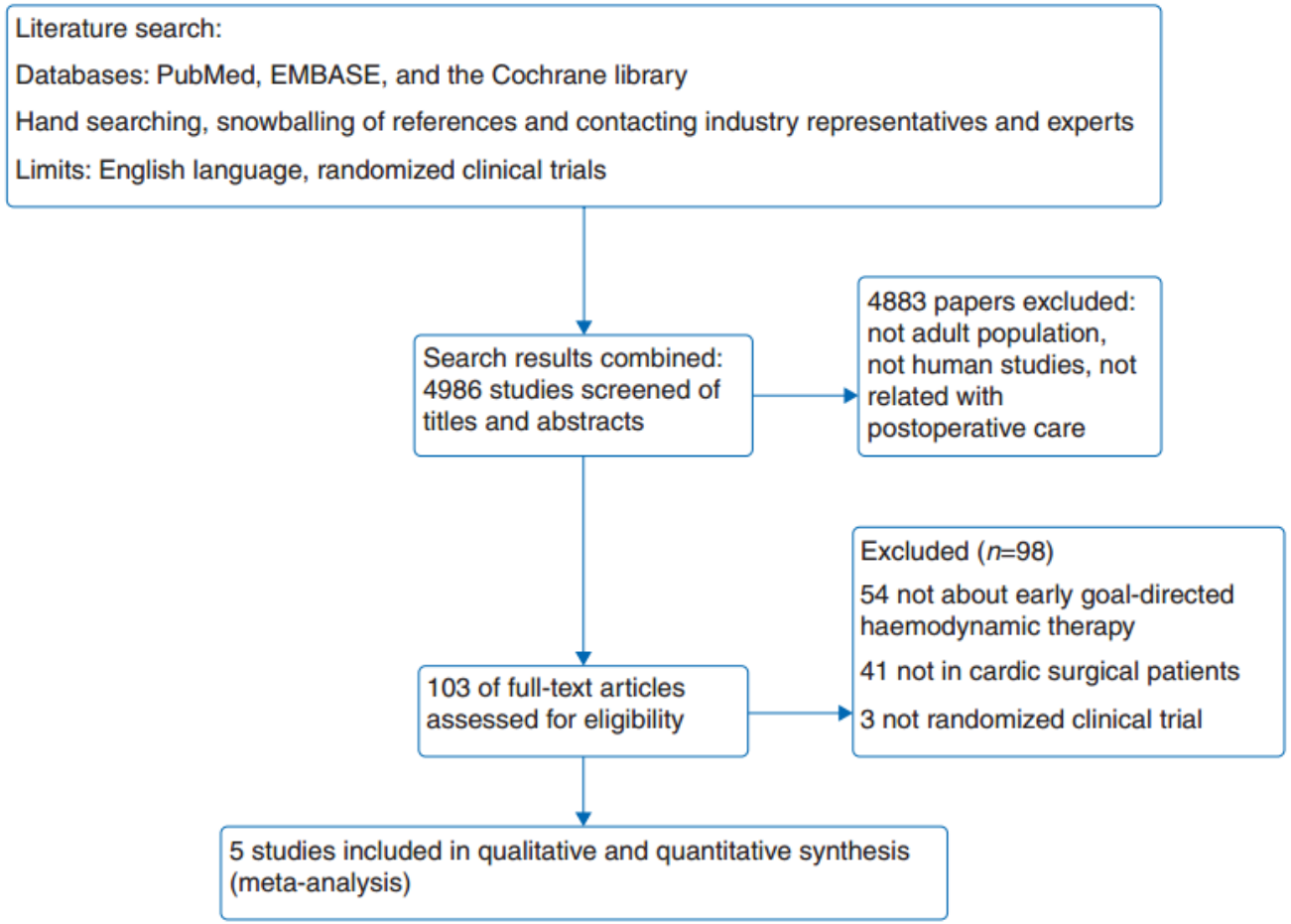


Fig 1 Flow chart showing the number of abstracts and articles identified and evaluated during the review process.

Br J Anaesth. 2013 Apr;110(4):510-7.

Table 1 Randomized clinical trials of goal-directed therapy in cardiac surgical patients. CI, cardiac index; CVP, central venous pressure; SVV, stroke volume variation; Scv_{O_2}, central venous saturation of oxygen; SVI, stroke volume index; SVRI, systemic vascular resistance index; DO_2I, delivery oxygen index; Hct, haematocrit; MAP, mean arterial pressure; UO, urine output; CABG, coronary artery bypass graft; CPB, cardio-pulmonary bypass

Author	Year	Participants	Intervention	Timing	Monitor	Goals of therapy	Control group
Smetkin and colleagues	2009	40 patients (20 EGDT and 20 control group). CABG off-pump. EuroSCORE 2 control group, 2.5 EGDT group	Fluids, inotropes and blood transfusion	Perioperative	PiCCO*plus* cardiac output monitoring and CeVOX (continuous Scv_{O_2} monitoring)	ITBVI=850–1000 ml m^{-2}; MAP=60–100 mm Hg; HR <90 bpm; Hb ≥8 g dl^{-1}; CI ≥2 litre min^{-1} m^{-2}; Scv_{O_2} >60%	CVP=6–14 mm Hg; MAP=60–100 mm Hg; HR <90 bpm
Kapoor and colleagues	2008	30 patients (13 intervention, 14 control). CABG on CPB. EuroSCORE ≥3	Fluids and inotropes	Postoperative	FloTrac™ cardiac output monitoring sensor and PreSep™ catheter (continuous central venous oximetry)	CI 2.5–4.2 ml min^{-1} m^{-2}; CVP 6–8 mm Hg; SVV <10%; Scv_{O_2} >70%; SVI 30–65 ml bet $^{-1}$ m^{-2}; SVRI 1500–2500 dynes s cm^{-5} m^{-2}; DO_2I 450–600 ml min^{-1} m^{-2}; Hct >30%; MAP 90–105 mm Hg; pH 7.35–7.45; Po_2 >100 mm Hg; Pco_2 35–45 mm Hg; Sp_{O_2} >95%; UO >1 ml kg^{-1} h^{-1}	Hct ≥ 30%; MAP 90–105 mm Hg; pH 7.35–7.45; Po_2 >100 mm Hg; Pco_2 35–45 mm Hg; Sp_{O_2} >95%; UO >1 ml kg^{-1} h^{-1}
McKendry and colleagues	2004	179 patients (89 EGDT and 90 control group). CABG, valve replacement or both on CPB. Parsonnet score 9.7 both groups	Fluids, inotropes and nitrates	Postoperative	Oesophageal Doppler	SVI >35 ml m^{-2}; MAP=70 mm Hg	Standard care
Pölönen and colleagues	2000	403 patients (9 excluded; 196 EGDT group; 197 control group). CABG, valve replacement or other surgery on CPB	Fluid and inotropes	Postoperative	Thermodilution pulmonary artery catheter	Scv_{O_2} >70% and Lactate ≤2 mmol $litre^{-1}$ up to 8 h post-op	Standard care
Mythen and colleagues	1995	60 patients (30 protocol group, 30 control group). CABG, valve replacement or both on CPB	Fluids	Perioperative	Oesophageal Doppler	Maximum SV, increase of CVP <3 mm Hg	Standard care

Table 2 Length of stay (LOS) in days for hospital and intensive care unit for early goal-directed therapy group (EGDT) *vs* control group among different studies. *Median with interquartile range. † Mean with range

Author/Study	LOS ICU (days)		LOS hospital (days)	
	EGDT	Control	EGDT	Control
Smetkin and colleagues*	0.8 (0.8–1.0)	1.0 (0.9–1.6)	12 (8–19)	15 (13–24)
Kapoor and colleagues	2.6 ± 0.9	4.9 ± 1.8	5.8 ± 1.2	8.8 ± 2.1
McKendry and colleagues	2.5	3.2	11.4 ± 13.2	13.9 ± 15
Pölönen and colleagues*	1 [1–1]	1 [1–1]	6 [5–7]	7 [5–8]
Mythen and colleagues†	1 [1,1]	1.7 [1,11]	6.4 [5, 9]	10.1 [5, 48]

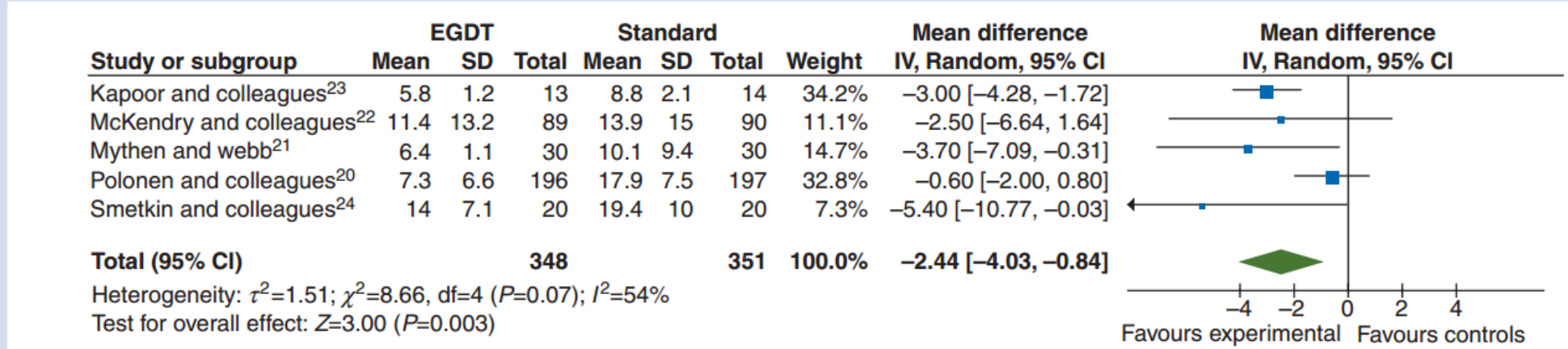


Fig 4 Forest plot showing the effect of early goal-directed therapy (EGDT) on hospital length of stay (LOS) *vs* control group. IV, inverse of variance. Data obtained by direct contact with author.

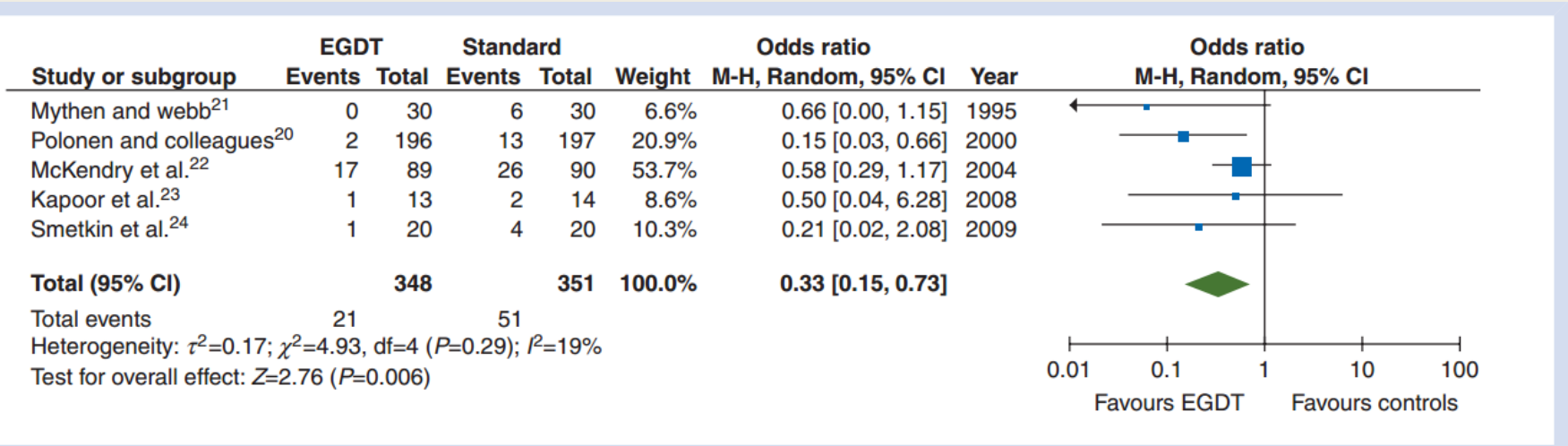


Fig 3 Forest plot showing the effect of early goal-directed therapy (EGDT) on postoperative complications rate *vs* control group. M-H, Mantel–Haenszel.

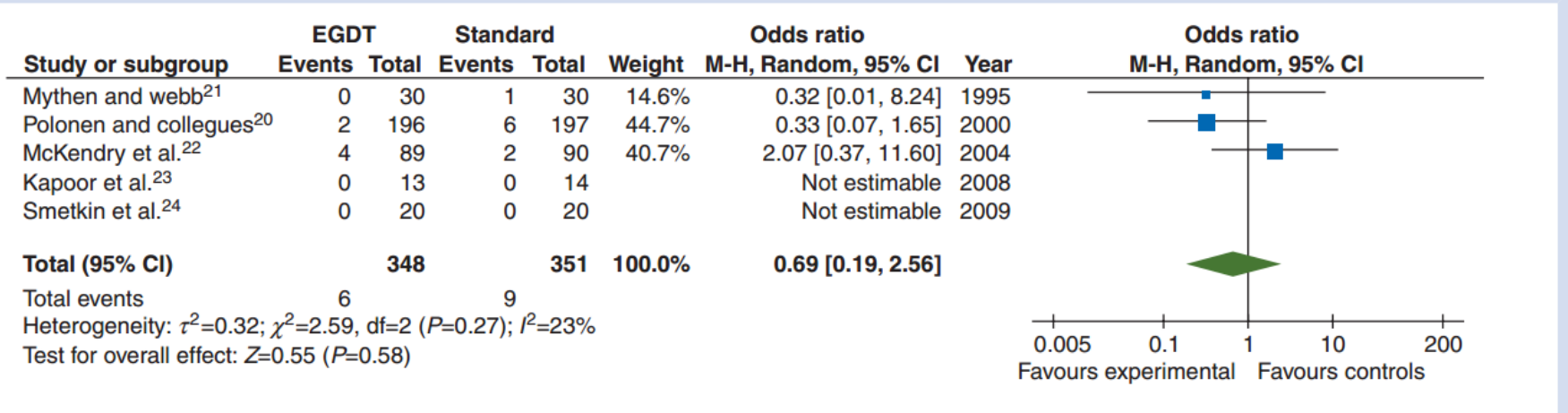


Fig 2 Forest plot showing the effect of early goal-directed therapy (EGDT) on mortality rate *vs* control group. M-H, Mantel–Haenszel.

Original Article

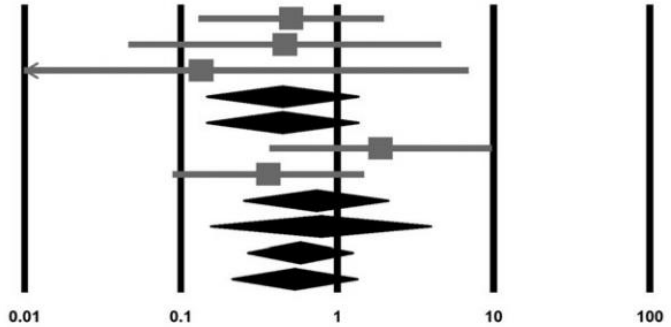
Significance of perioperative goal-directed hemodynamic approach in preventing postoperative complications in patients after cardiac surgery: a meta-analysis and systematic review

The protocol of goal-directed therapy.

First author (year)	Timing of optimization	Modality of optimization	Goals of optimization	Monitor tools
Osawa (2016)	Intra-op	Fluid and vasoactive drugs	CI >3.0 L/min/m^2; SVI >/= 35 ml/m^2, MAP >65mmHg	LiDCOrapid
Fellahi (2015)	Intra-op	Fluid and vasoactive drugs	CI > =2.4 l/min/m^2; SVV < =11%	Endotracheal cardiac output monitor
Parke (2015)	Post-op	Fluid and vasoactive drugs	CI >2.5 l/min/m^2; SVV< =13%; MAP> =65 mmHg	FloTrac/EV1000 clinical platform
Goepfert (2013)	Intra-op	Fluid and vasoactive drugs	CI >2.0 l/min/m^2; SVV < =10%; MAP >65 mmHg; HR 50–100 bpm	PiCCOplus
Smetkin (2009)	Intra-op	Fluid and dobutamine/ephedrine	Iintrathoracic blood volume index: 850–1000ml/m^2; MAP 60–100mmHg; HR <90bpm; central venous oxygen saturation >60%	PiCCOplus
Kapoor (2008)	Post-op	Fluid and vasoactive drugs	Maintain CI at 2.5–4.2 l/min/m^2; SVI at 30–65 ml/beat/m^2; SVRI at 1500–2500 dyne/s/cm,DO2I at 450–600 ml/min/m^2; ScVO2 more than 70% and SVV less than 10%	FloTrac™/PreSep™
McKendry (2004)	Post-op	Fluid with or without vasodilators and inotropes	Maintain stroke index> = 35 ml/m^2	Esophageal Doppler flowmetry
Pölönen (2000)	Post-op	Fluid with or without vasodilators and inotropes	Maintain Svo2 > 70% and lactate concentration< =2.0 mmol/L from admission to the ICU and up to 8 h thereafter	
Mythen (1995)	Intra-op	Fluid	Maintain stoke volume and rise of CVP> 3mmHg	Esophageal Doppler system

Ann Med. 2017 Jun;49(4):343-351.

Study name	Peto Odds ratio	Lower limit	Upper limit	Z-Value	P-Value	Relative Weight
Osawa (2016)	0.51	0.13	1.96	-0.98	0.325	68.191
Fellahi (2015)	0.46	0.05	4.57	-0.66	0.509	23.712
Mythen (1995)	0.14	0.00	6.82	-1.00	0.317	8.097
Subgroup of intratoperative GDT (fixed)	**0.45**	**0.15**	**1.36**	**-1.42**	**0.156**	
Subgroup of intratoperative GDT (random)	0.45	0.15	1.36	-1.42	0.156	
McKendry (2004)	1.90	0.37	9.62	0.77	0.440	46.745
Pölönen (2000)	0.36	0.09	1.47	-1.42	0.156	53.255
Subgroup of postoperative GDT (fixed)	0.73	0.25	2.12	-0.57	0.567	
Subgroup of postoperative GDT (random)	**0.79**	**0.16**	**3.96**	**-0.29**	**0.770**	
Pooled effects (fixed)	**0.58**	**0.27**	**1.25**	**-1.39**	**0.164**	
Pooled effects (random)	0.54	0.21	1.34	-1.33	0.182	



Heterogeneity test:

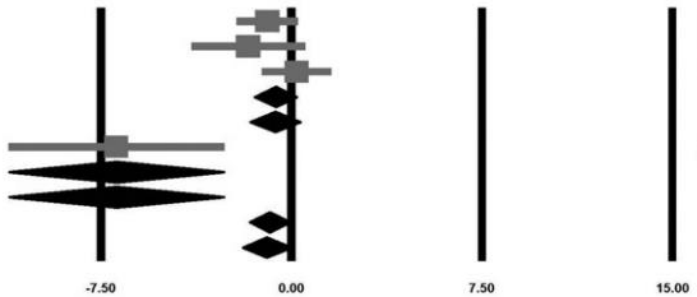
Subgroup of intratoperative GDT
Q =0.3914, df = 2, P = 0.822, I-square = 0%
Subgroup of postoperative GDT
Q =2.283, df = 1, P = 0.131, I-square = 56.20%
Total
Q =3.077, df = 4, P = 0.545, I-square = 0%

Figure 3. Meta-analysis for all-cause mortality.

(A) duration of mechanical ventilation,

(A)

Study name	Difference in means	Lower limit	Upper limit	Z-Value	P-Value	Relative Weight
Osawa (2016)	-0.95	-2.12	0.22	-1.60	0.110	48.964
Goepfert (2013)	-1.70	-3.90	0.50	-1.51	0.130	13.724
Smetkin (2009)	0.20	-1.14	1.54	0.29	0.769	37.312
Subgroup of intratoperative GDT (fixed)	**-0.62**	**-1.44**	**0.19**	**-1.50**	**0.134**	
Subgroup of intratoperative GDT (random)	-0.64	-1.62	0.33	-1.29	0.196	
Kapoor (2008)	-6.90	-11.11	-2.69	-3.21	0.001	100.000
Subgroup of postoperative GDT (fixed)	-6.90	-11.11	-2.69	-3.21	0.001	
Subgroup of postoperative GDT (random)	-6.90	-11.11	-2.69	-3.21	0.001	
Pooled effects (fixed)	-0.85	-1.65	-0.05	-2.08	0.037	
Pooled effects (random)	**-1.48**	**-3.24**	**0.28**	**-1.65**	**0.099**	



Heterogeneity test:

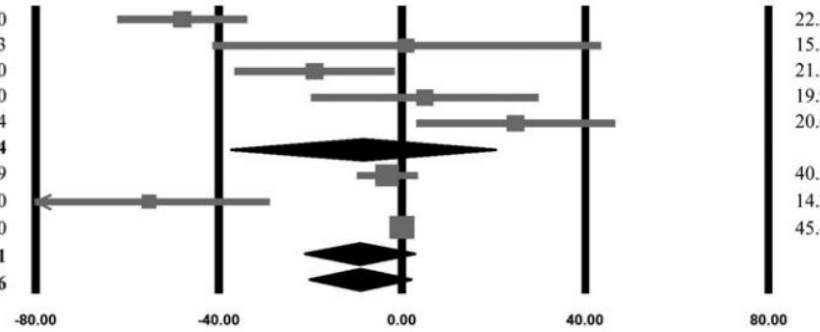
Subgroup of intratoperative GDT
Q =2.679, df = 2, P =0.262, I-square = 25.34%
Total
Q =10.90, df = 3, P = 0.012, I-square = 72.48%

Ann Med. 2017 Jun;49(4):343-351.

(B)

(B) length of ICU stay

Study name	Difference in means	Lower limit	Upper limit	Z-Value	P-Value	Relative Weight
Osawa (2016)	-48.00	-61.97	-34.03	-6.73	0.000	22.174
Fellahi (2015)	1.00	-41.20	43.20	0.05	0.963	15.561
Goepfert (2013)	-19.10	-36.36	-1.84	-2.17	0.030	21.581
Smetkin (2009)	5.00	-19.58	29.58	0.40	0.690	19.984
Mythen (1995)	24.80	3.33	46.27	2.26	0.024	20.699
Subgroup of intratoperative GDT	**-8.48**	**-37.24**	**20.29**	**-0.58**	**0.564**	
Parke (2015)	-3.20	-9.62	3.22	-0.98	0.329	40.190
Kapoor (2008)	-55.20	-81.29	-29.11	-4.15	0.000	14.352
Pölönen (2000)	0.00	-0.20	0.20	0.00	1.000	45.458
Subgroup of postoperative GDT	**-9.21**	**-21.16**	**2.74**	**-1.51**	**0.131**	
Pooled effects	**-9.10**	**-20.14**	**1.93**	**-1.62**	**0.106**	

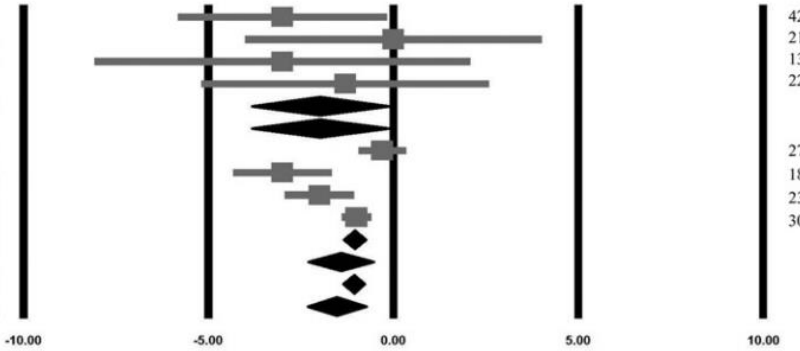


Heterogeneity test:
Subgroup of intratoperative GDT
Q =37.054, df = 4, P < 0.001, I-square = 89.21%
Subgroup of postoperative GDT
Q =18.147, df = 2, P < 0.001, I-square = 88.98%
Total
Q =73.452, df = 7, P < 0.001, I-square = 90.47%

(C)

(C) length of hospital stay.

Study name	Difference in means	Lower limit	Upper limit	Z-Value	P-Value	Relative Weight
Osawa (2016)	-3.00	-5.80	-0.20	-2.10	0.036	42.941
Fellahi (2015)	0.00	-3.99	3.99	0.00	1.000	21.230
Smetkin (2009)	-3.00	-8.05	2.05	-1.16	0.244	13.223
Mythen (1995)	-1.30	-5.16	2.56	-0.66	0.510	22.606
Subgroup of intratoperative GDT (fixed)	**-1.98**	**-3.82**	**-0.14**	**-2.11**	**0.035**	
Subgroup of intratoperative GDT (random)	-1.98	-3.82	-0.14	-2.11	0.035	
Parke (2015)	-0.30	-0.91	0.31	-0.96	0.338	27.504
Kapoor (2008)	-3.00	-4.30	-1.70	-4.51	<0.001	18.666
McKendry (2004)	-2.00	-2.90	-1.10	-4.35	<0.001	23.785
Pölönen (2000)	-1.00	-1.37	-0.63	-5.25	<0.001	30.045
Subgroup of postoperative GDT (fixed)	-1.05	-1.34	-0.75	-7.00	<0.001	
Subgroup of postoperative GDT (random)	**-1.42**	**-2.30**	**-0.54**	**-3.17**	**0.002**	
Pooled effects (fixed)	-1.07	-1.36	-0.78	-7.25	<0.001	
Pooled effects (random)	**-1.52**	**-2.31**	**-0.73**	**-3.77**	**<0.001**	



Heterogeneity test:
Subgroup of intratoperative GDT
Q =1.732, df = 3, P = 0.630, I-square = 0%
Subgroup of postoperative GDT
Q =18.666, df = 3, P < 0.001, I-square = 83.93%
Total
Q =21.362, df = 7, P = 0.003, I-square = 69.237%

Ann Med. 2017 Jun;49(4):343-351.

Journal of Clinical Medicine
MDPI

Perioperative Individualized Goal Directed Therapy for Cardiac Surgery: A Historical-Prospective, Comparative Effectiveness Study

J Clin Med. 2021 Jan 21;10(3):400.

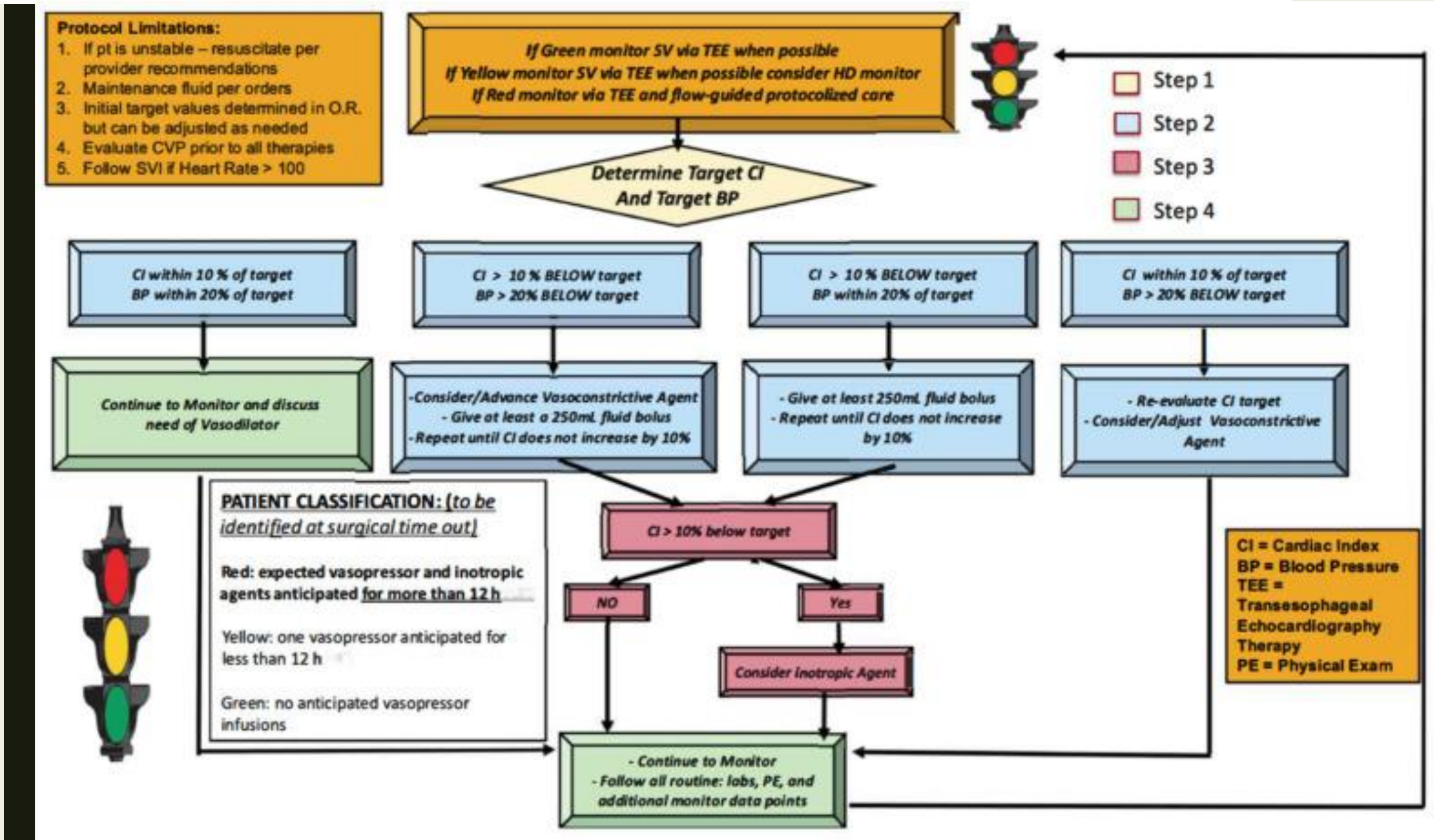


Table 2. Study Outcome Measures. All complications were determined based on electronic health record review for documented diagnosis during ICU stay.

Variable		Group 1 (2017) $n = 175$	Group 2 (2018) $n = 217$	Combined Group 1–2 (2017–2018) $n = 392$	Group 3 (2019) $n = 158$	Comparison Group	95% CI Estimate (Upper, Lower)	p Values
HLOS (in days)	Median (IQR)	7.00 (5.00)	6.00 (5.00)	7.00 (6.00)	6.00 (6.00)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.00 (0.00, 1.00) 0.00 (-5×10^{-5}, 0.00) 0.00 (0.00, 1.00)	0.071 0.609 0.210
ICU LOS (in days)	Median (IQR)	6.19 (4.88)	5.88 (4.46)	6.01 (4.86)	4.00 (3.00)	2017 to 2019 2018 to 2019 2017–2018 to 2019	2.11 (1.87, 2.93) 1.89 (1.13, 2.12) 2.00 (1.55, 2.28)	<0.001 <0.001 <0.001
30 Day Hospital Readmission Yes	Count (Percentage)	61 (35%)	67 (31%)	128 (33%)	52 (33%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.09 (0.67, 1.76) 0.911 (0.57, 1.45) 0.988 (0.67, 1.50)	0.729 0.736 1
Stroke Present	Count (Percentage)	7 (4%)	5 (2%)	12 (3%)	2 (1%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	3.24 (0.60, 32.42) 1.84 (0.30, 19.53) 2.46 (0.54, 22.88)	0.179 0.704 0.369
AKI Present	Count (Percentage)	23 (13%)	27 (12%)	50 (13%)	20 (13%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.044 (0.52, 2.10) 0.98 (0.51, 1.92) 1.01 (0.56, 1.86)	1 1 1
Respiratory Failure Present	Count (Percentage)	14 (8%)	18 (8%)	32 (8%)	10 (6%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.28 (0.51, 3.34) 1.34 (0.56, 3.34) 1.31 (0.61, 3.08)	0.673 0.553 0.595
Surgical Site Infection Present	Count (Percentage)	4 (2%)	6 (3%)	10 (2.5%)	3 (2%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.21 (0.20, 8.38) 1.47 (0.31, 9.21) 1.35 (0.34, 7.74)	1 0.739 0.766
Event (Stroke, AKI, RF, SSI) Present Absent	Count	47 events (7%)	56 events (6%)	104 events (7%)	35 events (5%)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.23 (0.76, 1.99) 1.18 (0.75, 1.87) 1.21 (0.81, 1.85)	0.424 0.512 0.384

HLOS = hospital length of stay; ICU LOS = intensive care unit length of stay; AKI = acute kidney injury; RF = renal failure; SSI = surgical site infection.

Table 3. Amount of vasopressor, blood products and IV fluid administration.

Variable		Group 1 (2017)	Group 2 (2018)	Combined Group 1–2 (2017–2018)	Group 3 (2019)	Comparison Group	95% CI Estimate (Upper, Lower)	*p* Values
Total Norepinephrine (mL)	Median (IQR)	113.46 (239.56)	139.74 (333.01)	120.015 (264.46)	131.25 (302.97)	2017 to 2019 2018 to 2019 2017–2018 to 2019	−24.34 (−71.25, 13.13) −16.8 (−61.92, 29.99) −20.66 (−60.08, 13.19)	0.202 0.431 0.231
Total Phenylephrine (mL)	Median (IQR)	1061.36 (1491.28)	2311.25 (2155.22)	1728.75 (2124.56)	648.75 (834.44)	2017 to 2019 2018 to 2019 2017–2018 to 2019	490.36 (−753.90, 6048.14) 1557.42 (−476.25, 3110.27) 972.90 (−476.25, 2500.90)	0.412 0.214 0.221
Total Milrinone (mL)	Median (IQR)	317.87 (338.30)	310.54 (331.80)	313.17 (333.95)	215.48 (278.62)	2017 to 2019 2018 to 2019 2017–2018 to 2019	103.84 (36.12, 171.30) 88.83 (23.49, 155.49) 95.63 (38.29, 153.48)	<0.01 <0.01 <0.01
Total Epinephrine (mL)	Median (IQR)	165.00 (318.73)	221.32 (330.49)	180.00 (328.11)	180.11 (274.33)	2017 to 2019 2018 to 2019 2017–2018 to 2019	41.39 (−42.25, 108.75) 41.22 (−37.58, 118.00) 41.25 (−22.66, 101.32)	0.271 0.281 0.201
Total Vasopressin (mL)	Median (IQR)	312.00 (909.75)	282.00 (411.00)	300.00 (471.00)	229.50 (342.75)	2017 to 2019 2018 to 2019 2017–2018 to 2019	69.00 (−78.00, 312.00) 72.00 (−48.00 177.00) 71.86 (−39.00, 180.00)	0.344 0.219 0.182
Fresh Frozen Plasma (unit)	Median (IQR)	2.00 (0.75)	1.00 (1.00)	2.00 (1.00)	1.00 (1.00)	2017 to 2019 2018 to 2019 2017–2018 to 2019	0.00 (0.00, 0.00) 0.00 (0.00, 0.00) 0.00 (0.00, 1.00)	0.043 0.831 0.129
Packed Red Blood Cells (unit)	Median (IQR)	4.00 (2.00)	3.00 (2.00)	4.00 (2.00)	2.00(4.00)	2017 to 2019 2018 to 2019 2017–2018 to 2019	0.00 (0.00, 0.00) 0.00 (0.00, 0.00) 0.00 (0.00, 0.00)	0.792 0.665 0.6862
Platelets (unit)	Median (IQR)	2.00 (0.75)	1.00 (0.00)	1.50 (1.00)	1.00 (0.00)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1.00 (0.00, 1.00) NA 0.742 (0.00, 1.00)	0.033 NA 0.095
IV Fluids Intra Op (mL)	Median (IQR)	2481.83 (1256.11)	2167.64 (1042.81)	2290.14 (1153.36)	978.75 (899.63)	2017 to 2019 2018 to 2019 2017–2018 to 2019	1572.65 (1388.23, 1766.17) 1253.40 (1105.80, 1398.33) 1383.05 (1239.96, 1527.90)	<0.001 <0.001 <0.001
IV Fluids ICU (mL)	Median (IQR)	1200.00 (662.50)	1023.75 (800.00)	1100.00 (750.00)	2274.02 (1043.42)	2017 to 2019 2018 to 2019 2017–2018 to 2019	−1117.98 (−1293.80, −949.85) −1224.90 (−1393.80, −1065.88) −1177.88 (−1324.74, −1028.34)	<0.001 <0.001 <0.001
IV Fluids Total (mL)	Median (IQR)	3788.31 (1481.48)	3307.18 (1336.39)	3473.23 (1363.17)	3309.93 (1285.78)	2017 to 2019 2018 to 2019 2017–2018 to 2019	346.65 (83.46, 613.74) 9.96 (−244.67, 255.33) 160.37 (−71.67, 386.17)	0.011 0.951 0.171

Table 1
Notable cardiac surgery GDT studies

Reference	Location	No. of Patients	Design	Intervention	Primary End Point	Major Findings
Pölönen et al,[72] 2000	Kuopio, Finland	N = 393 (196 in protocol group; 197 in control group)	Randomized controlled trial	GDT guided by lactate and hemodynamics	Hospital and ICU LOS	Median hospital LOS reduced in the protocol group (6 d vs 7 d; *P*<.05) Less-frequent morbidity in the protocol group (1.1% vs 6.1%, *P*<.01)
Meersch et al,[67] 2017	Münster, Germany	N = 276 (138 in intervention group; 138 in control group)	Randomized controlled trial	KDIGO bundle, urinary biomarkers after cardiac surgery	AKI within 72 h after cardiac surgery	AKI reduced in intervention group (55% vs 72%, *P* = .004)
Kapoor et al,[73] 2017	New Delhi and Gurgaon, India	N = 163 (75 in GDT group; 88 in control group)	Randomized, prospective; 2 centers	GDT with hemodynamic management	Duration of mechanical ventilation, inotropic support, and ICU and hospital LOS	ICU LOS (2.5 d vs 4.2 d, *P*<.001) and hospital LOS (5.6 d vs 7.4 d, *P*<.001) reduced in GDT group Duration of inotropes (2.9 h vs 3.2 h, *P* = .005) reduced in GDT group
Goepfert et al,[74] 2007	Munich, Germany	N = 80 (40 in GDT group; 40 in control group)	Prospective vs historical control	GDT hemodynamic management guided by GEDVI	Vasopressors, catecholamines, fluid administration, mechanical ventilation, LOS	GDT decreased the need for vasopressors (187 min vs 1458 min, *P*<.01), catecholamines (0.01 mg vs 0.8 mg, *P*<.01), mechanical ventilation (12.6 h vs 15.4 h, *P* = .002), and reduced ICU LOS (25 h vs 33 h, *P* = .03)
Johnston et al,[75] 2019	Virginia, USA	N = 1979 (725 in pre-QI group; 1254 in post-QI group)	Observational, retrospective; multicenter	QI initiative: GDT volume resuscitation	Rate of AKI by RIFLE criteria	GDT group had less renal injury or failure (7.8% vs 12.4%, *P* = .001)

Innovation & Research

- Novel data sources, improved data management, advanced analytics
  - ➔ extend insights into risk-assessment & tx. strategies

- DeepMind's AI AKI research study
  - *Investigated 703,782 patients*
  - *Developed a model providing up to 48hrs of advance warning*
    - ➔ *Predicted*
      - *55.8% of AKIs overall & 90.2% of AKIs require dialysis*

Google Algorithm Aims to Identify At-Risk Kidney Injury Patients

DeepMind unit's effort marks new application of machine learning in health care, but experts say model needs further testing before being applied in a live hospital setting

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July 31, 2019 1:00 pm ET

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The Streams app can use AI-powered software to detect the risk of kidney damage. PHOTO: DEEPMIND

Conclusions

- Goal directed hemodynamic & fluid therapy (GDT) is a standardized algorithm to achieve adequate oxygen delivery to the tissues
- GDT-directed hemodynamic therapy may reduce postoperative complications & length of ICU/hospital stay
- Guidelines strongly recommended GDT guided resuscitation after cardiac surgery
- Much work remains for GDT to be both personalized & comprehensive, adopting novel biomarkers/biosensors, big data, analytical/decision support information technology.