Set your intravascular volume right

Jost Mullenheim

James Cook University Hospital, Middlesbrough

Set your intravascular volume right

- -Why ?
- -When ?
- -Which parameters should be used ?
  - Filling pressures
  - Dynamic parameters
  - Venous blood gas analysis

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Shock = imbalance of oxygen delivery and tissue demands

↓

CO x oxygen content

↓

SV x HR

↓

Preload

Afterload

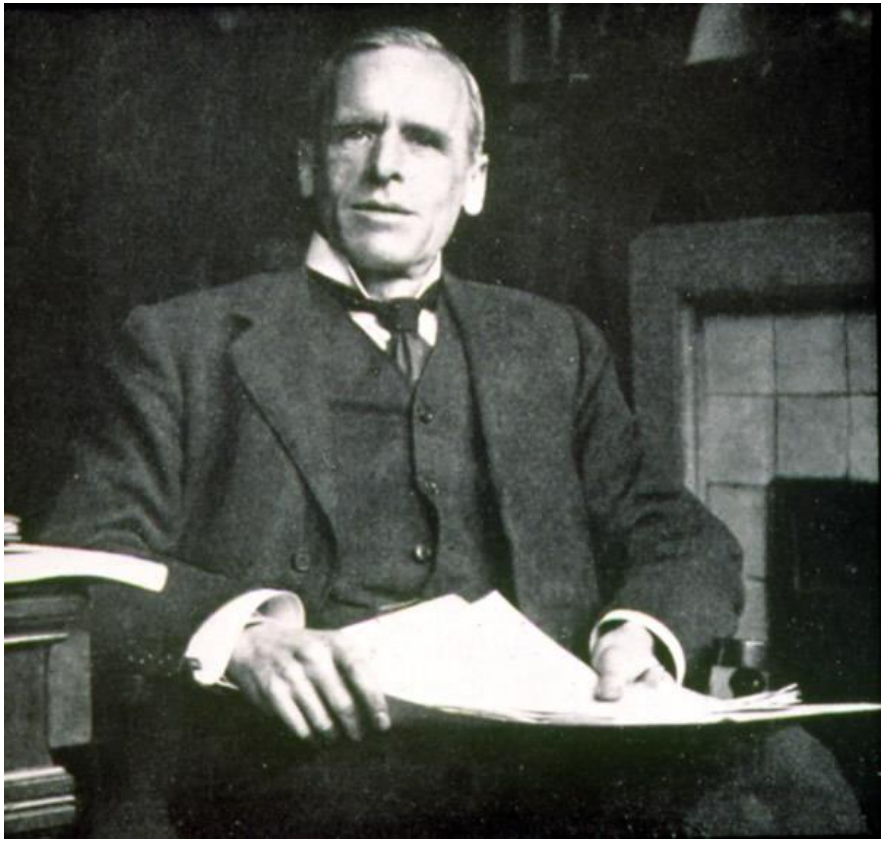
Inotropy

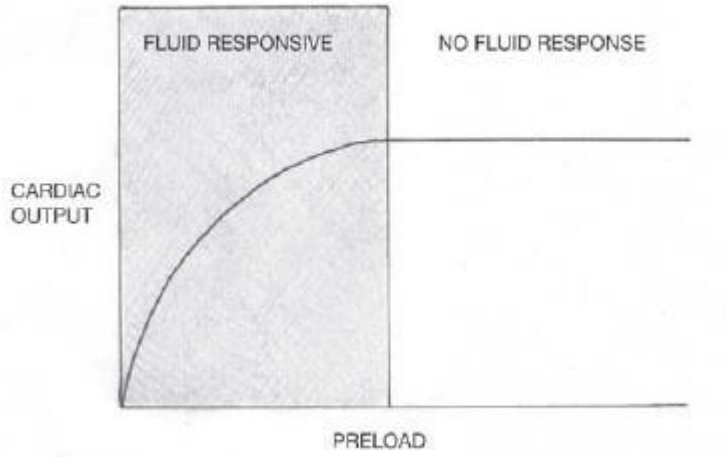
Does the patient respond to fluid with an increase in SV ?

Only 50 % of haemodynamically unstable patients will do so

~~Set your intravascular volume right~~

Predicting fluid responsiveness





"This relation between the length of the heart fibre and its power of contraction I have called `the law of the heart`"

Starling EH: The Linacre Lecture on the Law of the Heart. London: Longmans, Green and Co.,1918;(a) pp.26-27

Carl Ludwig (1816-1895), Leipzig, Germany

1856: “…filling of the heart with blood changes the extent of contractile power”

(Ludwig CFW: Lehrbuch der Physiologie des Menschen. Vol 2. Leipzig, Germany: CF Winter;1852-6;73)

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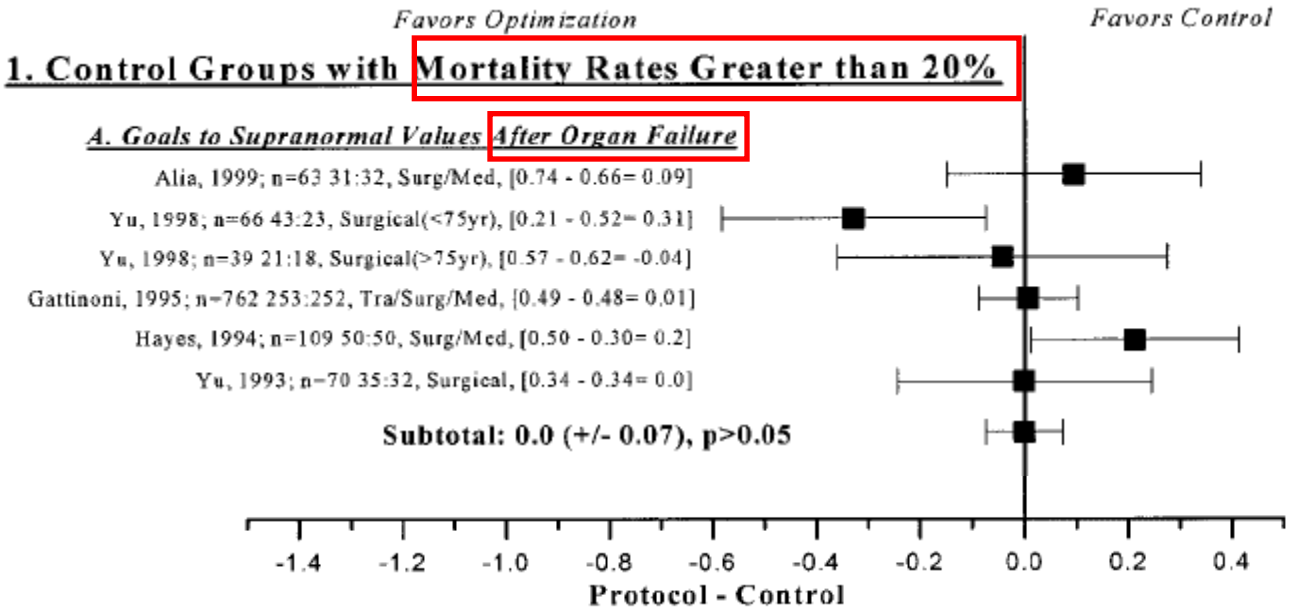
Optimisation for everybody ?

Meta-analysis of hemodynamic optimization in high-risk patients*

Jack W. Kern, PharmD; William C. Shoemaker, MD

Crit Care Med 2002; 30:1686-1692



Optimisation of high risk patients

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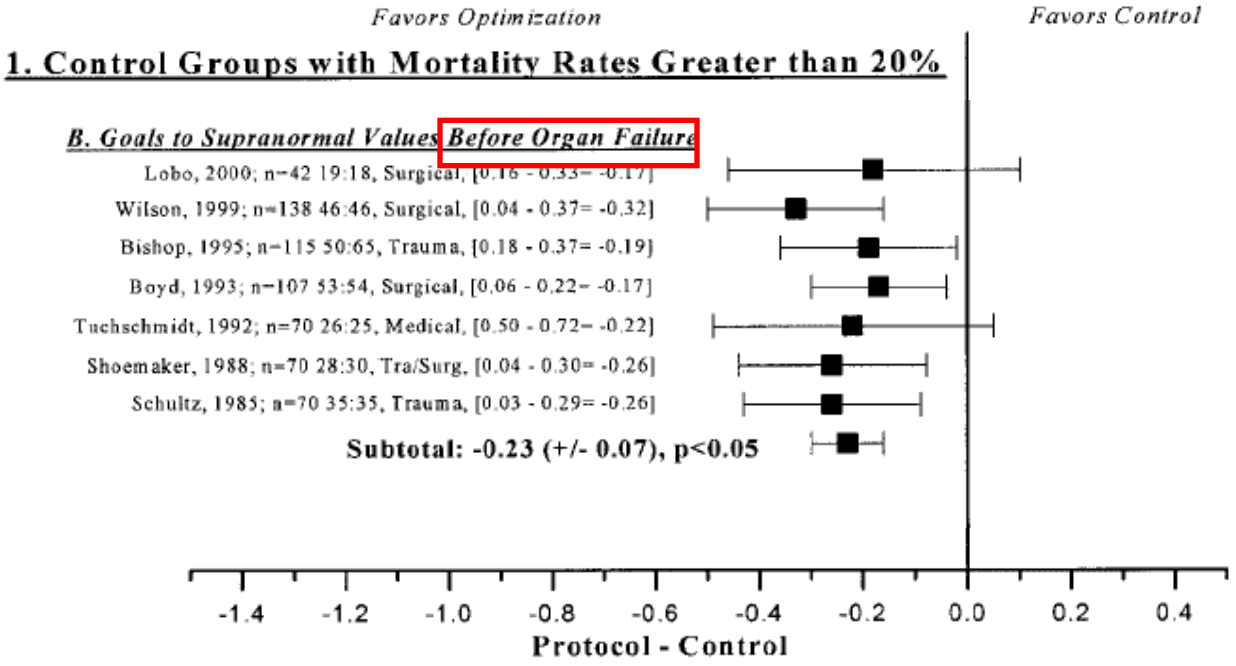

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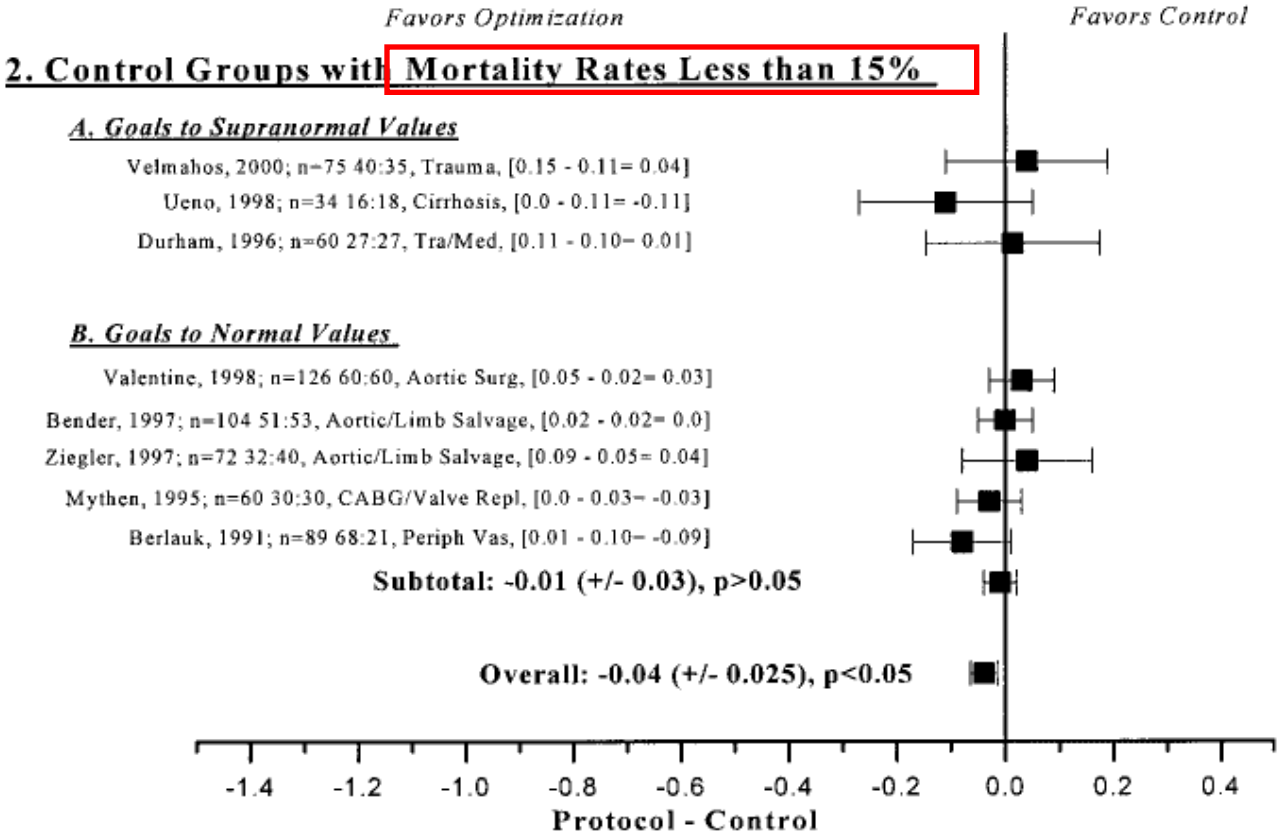

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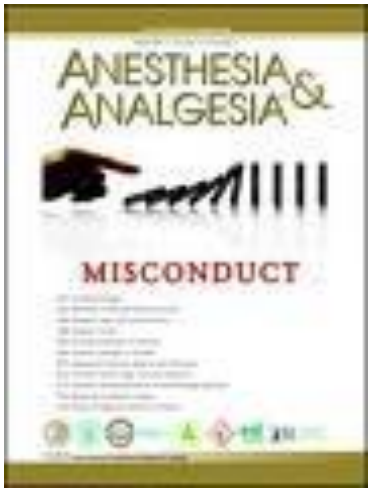

Boldt J et al. Volume replacement strategies on intensive care units: results from a postal survey.
Intensive Care Med 1998;24:147-151

>90% use CVP to guide fluid resuscitation

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association®
Learn and Live℠

2009 Focused Update Incorporated Into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: Developed in Collaboration With the International Society for Heart and Lung Transplantation

2005 WRITING COMMITTEE MEMBERS, Sharon Ann Hunt, William T. Abraham, Marshall H. Chin, Arthur M. Feldman, Gary S. Francis, Theodore G. Ganiats, Mariell Jessup, Marvin A. Konstam, Donna M. Mancini, Keith Michl, John A. Oates, Peter S. Rahko, Marc A. Silver, Lynne Warner Stevenson and Clyde W. Yancy

Circulation 2009;119;e391-e479; originally published online Mar 26, 2009;
DOI: 10.1161/CIRCULATIONAHA.109.192065
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 72514
 Print ISSN: 0009-7322. Online ISSN: 1524-4539

Class I recommendation

Invasive hemodynamic monitoring should be performed to guide therapy in patients who are in respiratory distress or with clinical evidence of impaired perfusion in whom the adequacy or excess of intracardiac filling pressures cannot be determined from clinical assessment. (*Level of Evidence: C*)

Surviving Sepsis Campaign: International guidelines for management of severe sepsis and septic shock: 2008*

R. Phillip Dellinger, MD; Mitchell M. Levy, MD; Jean M. Carlet, MD; Julian Bion, MD; Margaret M. Parker, MD; Roman Jaeschke, MD; Konrad Reinhart, MD; Derek C. Angus, MD, MPH; Christian Brun-Buisson, MD; Richard Beale, MD; Thierry Calandra, MD, PhD; Jean-Francois Dhainaut, MD; Herwig Gerlach, MD; Maurene Harvey, RN; John J. Marini, MD; John Marshall, MD; Marco Ranieri, MD; Graham Ramsay, MD; Jonathan Sevransky, MD; B. Taylor Thompson, MD; Sean Townsend, MD; Jeffrey S. Vender, MD; Janice L. Zimmerman, MD; Jean-Louis Vincent, MD, PhD; for the International Surviving Sepsis Campaign Guidelines Committee

Initial resuscitation (first 6 hrs)

- Begin resuscitation immediately in patients with hypotension or elevated serum lactate >4 mmol/L; do not delay pending ICU admission (1C)
- Resuscitation goals (1C)
  CVP 8–12 mm Hg[a]
  Mean arterial pressure ≥ 65 mm Hg
  Urine output ≥0.5 $mL \cdot kg^{-1} \cdot hr^{-1}$
  Central venous (superior vena cava) oxygen saturation ≥70% or mixed venous ≥65%
  - If venous oxygen saturation target is not achieved (2C)
    Consider further fluid
    Transfuse packed red blood cells if required to hematocrit of ≥30% and/or
    Start dobutamine infusion, maximum 20 $\mu g \cdot kg^{-1} \cdot min^{-1}$

[a]A higher target CVP of 12–15 mm Hg is recommended in the presence of mechanical ventilation or preexisting decreased ventricular compliance.

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Table 4. Hemodynamic support and adjunctive therapy

Strength of recommendation and quality of evidence have been assessed using the GRADE criteria, presented in parentheses after each guideline.

- ● Indicates a strong recommendation, or "we recommend"
- ○ Indicates a weak recommendation, or "we suggest"

Fluid therapy

- ● Fluid-resuscitate using crystalloids or colloids (1B)
- ● Target a CVP of ≥8 mm Hg (≥12 mm Hg if mechanically ventilated) (1C)
- ● Use a fluid challenge technique while associated with a hemodynamic improvement (1D)
- ● Give fluid challenges of 1000 mL of crystalloids or 300–500 mL of colloids over 30 mins. More rapid and larger volumes may be required in sepsis-induced tissue hypoperfusion (1D)
- ● Rate of fluid administration should be reduced if cardiac filling pressures increase without concurrent hemodynamic improvement (1D)

1: strong recommendation

C: quality of evidence = well done observational studies

Accurate measurement of CVP is difficult

Error in Central Venous Pressure Measurement

Katie K. Figg, MD*

Edward C. Nemergut, MD*†

BACKGROUND: The variability introduced by inconsistent placement of pressure transducers for invasive monitoring may result in significant measurement error. Our goals in this study were to quantify the degree of variation among health care providers and to identify a simple tool for reducing this error.

METHODS: A sample of 50 perioperative health care providers was recruited and asked to place a transducer at the appropriate level for central venous pressure (CVP) monitoring on two separate occasions: first without any additional standardization tools and second with a laser level to guide transducer placement. The variability among providers was calculated, and the results between sessions compared.

RESULTS: There was significant variation in transducer placement during both sessions, in some instances, of greater magnitude than a normal CVP value. The laser level did not significantly reduce this variation.

CONCLUSION: There is significant variation in transducer placement among health care providers. This variation is not reduced by a laser level and must be considered when interpreting CVP data. Hospital- or institution-wide standardization of a zero-level should be considered.

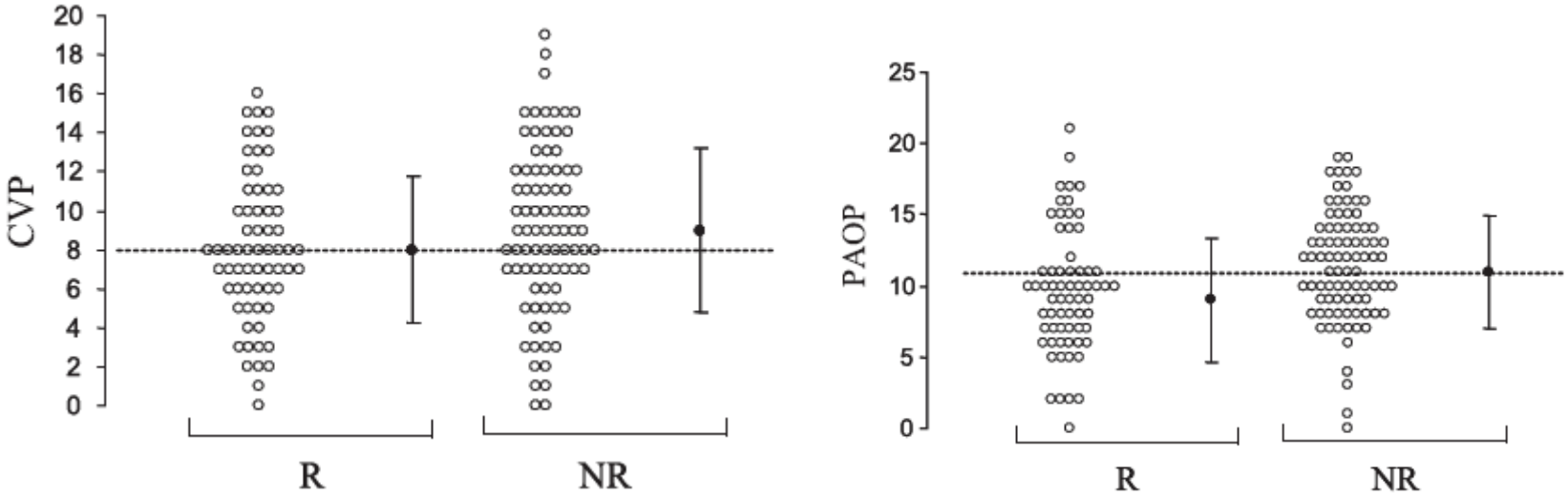
(Anesth Analg 2009;108:1209–11)

— *Anesth Analg 2009;108:1209-11*

Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge*

David Osman, MD; Christophe Ridel, MD; Patrick Ray, MD; Xavier Monnet, MD, PhD; Nadia Anguel, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2007; 35:64-68



CVP < 8 predicted fluid responsiveness with positive predictive value of 47 %

PAOP < 12 predicted fluid responsiveness with positive predictive value of 54 %

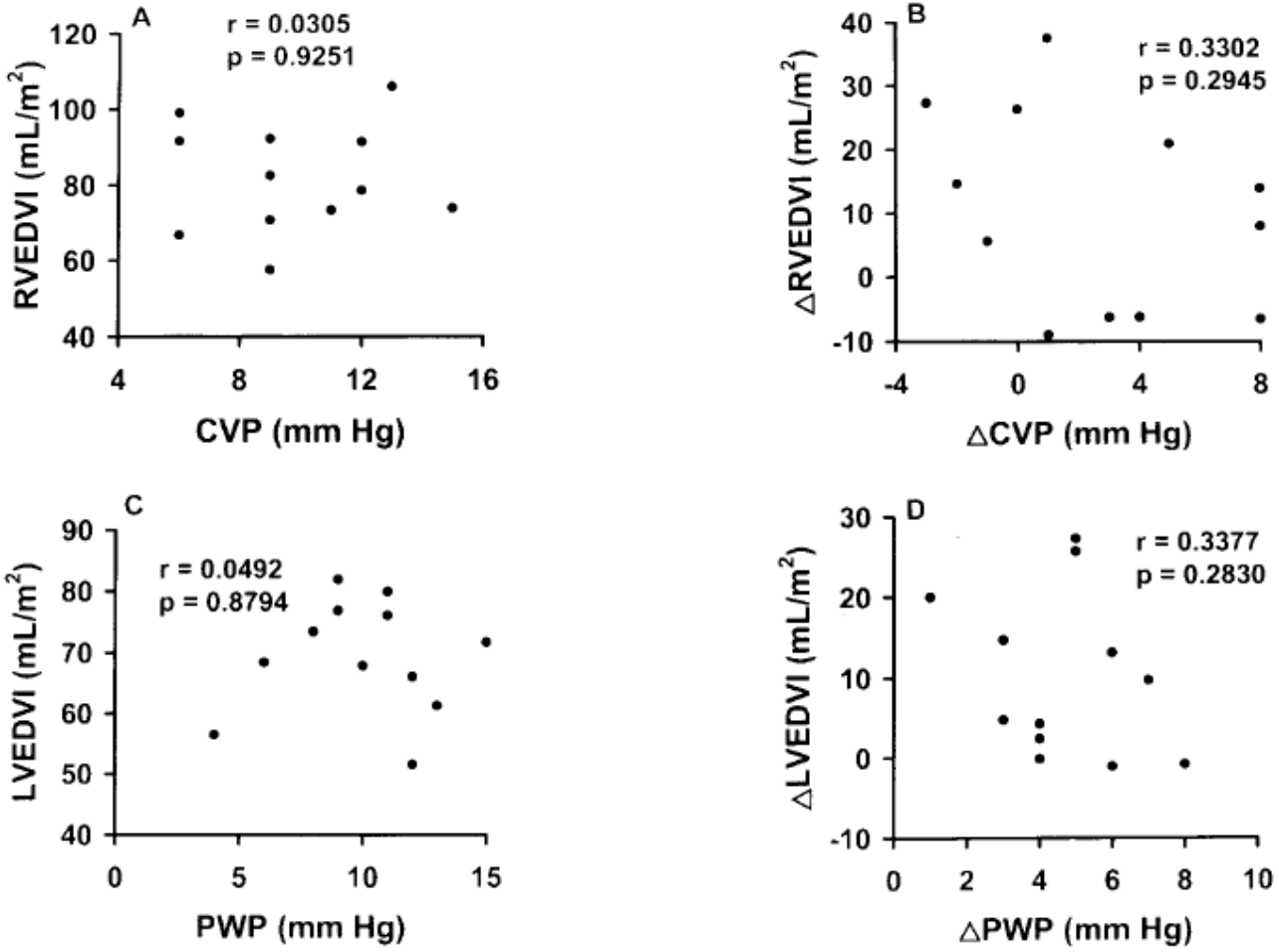
Pulmonary artery occlusion pressure and central venous pressure fail to predict ventricular filling volume, cardiac performance, or the response to volume infusion in normal subjects

Anand Kumar, MD; Ramon Anel, MD; Eugene Bunnell, MD; Kalim Habet, MD, MD; Sergio Zanotti, MD; Stephanie Marshall, RN; Alex Neumann, MS; Amjad Ali, MD; Mary Cheang, MS; Clifford Kavinsky, MD, PhD; Joseph E. Parrillo, MD

Kumar A et al. Crit Care Med. 2004 Mar;32(3):691-9.

Healthy volunteers

3L NaCl 0.9% over 3 h



Does Central Venous Pressure Predict Fluid Responsiveness? * : A Systematic Review of the Literature and the Tale of Seven Mares

Paul E. Marik, Michael Baram and Bobbak Vahid

Chest 2008;134;172-178
DOI 10.1378/chest.07-2331

24 studies included, 803 patients

5 studies compared CVP with measured circulating blood volume

-pooled correlation coefficient 0.16

19 studies: relationship between CVP/ΔCVP and SV/CI following fluid challenge

-pooled correlation coefficient between baseline CVP and change in SV/CI post fluid challenge 0.18 (pooled area under ROC curve 0.56)

-pooled correlation coefficient between ΔCVP and change in SV/CI post fluid challenge 0.11 (pooled area under ROC curve 0.56)

Conclusions: This systematic review demonstrated a very poor relationship between CVP and blood volume as well as the inability of CVP/ΔCVP to predict the hemodynamic response to a fluid challenge. CVP should not be used to make clinical decisions regarding fluid management.

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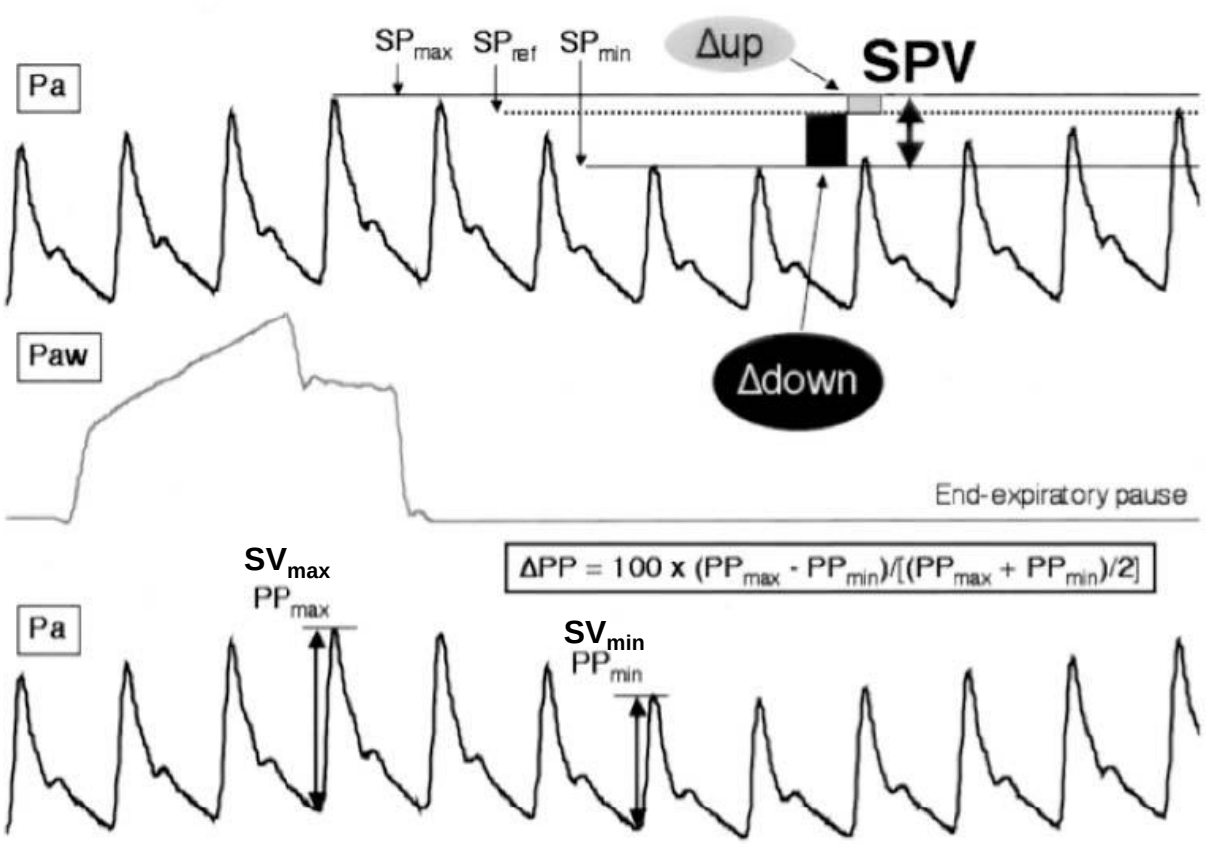
Predicting fluid responsiveness: “Dynamic parameters”

-only 50 % of haemodynamically unstable patients are fluid responsive



Michard F: Anesthesiology 103;419-28, 2005

Review Article

Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: A systematic review of the literature*

Paul E. Marik, MD, FCCM; Rodrigo Cavallazzi, MD; Tajender Vasu, MD; Amyn Hirani, MD

Crit Care Med 2009; 37:2642-2647

29 studies enrolling 685 patients

mean threshold values: PPV 12.5 %, SVV 11.6 %

ROC 0.55 for CVP

Limitations of dynamic parameters

-invasive

-expensive equipment

-controlled mechanical ventilation, no spontaneous breathing effort

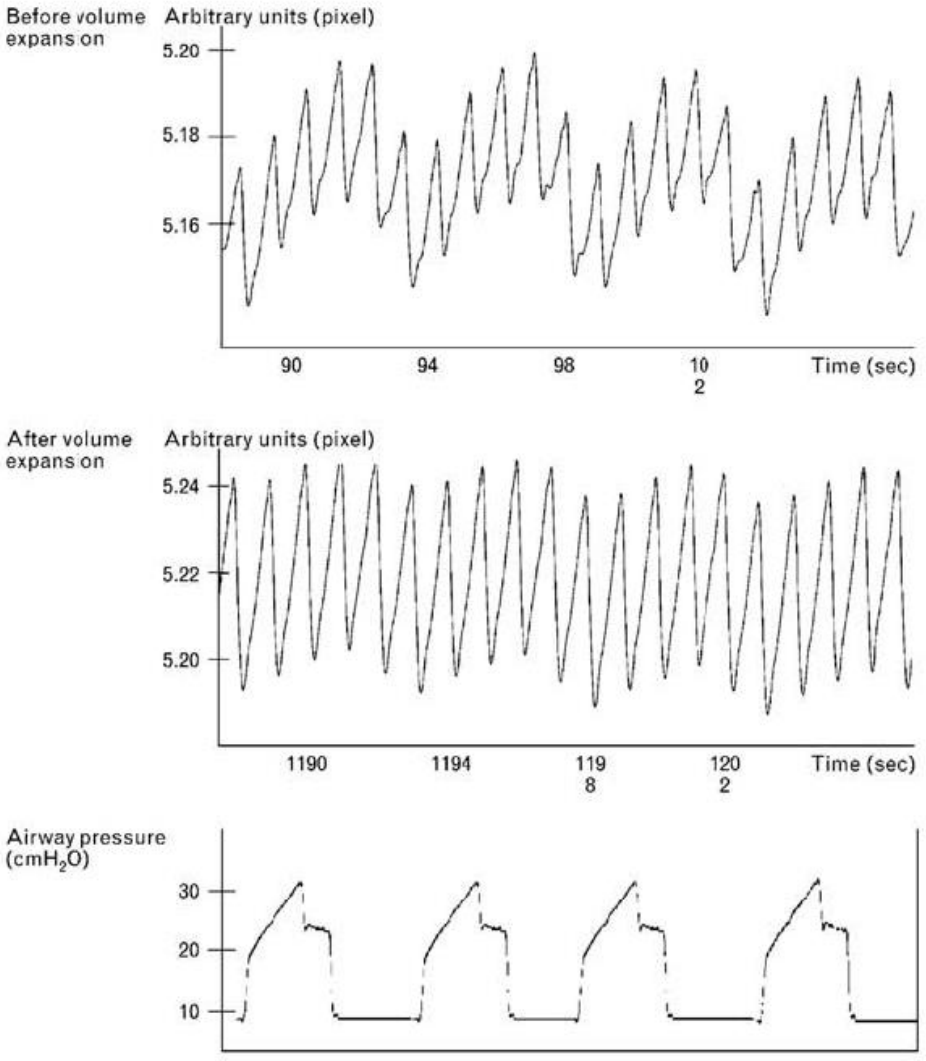
-Vt ≥ 8ml/kg

-no significant arrhythmias (AF, multiple premature extra beats)

-HR/RR > 3.6

-cor pulmonale

Respiratory variation in pulse oximetry waveform amplitude



Curr Opin Anesthesiol 2008; 21:772-8

Respiratory variation in pulse oximetry waveform amplitude

PVI = Pleth Variability Index

Theatre: PVI > 14% predicts fluid responsiveness

Cannesson M et al., BJA 2008;101:200-6

PVI in ICU patients

-30 patients with septic shock, on vasopressors

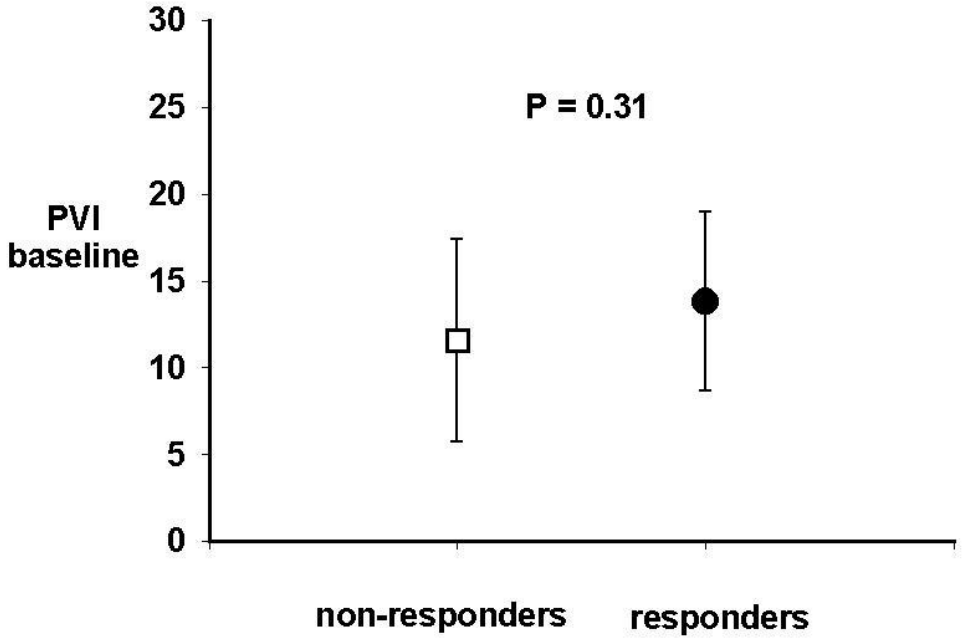
-sinus rhytm

-controlled ventilation, Vt ≥ 8ml/kg

-HR/RR > 3.6

-no cor pulmonale

-500 ml colloid over 30 min



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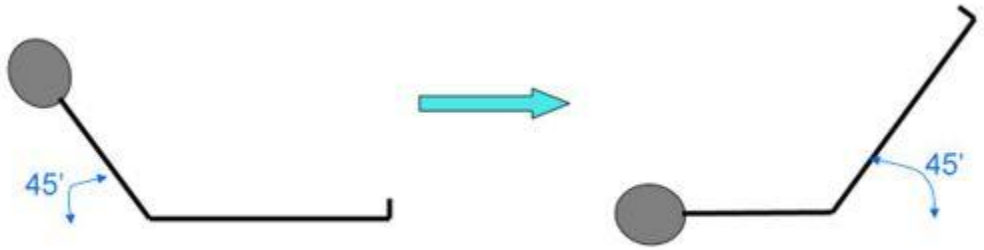
Solution ??

Passive leg raising (PLR) = transient and reversible “auto fluid challenge”



Fast response measurement of flow:

ΔSV or Δaortic blood flow ≥ 10 % predicts fluid responsiveness in spontaneously breathing ICU patients even in the presence of arrhythmias

(Monnet X et al., Crit Care Med 2006;34:1402-7; Preau S et al., Crit Care Med 2010;38:819-25)

ΔPP ??

Cave: Intraabdominal pressure > 16: false negative

(Mahjoub Y et al, Crit Care Med 2010;38:1824-9)

Limitations of dynamic parameters

-invasive

-expensive equipment

-controlled mechanical ventilation, no spontaneous breathing effort

-Vt ≥ 8ml/kg

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Venous oxygen saturation

$$\bullet \sout{SvO_2} = S_aO_2 - \frac{\dot{V}O_2}{Q \times CaO_2}$$

$$\bullet Sv_cO_2 = S_aO_2 - \frac{\dot{V}O_2}{Q \times CaO_2}$$

-$SvcO_2$ is in average 5 -10 % higher in ICU patients with shock

(Reinhart K et al., Intensive Care Med 2004;30:1572-8; Lee J et al., Anesthesiology 1972;36:472-8; Scheinman MM et al., Circulation 1969;11:165-72)

-However, the difference can range from -18 to +22 % (95% limits of agreement)

*(*Martin C et al., Intensive Care Med 1992;18:101-4; Edwards JD et al., Crit Care Med 1998;26:1356-60; Varpula M et al., Intensive Care Med 2006;32:1336-43))

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  Urine output ≥0.5 mL·kg^{-1}·hr^{-1}
  Central venous (superior vena cava) oxygen saturation ≥70% or mixed venous ≥65%
- If venous oxygen saturation target is not achieved (2C)
  Consider further fluid
  Transfuse packed red blood cells if required to hematocrit of ≥30% and/or
  Start dobutamine infusion, maximum 20 μg·kg^{-1}·min^{-1}

[a]A higher target CVP of 12–15 mm Hg is recommended in the presence of mechanical ventilation or preexisting decreased ventricular compliance.

Central venous oxygen saturation trend analysis

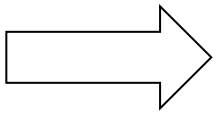
$$\bullet SvO_2 = S_aO_2 - \frac{\dot{V}O_2}{Q \times CaO_2}$$

-SvO_2 correlates well with CI

- *(Lee J et al., Anesthesiology 1972;36:472-8;*

-trend in $SvcO_2$ follows trend in SvO_2 closely

(Lee J et al., Anesthesiology 1972;36:472-8; Reinhart K et al., Chest 1989;95:1216-21; Dueck MH et al., Anesthesiology 2005;103:249-57)



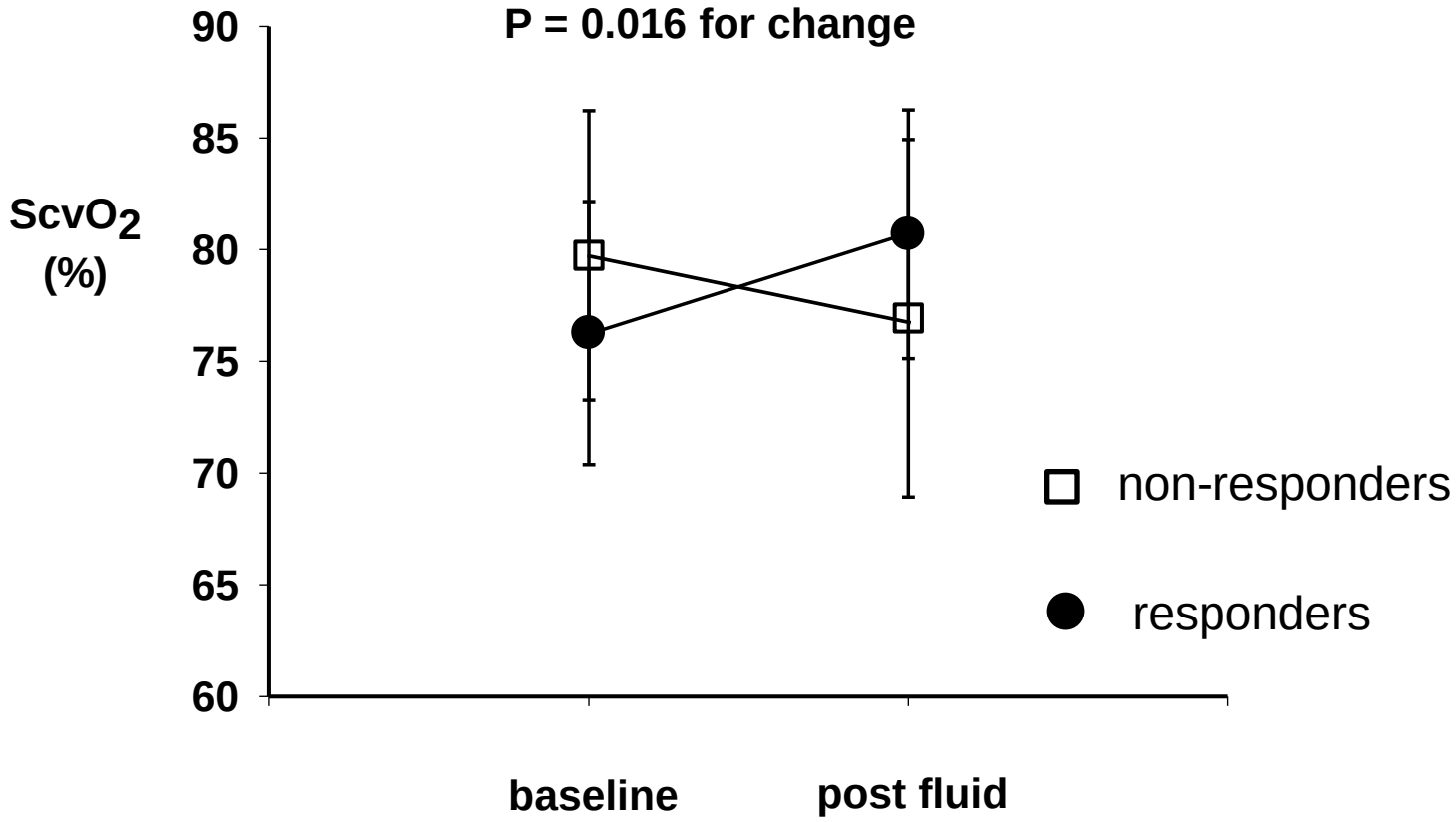
-trend in $SvcO_2$ might follow trend in CI

(post cardiac surgery: Yazigi A et al., Acta Anaesthesiol Scand 2008;52:1213-7)

Does the change in $SvcO_2$ in response to a fluid challenge correlate with the change in CI in septic patients ?

-30 ventilated patients with septic shock on vasopressors

-500 ml colloid over 30 min



Arterial-mixed venous pCO_2 difference

CO_2 production = $avDCO_2$ x Q

-Close negative correlation with CI

(Cuschieri J et al, Intensive Care Med 2005;31:818-22)

-Change in this difference correlates with change in CI after fluid

(Mecher CE et al., Crit Care Med 1990;18:585-9)

Arterial-~~mixed~~ central venous pCO_2 difference

-Close negative correlation with CI

(Cuschieri J et al, Intensive Care Med 2005;31:818-22)

-Is the trend in arterial-central venous pCO_2 difference inversely correlated with the change in CI after fluid loading ?

Summary

-optimisation of stroke volume needed ?

-only 50 % of patients will respond to a fluid challenge

-predicting fluid responsiveness 

-filling pressures 

-dynamic parameters PPV, SVV, SPV  PVI 

cave: limitations (spontaneous breathing, Vt > 8 ml/kg, arrhythmias, cor pulmonale, HR/RR > 3.6)

-Passive leg raising : flow response  ΔPP?

-$SvcO_2$ trend in response to fluid  rather than single numbers

-trend in arterial-central venous pCO_2 difference ?

The New England Journal of Medicine

EARLY GOAL-DIRECTED THERAPY IN THE TREATMENT OF SEVERE SEPSIS AND SEPTIC SHOCK

EMANUEL RIVERS, M.D., M.P.H., BRYANT NGUYEN, M.D., SUZANNE HAVSTAD, M.A., JULIE RESSLER, B.S., ALEXANDRIA MUZZIN, B.S., BERNHARD KNOBLICH, M.D., EDWARD PETERSON, PH.D., AND MICHAEL TOMLANOVICH, M.D., FOR THE EARLY GOAL-DIRECTED THERAPY COLLABORATIVE GROUP* *NEJM 2001; 345:1368-77*

	Total fluids (0-6 h)	CVP (average 0-6 h)
control	3499±2438	10.5±6.8
EGDT	4981±298 (P<0.001)	11.7±5.1 (P=0.22)

TABLE 2. VITAL SIGNS, RESUSCITATION END POINTS, ORGAN-DYSFUNCTION SCORES, AND COAGULATION VARIABLES.*

VARIABLE AND TREATMENT GROUP	BASE LINE (0 hr)	HOURS AFTER START OF THERAPY		
		6	0–6†	7–72‡
Heart rate (beats/min)				
Standard therapy	114±27	105±25	108±23	99±18
EGDT	117±31	103±19	105±19	96±18
P value	0.45	0.12	0.25	0.04
Central venous pressure (mm Hg)				
Standard therapy	6.1±7.7	11.8±6.8	10.5±6.8	11.6±6.1
EGDT	5.3±9.3	13.8±4.4	11.7±5.1	11.9±5.6
P value	0.57	0.007	0.22	0.68
Mean arterial pressure (mm Hg)				
Standard therapy	76±24	81±18	81±16	80±15
EGDT	74±27	95±19	88±16	87±15
P value	0.60	<0.001	<0.001	<0.001
Central venous oxygen saturation (%)				
Standard therapy	49.2±13.3	66.0±15.5	65.4±14.2	65.3±11.4
EGDT	48.6±11.2	77.3±10.0	71.6±10.2	70.4±10.7
P value	0.49	<0.001	<0.001	<0.001
Lactate (mmol/liter)				
Standard therapy	6.9±4.5	4.9±4.7	5.9±4.2	3.9±4.4
EGDT	7.7±4.7	4.3±4.2	5.5±4.2	3.0±4.4
P value	0.17	0.01	0.62	0.02
Base deficit (mmol/liter)				
Standard therapy	8.9±7.5	8.0±6.4	8.6±6.0	5.1±6.7
EGDT	8.9±8.1	4.7±5.8	6.7±5.6	2.0±6.6
P value	0.81	<0.001	0.006	<0.001
Arterial pH				
Standard therapy	7.32±0.19	7.31±0.15	7.31±0.12	7.36±0.12
EGDT	7.31±0.17	7.35±0.11	7.33±0.13	7.40±0.12
P value	0.40	<0.001	0.26	<0.001
APACHE II score				
Standard therapy	20.4±7.4	17.6±6.2	—	15.9±6.4
EGDT	21.4±6.9	16.0±6.9	—	13.0±6.3
P value	0.27	<0.001		<0.001
MODS				
Standard therapy	7.3±3.1	6.8±3.7	—	6.4±4.0
EGDT	7.6±3.1	5.9±3.7	—	5.1±3.9
P value	0.44	<0.001		<0.001
Hematocrit (%)				
Standard therapy	34.7±8.5	32.0±6.9	—	30.1±4.1
EGDT	34.6±8.3	33.3±4.8	—	32.1±4.2
P value	0.91	0.03		<0.001
Prothrombin time (sec)				
Standard therapy	16.5±6.3	17.5±8.1	—	17.3±6.1
EGDT	15.8±5.0	16.0±3.6	—	15.4±6.1
P value	0.17	0.02		0.001
Partial-thromboplastin time (sec)				
Standard therapy	32.9±12.0	37.6±21.0	—	37.0±14.2
EGDT	33.3±20.4	32.6±8.7	—	34.6±14.1
P value	0.17	0.01		0.06
Fibrinogen (mg/dl)				
Standard therapy	361±198	319±142	—	358±134
EGDT	370±209	300±157	—	342±134
P value	0.51	0.01		0.21
Fibrin-split products (μg/dl)				
Standard therapy	39.0±61.6	54.9±84.0	—	62.0±71.4
EGDT	44.8±71.3	45.8±66.0	—	39.2±71.2
P value	0.76	0.13		<0.001
D-Dimer (μg/ml)				
Standard therapy	3.66±8.45	5.48±11.95	—	5.65±9.06
EGDT	4.46±10.70	3.98±9.41	—	3.34±9.02
P value	0.71	0.05		0.006
Platelet count (per mm³)				
Standard therapy	205,000± 110,000	164,000± 84,000	—	144,000± 84,000