PULSION Medical Systems

PiCCO Technology Literature

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- Very highly recommended
- Highly recommended
- Recommended

'This document is intended to provide information to an international audience outside of the US'
1. Reviews

1.1 General
Assaad S, Popescu W, Perrino A
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Anaesthesist 2005; 54:1135-53

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**How to measure and interpret volumetric measures of preload**
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*Bedside assessment of extravascular lung water by dilution methods: temptations and pitfalls*

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*Extravascular lung water measurements and hemodynamic monitoring in the critically ill: bedside alternatives to the pulmonary artery catheter*
Am J Physiol Lung Cell Mol Physiol 2006; 291: 1118-33

1.5 Pediatric
Lemson J, Nusmeier A, van der Hoeven JG
*Advanced Hemodynamic Monitoring in Critically Ill Children*
Pediatrics 2011; 128(3): 560-71

2. Guidelines and Standard Operating Procedures
*Prevention, diagnosis, treatment, and follow-up care of sepsis. First revision of the S2k Guidelines of the German Sepsis Society (DSG) and the German Interdisciplinary Association for Intensive and Emergency Care Medicine (DIVI)]*
Anaesthesist 2010; 59(4): 347-70

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*2007 American College of Critical Care Medicine clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock*
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Intensive Care Med 2008; 34(1): 17-60

Kortgen A, Niederprün P, Bauer M.
Implementation of an evidence-based „standard operating procedure“ and outcome in septic shock

3. Outcome papers

Lu NF, Zheng RQ, Lin H, Shao J, Yu JQ, Yang G
Improved sepsis bundles in the treatment of septic shock: a prospective clinical study

Early Intensive Versus Minimally Invasive Approach to Postoperative Hemodynamic Management After Subarachnoid Hemorrhage
Stroke 2014; 45(5): 1280-4

Extravascular lung water and pulmonary arterial wedge pressure for fluid management in patients with acute respiratory distress syndrome
Multidiscip Respir Med 2014; 9(1): 3

Individually Optimized Hemodynamic Therapy Reduces Complications and Length of Stay in the Intensive Care Unit: A Prospective, Randomized Controlled Trial
Anesthesiology 2013; 119(4); 824-36

Optimized fluid management improves outcomes of pediatric burn patients

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Resuscitation 2013; 84(2): 194-9

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Influence of extravascular lung water determination in fluid and vasoactive therapy
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Performance of Bedside Transpulmonary Thermodilution Monitoring for Goal-Directed Hemodynamic Management After Subarachnoid Hemorrhage
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Csontos C, Foldi V, Fischer T, Bogar L.
Arterial thermodilution in burn patients suggests a more rapid fluid administration during early resuscitation.
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Goal directed fluid management reduces vasopressor and catecholamine use in cardiac surgery patients
Intensive Care Medicine 2007; 33: 96-103
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Mitchell JP, Schuller D, Calandrino FS, Schuster DP.
Improved outcome based on fluid management in critically ill patients requiring pulmonary artery catheterization
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4a PiCCO PARAMETERS – METHODOLOGY

4a.1 FLOW (Cardiac Output)
Smith JA, Camporota L, Beale R
Monitoring arterial blood pressure and cardiac output using central or peripheral arterial pressure waveforms
Yearbook of Intensive and Emergency Medicine 2009; 285 - 296
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Segal E, Katzenelson R, Berkenstadt H, Perel A.
Transpulmonary thermodilution cardiac output measurement using the axillary artery in critically ill patients
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Sakka SG, Meier-Hellmann A.
Evaluation of cardiac output and cardiac preload
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4a.2  PRELOAD (Global End Diastolic Volume and Intrathoracic Blood Volume)
Volumetric preload measurement by thermodilution: a comparison with transoesophageal echocardiography
Br J Anaesth 2005; 94(6): 748-55

Buhre W, Buhre K, Kazmaier S, Sonntag H, Weyland A.
Assessment of cardiac preload by indicator dilution and transoesophageal echocardiography
Eur J Anaesthesiol 2001; 18(10): 662-7

McLuckie A, Bihari D.
Investigating the relationship between intrathoracic blood volume index and cardiac index
Intensive Care Med 2000; 26(9): 1376-8

4a.3  CONTRACTILITY (Global Ejection Fraction, Cardiac Function Index and Left Ventricular Contractility)
Michard F, Perel A.
Management of circulatory and respiratory failure using less invasive hemodynamic monitoring
In: Vincent JL (Ed.), Yearbook of Intensive Care and Emergency Medicine 2003; 508-20

Evaluation of the cardiac function index as a new bedside indicator of cardiac performance
Intensive Care Med 1994; 20(S2):21

4a.4  VOLUME RESPONSIVENESS (Stroke Volume Variation and Pulse Pressure Variation)
Reuter DA, Goepfert MS, Goresch T, Schmoeckel M, Kilger E, Goetz AE.
Assessing fluid responsiveness during open chest conditions
Br J Anaesth 2005; 94(3): 318-23

Prediction of fluid responsiveness in patients during cardiac surgery
Br J Anaesth 2004; 93(6): 782-8

Reuter DA, Felbinger TW, Kilger E, Schmidt C, Lamm P, Goetz AE.
Optimizing fluid therapy in mechanically ventilated patients after cardiac surgery by on-line monitoring of left ventricular stroke volume variations. Comparison with aortic systolic pressure variations
Br J Anaesth 2002; 88(1): 124-6

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Phillips C, Chesnutt M, Smith M.
Extravascular lung water in sepsis-associated acute respiratory distress syndrome: indexing with predicted body weight improves correlation with severity of illness and survival
Crit Care Med, 2008: 36(1); 69-73
Sakka SG, Klein M, Reinhart K, Meier-Hellmann A.  
**Prognostic value of extravascular lung water in critically ill patients**  
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Calbet JA and Boushel RC  
**Assessment of cardiac output with transpulmonary thermodilution during exercise in man**  

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Petzoldt M, Riedel C, Braeunig J, Haas S, Goepfert MS, Treede H, Baldus S, Goetz AE, Reuter DA  
**Stroke volume determination using transcardiopulmonary thermodilution and arterial pulse contour analysis in severe aortic valve disease**  

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**Effect of norepinephrine dosage and calibration frequency on accuracy of pulse contour-derived cardiac output**  

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Friesecke S, Heinrich A, Abel P, Felix SB  
**Comparison of pulmonary artery and aortic transpulmonary thermodilution for monitoring of cardiac output in patients with severe heart failure: validation of a novel method**  

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Lemson J, de Boode WP, Hopman JC, Singh SK, van der Hoeven JG  
**Validation of transpulmonary thermodilution cardiac output measurement in a pediatric animal model**  

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Felbinger TW, Reuter DA, Eltzschig HK, Bayerlein J, Goetz AE  
**Cardiac index measurements during rapid preload changes: a comparison of pulmonary artery thermodilution with arterial pulse contour analysis**  

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Marx G, Schuerholz T, Sumpelmann R, Simon T, Leuwer M  
**Comparison of cardiac output measurements by arterial trans-cardiopulmonary and pulmonary arterial thermodilution with direct Fick in septic shock**  
Eur J Anaesthesiol 2005; 22(2):129-34

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**Comparison of esophageal Doppler, pulse contour analysis, and real-time pulmonary artery thermodilution for the continuous measurement of cardiac output**  

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Reliability of a new algorithm for continuous cardiac output determination by pulse-contour analysis during hemodynamic instability
Crit Care Med 2002; 30(1):52-8

4b.2 PRELOAD (Global Enddiastolic Volume and Intrathoracic Blood Volume)
Global End-Diastolic Volume as a Variable of Fluid Responsiveness During Acute Changing Loading Conditions
J Cardiothorac Vasc Anesth 2007; 21(5): 650-4

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Influence of an acute increase in systemic vascular resistance on transpulmonary thermodilution-derived parameters in critically ill patients
Intensive Care Med 2007; 33:1619-23

Michard F, Alaya S, Zarka V, Bahloul M, Richard C, Teboul JL
Global end-diastolic volume as an indicator of cardiac preload in patients with septic shock
Chest 2003; 124(5):1900-8

4b.3 CONTRACTILITY (Global Ejection Fraction, Cardiac Function Index and Left Ventricular Contractility)
Aguilar G, Belda FJ, Ferrando C, Jover JL
Assessing the left ventricular systolic function at the bedside: the role of transpulmonary thermodilution-derived indices
Anesthesiol Res Pract 2011: 927421

Assessment of left ventricular systolic function during acute myocardial ischemia: A comparison of transpulmonary thermodilution and transesophageal echocardiography
Minerva Anestesiol 2011; 77(2): 132-41

Trepte CJ, Eichhorn V, Haas SA, Richter HP, Goepfert MS, Kubitz JC, Goetz AE, Reuter DA
Thermodilution-derived indices for assessment of left and right ventricular cardiac function in normal and impaired cardiac function
Crit Care Med 2011; 39(9): 2106-12

Cardiac function index provided by transpulmonary thermodilution behaves as an indicator of left ventricular systolic function

de Hert S, Robert D, Cromheecke S, Michard F, Nijs J, Rodrigues IE
Evaluation of Left Ventricular Function in Anesthetised Patients Using Femoral Artery dP/dtmax
J Cardio Thor Vasc Anes 2006; 20(3): 325-30
Combes A, Berneau JB, Lut CE, Trouillet JL
Estimation of left ventricular systolic function by single transpulmonary thermodilution
Intensive Care Med 2004; 30(7): 1377-83
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4b.4  VOLUME RESPONSIVENESS (Stroke Volume Variation and Pulse Pressure Variation)
Validation of pulse contour derived stroke volume variation during modifications of cardiac afterload
Br J Anaesth 2007; 98(5): 591-7
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Stroke volume and pulse pressure variation for prediction of fluid responsiveness in patients undergoing off-pump coronary artery bypass grafting
Chest 2005; 128(2):848-54
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Usefulness of left ventricular stroke volume variation to assess fluid responsiveness in patients with reduced cardiac function
Crit Care Med 2003; 31(5):1399-404
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4b.5  PULMONARY OEDEMA (Extravascular Lung Water)
Nusmeier A, Cecchetti C, Blohm M, Lehman R, van der Hoeven J, Lemson J
Near-normal values of extravascular lung water in children
Pediatr Crit Care Med 2015; 16(2): e28-33
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Measurement of extravascular lung water following human brain death; implications for lung donor assessment and transplantation
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Tagami T, Kushimoto S, Yamamoto Y, Atsumi T, Tosa R, Matsuda K, Oyama R, Kawaguchi T, Masuno T, Hirama H, Yokota H
Validation of extravascular lung water measurement by single transpulmonary thermodilution: human autopsy study
Crit Care 2010; 14(5): R162
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Assessing pulmonary permeability by transpulmonary thermodilution allows differentiation of hydrostatic pulmonary edema from ALI / ARDS
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Extravascular lung water assessed by transpulmonary single thermodilution and postmortem gravimetry in sheep
Crit Care 2004; 8(6):R451-8

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Accuracy of transpulmonary thermodilution versus gravimetric measurement of extravascular lung water
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Assessment of cardiac preload and extravascular lung water by single transpulmonary thermodilution

5. Fields of Application

5.1 ALI / ARDS
Jozwiak M, Teboul JL, Monnet X
Extravascular lung water in critical care: recent advances and clinical applications

Extravascular Lung Water and Pulmonary Vascular Permeability Index as Markers Predictive of Postoperative Acute Respiratory Distress Syndrome: A Prospective Cohort Investigation
Crit Care Med 2014; 43(3): 665 - 73

Early-phase changes of extravascular lung water index as a prognostic indicator in acute respiratory distress syndrome patients
Annals of Intensive Care 2014; 4: 27

Extravascular lung water and pulmonary arterial wedge pressure for fluid management in patients with acute respiratory distress syndrome
Multidiscip Respir Med 2014; 9(1): 3

Brown LM, Calfee CS, Howard JP, Craig TR, Matthay MA, McAuley DF
Comparison of thermodilution measured extravascular lung water with chest radiographic assessment of pulmonary oedema in patients with acute lung injury

Kushimoto S, Endo T, Yamanouchi S, Sakamoto T, Ishikura H, Kitazawa Y et al.
Relationship between extravascular lung water and severity categories of acute respiratory distress syndrome by the Berlin definition
Crit Care 2013; 17(4): R132

Jan 2016   Pulsion Medical Systems SE   PICCO Technology Literature List   Page 11 of 26
Quantitative Diagnosis of Diffuse Alveolar Damage Using Extravascular Lung Water
Crit Care Med 2013; 41(9); 2144-50
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Extravascular lung water is an independent prognostic factor in patients with acute respiratory distress syndrome
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The clinical usefulness of extravascular lung water and pulmonary vascular permeability index to diagnose and characterize pulmonary edema: a prospective multicenter study on the quantitative differential diagnostic definition for acute lung injury/acute respiratory distress syndrome
Crit Care 2012; 16(6): R232
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Letourneau JL, Pinney J, Phillips C
Extravascular lung water predicts progression to acute lung injury in patients with increased risk
Crit Care Med 2012; 40(3): 947-54
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Craig TR, Duffy MJ, Shyamsundar M, McDowell C, McLaughlin B, Elborn JS, McAuley D
Extravascular lung water indexed to predicted body weight is a novel predictor of intensive care unit mortality in patients with acute lung injury
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Accurate characterization of extravascular lung water in acute respiratory distress syndrome
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Phillips C, Chesnutt M, Smith M
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Monnet X, Anguel N, Osman D, Hamzaoui, Richard C, Teboul JL
Assessing pulmonary permeability by transpulmonary thermodilution allows differentiation of hydrostatic pulmonary edema from ALI / ARDS
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The beta-agonist lung injury trial (BALTI): a randomized placebo-controlled clinical trial
Am J Respir Crit Care Med 2006; 173(3): 281-7
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Sanchez-Sanchez M, Garcia-de-Lorenzo A, Herrero E, Lopez T, Galvan B, Asensio MJ, Cachafeiro L, Casado C
A protocol for resuscitation of severe burn patients guided by transpulmonary thermodilution and lactate levels: A 3-year prospective cohort study
Crit Care 2013; 17(4): R176

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Transpulmonary thermodilution for hemodynamic measurements in severely burned children

Bognar Z, Foldi V, Rezman B, Bogar L, Csontos C
Extravascular lung water index as a sign of developing sepsis in burns
Burns 2010; 8: 1263-70

Csontos C, Foldi V, Fischer T, Bogar L
Arterial thermodilution in burn patients suggests a more rapid fluid administration during early resuscitation

Reproducibility of transpulmonary thermodilution measurements in patients with burn shock and hypothermia

Holm C, Melcer B, Horbrand F, Henckel von Donnersmarck G, Muhlbauer W.
Arterial thermodilution: an alternative to pulmonary artery catheter for cardiac output assessment in burn patients
Burns 2001; 27(2):161-6

Holm C, Melcer B, Horbrand F, Worl H, von Donnersmarck GH, Muhlbauer W.
Intrathoracic blood volume as an end point in resuscitation of the severely burned: an observational study of 24 patients
J Trauma 2000; 48(4):728-34

5.3 Cardiac Surgery
Individually Optimized Hemodynamic Therapy Reduces Complications and Length of Stay in the Intensive Care Unit: A Prospective, Randomized Controlled Trial
Anesthesiology 2013; 119(4); 824-36

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Pulmonary artery vs. transpulmonary thermodilution for the assessment of cardiac output in mitral regurgitation: a prospective method comparison study
Eur J Anaesthesiol 2012; 29(9): 431-7
Smetkin AA, Kirov M, Kuzkov VV, Lenkin AI, Erremeev AV, Slastilin VY, Borodin VV, Bjertnaes LJ
Single transpulmonary thermodilution and continuous monitoring of central venous oxygen saturation during off-pump coronary surgery.

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Goal directed fluid management reduces vasopressor and catecholamine use in cardiac surgery patients
Intensive Care Medicine 2007; 33: 96-103

Wouters PF, Quaghebeur B, Sergeant P, Van Hemelrijck J, Vandermeersch E
Cardiac output monitoring using a brachial arterial catheter during off-pump coronary artery bypass grafting

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Transoesophageal echocardiography is more unreliable for cardiac output assessment after cardiac surgery compared with thermodilution
Anesthesia 2004; 59:1184-92

Comparison of continuous cardiac output measurements in patients after cardiac surgery
J Cardiothorac Vasc Anesth 2003; 17(2):211-6

Comparison of cardiac output assessed by pulse-contour analysis and thermodilution in patients undergoing minimally invasive direct coronary artery bypass grafting

Continuous, less invasive, hemodynamic monitoring in intensive care after cardiac surgery

5.4 Cardiogenic Shock
Schmid B, Fink K, Olschewski M, Richter S, Schwab T, Brunner M, Busch HJ
Accuracy and precision of transcardiopulmonary thermodilution in patients with cardiogenic shock
J Clin Monit Comput 2015; epub

Perny J, Kimmoun A, Perez P, Levy B
Evaluation of cardiac function index as measured by transpulmonary thermodilution as an indicator of left ventricular ejection fraction in cardiogenic shock
Biomed Res Int 2014: 598029

Ritter S, Rudiger A, Maggiorini M
Transpulmonary thermodilution derived cardiac function index identifies cardiac dysfunction in acute heart failure and septic patients: an observational study
Crit Care 2009; 13(4): R133
Friesecke S, Heinrich A, Abel P, Felix SB
Comparison of pulmonary artery and aortic transpulmonary thermodilution for monitoring of cardiac output in patients with severe heart failure: validation of a novel method

The impact of Intra-aortic Balloon Pumping on Cardiac Output Determination by Pulmonary Arterial and Transpulmonary Thermodilution in Pigs
J of Cardiovasc and Vasc Anesth 2006; 20 (3):320-4

5.5 Hypovolemic Shock
Nirmalan M, Niranjan M, Willard T, Edwards JD, Little RA, Dark PM
Estimation of errors in determining intrathoracic blood volume using thermal dilution in pigs with acute lung injury and haemorrhage

Berkenstadt H, Friedman Z, Preisman S, Keidan I, Livingstone D, Perel A
Pulse pressure and stroke volume variations during severe haemorrhage in ventilated dogs

Friedman Z, Berkenstadt H, Margalit N, Segal E, Perel A
Cardiac output assessed by arterial thermodilution during exsanguination and fluid resuscitation: experimental validation against a reference technique

5.6 Medical ICU
The effects of advanced monitoring on hemodynamic management in critically ill patients: a pre and post questionnaire study
J Clin Monit Comput 2015; epub

Kutter AP, Mosing M, Hartnack S, Raszplewicz J, Renggli M, Mauch JY, Hofer CK
The Influence of Acute Pulmonary Hypertension on Cardiac Output Measurements: Calibrated Pulse Contour Analysis, Transpulmonary and Pulmonary Artery Thermodilution Against a Modified Fick Method in an Animal Model

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Increased cardiac index attenuates septic acute kidney injury: a prospective observational study
BMC Anesthesiol 2015; 15: 22

Extravascular Lung Water, B-Type Natriuretic Peptide, and Blood Volume Contraction Enable Diagnosis of Weaning-Induced Pulmonary Edema
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Transpulmonary Thermodilution Enables to Detect Small Short-Term Changes in Extravascular Lung Water
Induced by a Bronchoalveolar Lavage
Crit Care Med 2014; 42(8): 1869-73

The impact of early goal-directed fluid management on survival in an experimental model of severe acute
pancreatitis

Chew MS, Ihrman L, During J, Bergenzaun L, Ersson A, Unden J, Ryden J, Akerman E, Larsson M
Extravascular lung water index improves the diagnostic accuracy of lung injury in patients with shock
Crit Care 2012; 16(1): R1

Saugel B, Ringmaier S, Holzapfel K, Schuster T, Phillip V, Schmid RM, Huber W
Physical examination, central venous pressure, and chest radiography for the prediction of transpulmonary
thermodilution-derived hemodynamic parameters in critically ill patients: A prospective trial
J Crit Care 2011; 26(4): 402-10

Henschel B, Schmid RM
Volume assessment in patients with necrotizing pancreatitis: A comparison of intrathoracic blood volume
index (ITBI), central venous pressure, and hematocrit, and their correlation to cardiac index and
extravascular lung water index
Crit Care Med 2008; 36 (8): 2348-54

Chung FT, Lin SM, Lin SY, Lin HC
Impact of extravascular lung water index on outcomes of severe sepsis patients in a medical intensive care
unit
Respir Med 2008; 102(7): 956-61

Kortgen A, Niederprüin P, Bauer M
Implementation of an evidence-based „standard operating procedure“ and outcome in septic shock

Mitchell JP, Schuller D, Calandrino FS, Schuster DP
Improved outcome based on fluid management in critically ill patients requiring pulmonary artery
catheterization

5.7 Neurology / Neurosurgery
Obata Y, Takeda J, Sato Y, Ishikura H, Matsu T, Isotani E
A multicenter prospective cohort study of volume management after subarachnoid hemorrhage: circulatory
characteristics of pulmonary edema after subarachnoid haemorrhage
J Neurosurg 2015; 1-10
Mutoh T, Kazumata K, Ueyama-Mutoh T., Taki Y, Ishikawa T
Transpulmonary Thermodilution-Based Management of Neurogenic Pulmonary Edema After Subarachnoid Hemorrhage

Impact of transpulmonary thermodilution-based cardiac contractility and extravascular lung water measurements on clinical outcome of patients with Takotsubo cardiomyopathy after subarachnoid hemorrhage: a retrospective observational study
Crit Care 2014; 18(4): 482

Early Intensive Versus Minimally Invasive Approach to Postoperative Hemodynamic Management After Subarachnoid Hemorrhage
Stroke 2014; 45(5): 1280-4

Tagami T, Kuwamoto K, Watanabe A, Unemoto K, Yokobori S, Matsumoto G, Yokota H.
Optimal Range of Global End-Diastolic Volume for Fluid Management After Aneurysmal Subarachnoid Hemorrhage: A Multicenter Prospective Cohort Study
Crit Care Med 2014; 42(6): 1348 - 56

Multicenter Prospective Cohort Study on Volume Management After Subarachnoid Hemorrhage: Hemodynamic Changes According to Severity of Subarachnoid Hemorrhage and Cerebral Vasospasm
Stroke 2013; 44(8); 2155-61

Sato Y, Isotani E, Kubota Y, Otomo Y, Ohno K
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