Fluid management during surgery has been described as liberal or standard, restricted or zero balance, and or goal-directed fluid therapy (GDFT). The standard fluid calculation follows the 4-2-1 rule plus calculating the deficit of fasting and insensitive losses including compensatory intravascular volume expansion plus evaporation losses (10 mL/kg/h), plus the total blood loss. Restrictive fluid therapy includes replacement of the loss only but fluid overload recognized as postoperative weight gain should be avoided. Several investigators have measured insensitive perspiration (evaporation from the skin and airways). They found insensitive perspiration to be approximately 0.3 mL/kg/h.\(^2\) Another investigator documented the same result for patients during abdominal surgery, with 0.2 mL/kg/h water loss from respiration. That makes the daily insensitive perspiration amount 0.5 mL/kg/h or 10 mL/kg/day.\(^3\) Sensible perspiration is visible sweat. The volume varies depending on the surrounding temperature and physiological stress. It was estimated in a patient with rectal temperature of 39°C to account for 600 mL/day (0.3 mL/kg/h). In a clinical setting, sensible perspiration is not generally considered, but may be significant in a patient with severe sepsis.\(^4\) GDFT is a term that describes the protocollled use of cardiac output (CO) and related parameters as end-points for the administration of fluids and/or inotropic therapies with the objective of optimizing organ perfusion with improvement of surgical outcome.\(^5\) The term GDFT was first coined by Shoemaker et al. who in 1988 showed that placement of a pulmonary artery catheter (PAC) and attainment of supraphysiologic parameters (i.e., confidence interval >4.5 L/min/m², DO\(_2\) >600 mL/min) were associated with a greater chance of survival in high-risk surgical patient.\(^6\) Conventional parameters such as heart rate, mean arterial blood pressure, central venous pressure, urine output, and arterial lactate level are not reliable in terms of GDFT because they are affected by anesthesia and surgical stress. Advanced hemodynamic monitoring is as follow. First, is noninvasive, the ultrasound Doppler-based CO monitoring devices such as transesophageal echocardiography (Deltex Medical, Chichester, UK).\(^7\) Second, is invasive which requires arterial line insertion, the pulse wave pressure devices either calibrated such as pulse-induced contour cardiac output (PiCCO) (Pulsion Medical Systems, Munich, Germany) and lithium dilution cardiac output (LiDCO) (LiDCO, London, UK) or uncalibrated such as the FloTrac (Edwards Lifesciences, LLC, CA, USA).\(^8\) The LiDCO and PiCCO used dilution analysis, and both use arterial waveform analysis method, the difference between them and PAC is that both allow for dilution through the systemic or left-sided circulation versus just the right heart. Third, noninvasive, the pulse oximeter plethysmographic waveform analysis (Masimo Rainbow SET Corporation, Irvine, CA, USA) which differs from the arterial pressure waveform by measuring volume rather than pressure changes in both arterial and venous vessels. The “Pleth Variability Index” (PVI) is an automated measure of the dynamic change in the “perfusion index” (PI) that occurs during a respiratory cycle. The PI is the infrared pulsatile signal indexed against the nonpulsatile signal and reflects the amplitude of the pulse oximeter waveform. The PVI correlates closely with the respiratory-induced variation in the plethysmographic and arterial pressure waveforms and can predict fluid responsiveness noninvasively (without inserted arterial line) in the mechanically ventilated surgical patients.\(^9\) Fourth, noninvasive, the finger cuffs which uses the volume clamp method to continuously measure blood pressure and stroke volume from the finger cuff.\(^10\) Fifth, noninvasive, the partial carbon dioxide rebreathing using the reverse Fick principle to calculate CO.\(^11\) Sixth, noninvasive, the transthoracic bioimpedence and bioreactance which exploits the variation in electrical resistance with intrathoracic blood volume during the cardiac cycle.\(^12\) The following case which was reported by Gutierrez et al. illustrated that the importance of using GDFT to guide perioperative fluid administration. This is a 63-year-old female patient scheduled for choledochojjunostomy for cholelithiasis and a possible ampullary mass. The FloTrac/Vigileo hemodynamic monitoring was used after inserting arterial line to keep the stroke volume variation between 10% and 13%. The procedure lasted for 4 h. She received a total of 2100 mL of intravenous fluid. Her urine output was 725 mL for the entire procedure. Her vital signs remained stable intraoperatively. If the standard fluid calculation was used for her weight (64.5 kg) following 4-2-1 rule, calculating a deficit per 8 h of fasting and insensitive losses of 10 mL/kg/h plus the total blood loss of 500 mL, the total estimated amount of crystalloids needed
was 6366 mL. However, she received only 2100 mL using GDFT concept with positive impact on enhanced recovery after anesthesia (ERAA).[13] The term ERAA was first coined in 2016.[14] There is intimate relation between ERAA and GDFT. It is well known that with hypervolemia there is increased risk of cellular edema, ileus, postoperative nausea and vomiting, and cardiopulmonary complications.[15] Hypervolemia also releases atrial natriuretic peptide which in turn damages the endothelial wall barrier, namely, glycocalyx (GCX) with subsequent capillary leak syndrome. The endothelial GCX is carbohydrate layer located on the luminal side of healthy vasculature, plays a vital role in vascular permeability by constituting a vascular barrier together with the endothelial cells themselves.[16] There are many animal and human studies on the effects of different fluid items on the GCX with conflicting results.[17–21] Crystalloids and colloids do have different distribution patterns: crystalloids mostly remain in the extracellular space, therefore, they are commonly used for ongoing extracellular losses. If beyond that in case of acute surgical bleeding, isotonic preparations such as hydroxyethyl starch to be considered. However, the decision has to be made on individual basis taking into account the nature of the acute problem and the preexisting illness as well as the economic aspect. Interstitial edema is a relevant clinical problem which affects the outcome. Its incidence is closely related to perioperative fluid therapy. Hypervolemia has to be avoided in elective surgical procedures as it breaks down the integrity of the vascular barrier GCX and causing interstitial edema with bad outcome. We believe that the triple model [Figure 1] described in this editorial plays an important role in the surgical patient outcome.

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Conflicts of interest
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References


Figure 1: Enhanced recovery after anesthesia, goal directed fluid therapy, glycocalyx

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