The cornerstone of Goal Directed Fluid Therapy (GDT) is the use of an algorithm or protocol for fluid and hemodynamic management. The algorithm should be based on physiology and medical evidence, and be easy to use. There are a number of algorithms that have been tested and shown to be effective in providing GDT. Typically they involve a flow parameter such as Stroke Volume Index (SVI). They may also invoke a parameter to predict fluid responsiveness such as Stroke Volume Variation (SVV, FloTrac™) or Corrected Flow Time (FTc, esophageal Doppler).

At UCSD we use have two minimally invasive flow monitors that can facilitate providing GDT. One is arterial pressure-based (FloTrac™), requiring an arterial line, and the other is based on Doppler flow velocity measurement in the descending aorta via the esophagus (esophageal Doppler, Deltex CardioQ™). These monitors are used in addition to standard ASA monitors, and are available at the Hillcrest, Thornton, and VAMC sites.

At UCSD, for a major surgery, we use one of three algorithms or a “Four Quadrant Approach”. The choice depends upon the monitor employed, patient characteristics, and provider preference. All three algorithms have SVI as the primary target parameter, with the suggestion that 35 ml/m² be the lower limit. This target can be modified according the clinical situation and judgment of the provider. For example, in some elderly patients with cardiac disease the expectation that they will achieve SVI ≥ 35ml/m² may not be reasonable, and perhaps 30 ml/m² should be used. In young, athletic patients, perhaps 40ml/m² should be used. These targets may altered according to patient characteristics, and other classical parameters of fluid management (HR, BP, urine output, base deficit). In general, however, SVI ≥ 35 ml/m² is a pretty good place to start. All three algorithms call for a low baseline rate of fluid administration (1 ml/kg/hr), with boluses of fluid (either crystalloid or colloid) to optimize hemodynamics and maintain stability. Fluid boluses may be 250ml, but will depend upon the clinical situation. The low baseline rate is designed to limit unnecessary salt and fluid administration, which has been shown to be harmful and counter to the aims of Enhanced Recover Programs (ERP). A very important point is that these algorithms merely represent guidelines and suggestions. The actual medical care is at the discretion of the provider. All the available data from all the monitors and the patient should be used in making clinical decisions. The providers are reminded, however, that use of an algorithm or other systematic approach to fluid and hemodynamic management has repeatedly been shown to improve outcomes in high-risk surgeries.

The algorithms are as follows:
I. **GDT with Corrected Flow Time (FTc)**

When esophageal Doppler is employed, Corrected Flow Time (FTc) can often be used as a fluid responsiveness indicator. SVI is the primary target, but fluid bolus is called for if the FTc < 350 msec. The lower left section of the algorithm has a section (red dotted box) to prompt search for noncardiac, or right-sided causes for low SVI when attempts at treatment with fluid have been unsuccessful in bringing the SVI up to an acceptable value. Further, blood pressure is used (low, med, high) in the decision process in cases in which SVI is low and the etiology is unclear. One possible maneuver is to lighten anesthesia in cases in which the BP is low (anesthetics cause vasodilation and/or myocardial depression). Of course this should be done with care, preferably with the guidance of processed EEG monitoring and other indicators of anesthetic depth. Cardiovascular parameters that are not in the algorithm, such as Peak Velocity (an indicator of myocardial contractility) can be used to guide management as well.
II. **GDT with Stroke Volume Variation (SVV)**

The GDT with Stroke Volume Variation algorithm is essentially the same as GDT with FTc, except SVV, using the FloTrac™, is used as the fluid responsiveness indicator instead of FTc. An SVV > 12% prompts a fluid bolus, although it may be necessary to alter this parameter depending upon the clinical situation. Since the FloTrac™ can be a little “jumpy” in its reporting of SVV, with artifact sometimes causing rapid fluctuations in the reported value, the provider should wait for the monitor to consistently show a value prior to acting on it. As with all monitoring, the provider should assure the data they are using is as valid and accurate as possible prior to intervening with therapies.

SVV should be used only when the patient receives positive pressure controlled ventilation ≥8ml/kg tidal volume, does not have frequent cardiac dysrhythmias or atrial fibrillation, and does not have pathology that causes high SVV irrespective of volume status. For example, volume administration may not be the primary treatment for some conditions causing a high SVV (e.g. pneumothorax, abdominal compartment syndrome, bronchospasm, constrictive pericarditis).
III. **GDT with Stroke Volume Only**

In some situations a volume responsiveness parameter such as SVV or FTc is unavailable or its application would be inappropriate. The “**GDT no SVV or FTC**” algorithm can then be used. This algorithm simply calls for trial fluid bolus if the SVI\(\leq 35 \text{ ml/m}^2\). Other maneuvers that can enhance cardiac filling, such as Trendelenburg Position and Passive Leg Raising can be used in lieu of a fluid bolus to predict response fluid responsiveness. This can assist in the decision to administer a fluid bolus. For example, if 20° Trendelenburg position or passive leg raising results in an increase in SVI by 10% or more, it is predictable that the patient would respond favorably to a fluid bolus.
IV. The Four Quadrant Approach

The “Four Quadrant Approach” is an intuitive, physiologic approach to hemodynamic problem solving and GDT. An X-Y plot is created, with SVI on the X axis and Mean Arterial Pressure (MAP) on the Y axis. A target zone is created by the provider, using target MAP and SVI values. When parameters fall out of the target zone, they land in one of the four Quadrants:

**Quadrant I**
Quadrant I (high SVI and high MAP) indicates hyperdynamic circulation. This may be caused by:
- light anesthesia, pain
- beta blocker withdrawal
- thyrotoxicosis
- pheochromocytoma
- Malignant Hyperthermia
- excessive administration of catecholamines

Depending upon the reason for the hyperdynamic state, these patients can be treated by deepening of the anesthetic, treatment of pain, and administration of beta blockade,
**Quadrant II**

Quadrant II (Low SVI and high MAP indicates high afterload. This can be caused by vasoconstrictor administration (vasopressin, phenylephrine) and conditions that cause vasoconstriction such as hypothermia.

**Quadrant III**

Quadrant III (low SVI, low MAP) indicates shock that may be cardiogenic, hypovolemic, or secondary to mechanical problems with preload (abdominal compartment syndrome) or right-sided problems (pneumothorax, pulmonary hypertension with RV failure). Preload responsiveness determination using SVV, FTc, fluid challenge, passive leg raise, or Trendelenburg position is particularly helpful in this quadrant since differentiating cardiac failure vs. hypovolemia is critical. If diagnosis is difficult, TEE, TTE, and invasive monitoring should rapidly be considered.

**Quadrant IV**

Quadrant IV (high SVI, low MAP) indicates low systemic vascular resistance. This can result from vasodilatory states such as sepsis, vasoplegia, and vasodilator administration (including anesthesia).

**CONCLUSION**

The medical literature strongly favors the use of a systematic, physiologic approach to fluid administration and hemodynamic management in major surgeries. At UCSD there are algorithms and tools available that are based on physiologic principles and medical evidence.

**REFERENCES**


