ProAQT Technology

Your navigator in perioperative hemodynamic monitoring

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MAQUET

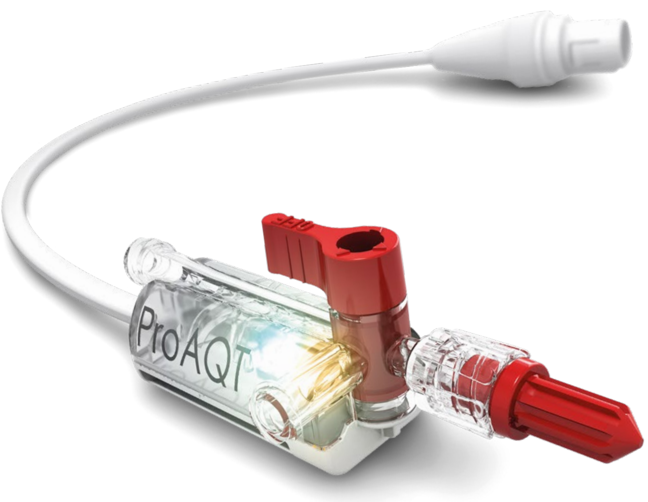
Proactive decision-making

Individualized therapy with ProAQT

Patients undergoing high- and medium-risk surgeries always benefit from close vigilance[1]. Optimal perioperative fluid administration is the key to successful recovery[2,3]. With a dynamic range of hemodynamic parameters, you can successfully optimize the best individual treatment for your patients[4].

Based on over 20 years of research with the PiCCO pulse contour algorithm, ProAQT allows a reliable interpretation of your patient 's hemodynamic status by measuring a variety of parameters, less invasively. The ProAQT sensor can be easily integrated into the existing blood pressure measurement system and provides valuable parameters such as blood flow, volume responsiveness, afterload and contractility.

ProAQT's outstanding technological profile allows the implementation of goal-directed fluid therapy, continuous hemodynamic monitoring in the perioperative period and a review of interventional success.



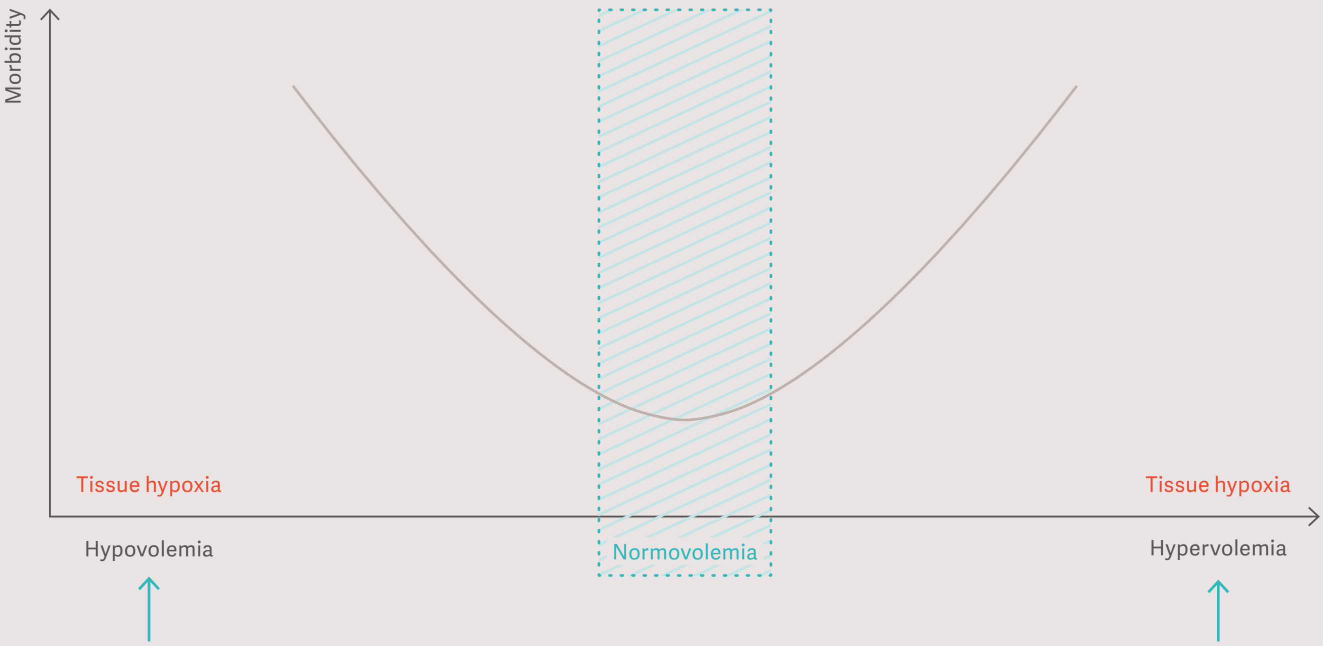
- Easy, fast and safe setup
- Based on PiCCO pulse contour algorithm
- Utilizes existing arterial-lines
- Less invasive
- Automatic start value determination of advanced hemodynamic parameters with optional calibration via CI value from an external source (e.g. echo)

Why hemodynamic monitoring?

Visualizing hemodynamics gives us information on the performance of the heart and perfusion of the tissue. Our ability to monitor hemodynamics allows dynamic interventions in high- and medium-risk care. It has been demonstrated that advanced dynamic and flow-based parameters are more reliable than conventional static measurements predicting fluid responsiveness in patients.[5,6]

In critical and anesthesiological care, the goal of hemodynamic monitoring is to guide fluid therapy via dynamic parameters in order to optimize the balance between oxygen delivery and oxygen consumption. Keeping the patient's fluid status in balance between hypo- and hypervolemia is the most effective way to combat global tissue hypoxia, shock and multi organ failure.[3]

Individualized fluid therapy helps avoid hypervolemia or hypovolemia (and) related complications [5]

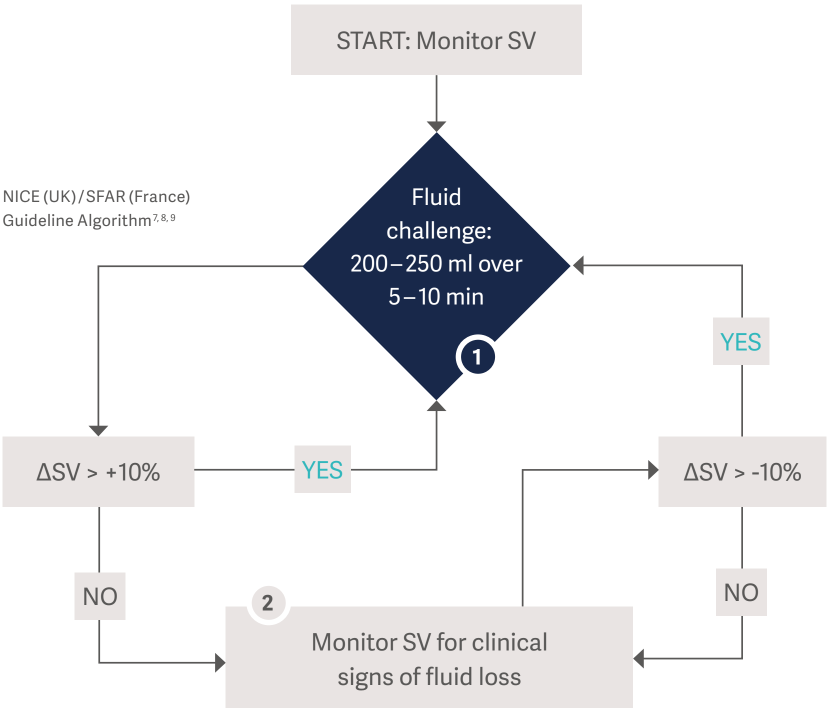


Fluid under-resuscitation
Low cardiac output
Infection
Organ failure
Poor wound healing
Reduced blood flow
Organ hypoperfusion

Fluid over-resuscitation
Tissue/lung edema
Hypoperfusion
Hemodilution
Congestive heart failure
Organ dysfunction
Tissue edema

How to perform perioperative fluid management?

NICE (UK)/SFAR (France) Guideline Algorithm[7,8,9]



Improve patient outcome

ProAQT provides multiple advanced hemodynamic parameters that can be used in GDFT to control variability in volume administration to help you maintain your patient in the optimal volume range. ProAQT quickly provides a dynamic assessment of fluid responsiveness which helps to guide fluid therapy in pre-, intra- and postoperative settings.

1 **SV MAX (Fluid First)**
Give fluid, observe response, continue to give fluid and other therapies until target is achieved

2 **Hemodynamic Stability (Observe First)**
Measure deterioration of clinical condition and titrate therapy using a variety of parameters

Significant difference of infectious complications

The Swalzwedet et. al. study shows the evidence of the beneficial effects of perioperative GDFT with ProAQT (in abdominal surgery).[2]

Control Group:
Number of Patients: 81
Patients with infectious complications: 21

Study Group:
Number of Patients: 79
Patients with infectious complications: 9

Why combine hemodynamic monitoring and lung recruitment?

Lung recruitment fact

5–10 %

of all surgical patients develop postoperative pulmonary complications (PPCs). In thoracic or abdominal surgeries up to 30–40 % develop PPCs[10].

Fluid management fact

37 %–55 %

of postoperative complications can be prevented through perioperative goal-directed fluid therapy[11,12].

Use of advanced patient monitoring shows your patient's response to lung recruitment

The change of CO and SV is detected in realtime. Preload (SVV, PPV), afterload (SVRI) and contractility (dPmx, CPI) parameters provide clinicians with better insights. Occult hypovolemia can be detected prior to the recruitment maneuver, followed by appropriate perioperative fluid management that will decrease postsurgical complications.

Heart-lung interactions during the recruitment maneuver can be monitored by the ProAQT Technology

90 % Atelectasis

Start anesthesia

Lung recruitment performed to avoid atelectasis

Effects on hemodynamics

- ↑ **Intrathoracic pressures**
- ↓ **Venous return**
- ↓ **LV preload**
- ↓ **SV**

ProAQT continuously monitors the parameters SVV, PPV, CO, HR, SV

Recruitment maneuver (RM)

Prior	optimize volume status (SVV, PPV)
During	Δ CO > 15 % adjust RM[13]
After	Δ SV > 30 % consider fluid Patient is preload responsive[14]

Avoids hypoxemia

Reduce complications, increase efficiency

Financial advantages

Postoperative complications are associated with an increase in mortality, length of hospital stay, and hospital costs.[15, 16, 17]

Complications are costly

Healthcare expenditure is currently rising exponentially, and postoperative complications contribute significantly to these increased costs[18, 21].

Patients who develop complications consume a disproportionately larger share of the available resources[17]. Postoperative morbidity has effects that last beyond discharge e.g. prolonged sick leave or permanent incapacity for patients[17].

The Cost of Complications

53 %

readmitted patients had post-operative complications before previous discharge[19]

21x

increased in-hospital mortality for patients with 1+ postsurgical complications[16]

2.2 days

increase in length of stay for patients with 1+ complications[20]

172 %

increase in hospital costs for patients with 1+ post-surgical complications[15]

Cost saving potential

Many studies have shown decreased morbidity in major surgery when GDFT is used[18, 21]. The premise is simple: GDFT helps reduce postoperative complications which, in turn, reduces costs. Indeed, a favourable financial impact of GDFT resulting from reduction of complication rates has been reported in many studies[19, 22].

32 – 55 million USD

the total potential savings per year for GDFT implemented for colectomies in the USA[24]

2.5 – 4 USD savings

from each dollar invested by hospitals to implement GDFT[24]

1.16 – 1.95 days

reduction in length of stay when GDFT was implemented[18, 23]

GDFT is recommended by:

- National Health Service in UK[4]
- French Society of Anesthesiology[15]
- Enhanced Recovery After Surgery (ERAS) Society in Europe[16]

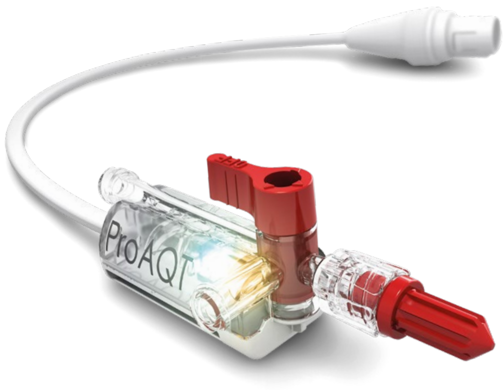
Application areas and benefits

Key features of ProAQT

ProAQT allows optimized fluid management by providing key flow parameters to help determine your patient's fluid status[2].

ProAQT has the following applications:

- Perioperative fluid management in goal-directed fluid therapy[2]
- Complex procedures with high-risk of intra- and postoperative complications[2]
- Anticipated high blood loss and volume shifts during the procedure which can result in hypo- or hypervolemia[2]
- Extended surgery time (> 120 min)[2]



Exceptional flexibility of the PulsioFlex monitor

- Small footprint conserves precious space in care units
- Seamless integration into existing PDMS system
- Integration of PiCCO, CeVOX and LiMON technology allows easy escalation of monitoring options
- Flexible mounting options permit outstanding mobility

ProAQT provides support during the perioperative period.

Outstanding clinical performance of ProAQT

- Continuously derived hemodynamic parameters support physicians in critical therapeutic decisions[5]
- Provides a minimally invasive approach by utilizing existing arterial access of choice (e.g. radial artery)
- Possibility to use automatic start-value determination or external manual calibration (e. g. echocardiography)
- Tracking of fluid challenges like passive leg raising (PLR) or fluid bolus[25]
- Tailor your fluid therapy to your patient's specific parameters[2]
- Recognize unstable patients quicker[2]
- Track the success of your therapy

Parameters provided by ProAQT

Blood Flow		Preload		Contractility		Afterload
CI_{Trend} Cardiac Index	**SVI** Stroke Volume Index	**SVV** Stroke Volume Variation	**PPV** Pulse Pressure Variation	**dPmx** Left Ventricular Contractility	**CPI** Cardiac Power Index	**SVRI** Systemic Vascular Resistance

Monitoring continuous hemodynamic parameters in moderate – and high-risk surgical patients not only improves outcome, but also provides an actual and relative cost savings[4, 24]. This has important implications for the management of these patients and the the cost-burden of anesthesia[2].

The rationale behind hemodynamic optimization is simple and clear: goal-directed fluid therapy improves clinical outcome and reduces costs at the same time.[18]

ProAQT Parameters

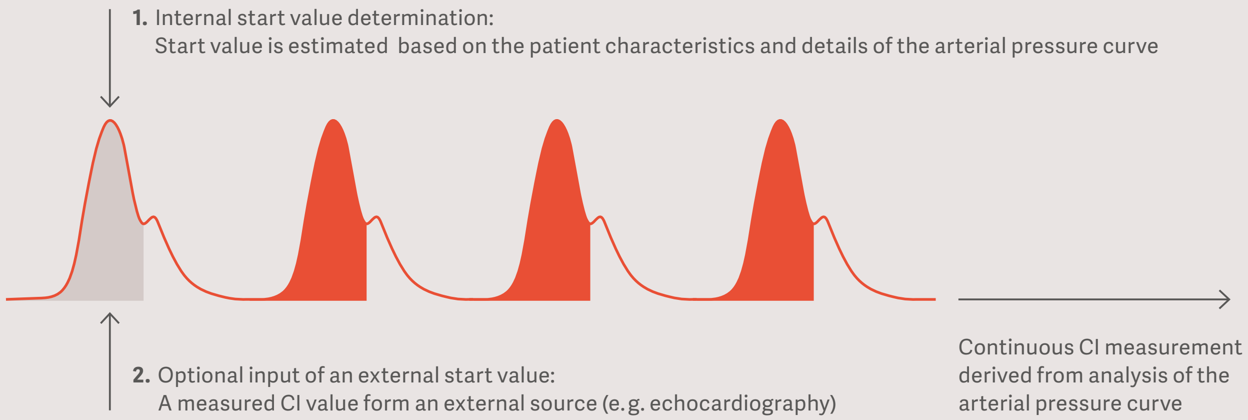
Basics of the pulse contour analysis and calibration procedure

The theoretical basis of pulse contour analysis was published for the first time in 1899[26].

Principle of pulse contour analysis

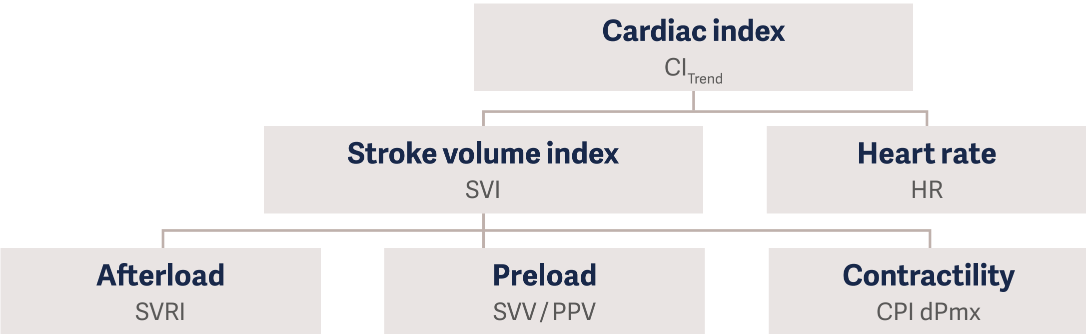
- The analysis of the continuous arterial pressure provides more information than just the systolic, diastolic and mean value.
- The algorithm detects the opening of the aortic valve (moment of the increase of the systolic pressure) and its closure (incision in the pressure curve: the dicrotic notch).
- The time in between represents the duration of the systole and the area under the systolic part of the pressure curve directly reflects the stroke volume (SV): the volume of blood (in millilitres) which is ejected by the left ventricle with every single heartbeat.
- SV multiplied by heart rate (HR) gives cardiac output, the pump flow of the heart in litres per minute.
- The shape of the arterial pressure curve and thus the area under the curve is influenced not only by the stroke volume, but also by the individual compliance of the vascular system. The ProAQT system estimates dynamic parameters through arterial pressure waveform analysis.

ProAQT principle and calibration procedure



The patient characteristics used within the ProAQT calibration algorithm operate on some assumptions about patient demographics and change in vascular tone of the patient. This may lead to some discrepancies in the calculated values.

Blood flow and afterload



Cardiac index and its determinants

Cardiac index (CI)

Cardiac index is the amount of blood pumped by the heart per minute indexed to $1m^2$ of the body surface area (BSA); the cardiac index represents the global blood flow. A decrease in cardiac index is a clear alarm signal and requires appropriate measures to manage the situation.

Stroke volume index (SVI)

Stroke volume, the volume of blood pumped by the left ventricle per beat, is affected by preload, afterload and contractility. Thus, information on the determinants of cardiac index allow a more comprehensive picture of the hemodynamic status for choosing an appropriate treatment.

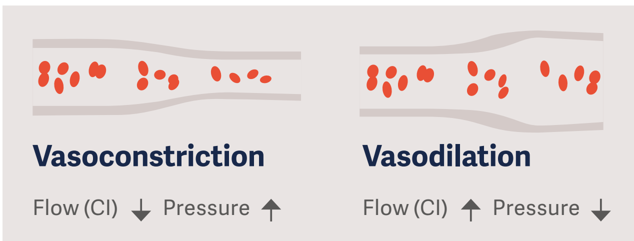
Systemic vascular resistance index (SVRI)

The physiological meaning of SVRI is the tension or resistance that builds up in the wall of the left ventricle during ejection. In the clinical context things are often simplified and so the afterload is seen as the resistance the heart has to pump against.

- If the afterload (SVRI) is increased, the heart must pump with more power to eject the same amount of blood as before
- A higher afterload may decrease the cardiac output
- A lowered afterload may increase the cardiac output

$$SVRI = \left[\frac{(MAP - CVP)}{CI} \right] \times 80$$

If the afterload exceeds the performance of the myocardium, the heart may decompensate.



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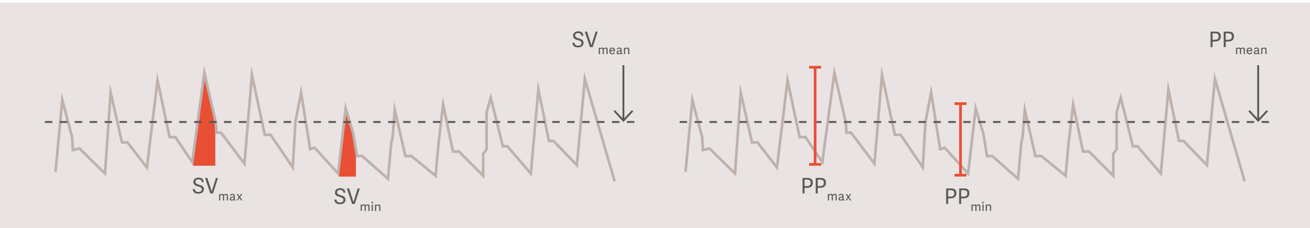
CI	SVI	SVRI
3–5 $l/min/m^2$	40–60 ml/m^2	1700–2400 $dyn*s*cm^{-5}*m^2$

Volume responsiveness



Stroke volume variation (SVV)

Pulse pressure variation (PPV)

Stroke volume variation (SVV) and pulse pressure variation (PPV)

- Prediction of the response of blood flow to volume loading
- Quantification of fluctuations in the arterial pressure curve due to mechanical ventilation

Explanation:
The inspiration and expiration phases in mechanical ventilation changes the intrathoracic pressure. High ventilation induced intrathoracic pressure reduces the venous return and the filling capacity of the heart and vessels. This variation of the vascular filing status is visible by a ventilation cycle induced fluctuation of the arterial pressure curve.

$$SVV = \frac{(SV_{max} - SV_{min})}{SV_{mean}}$$

$$PPV = \frac{(PP_{max} - PP_{min})}{PP_{mean}}$$

The higher the variation the more likely the patient is to be volume responsive. For proper use of the parameters, the following preconditions must be fulfilled:

- Fully controlled mechanical ventilation with a tidal volume ≥ 8 ml/kg PBW (predicted body weight)
- Sinus rhythm
- Pressure curves free of artifacts

If these criteria cannot be met, the following tests can be performed:

- End-expiratory occlusion (EEO) Test
- Tidal Volume Challenge
- Lung Recruitment Maneuver (RM)

OK

SVV/PPV

$< 10\,\%$

Contractility

Contractility of the myocardium represents the ability of the heart to contract independent of the influence of preload or afterload. Substances that cause an increase in intracellular calcium ions lead to an increase in contractility. Different concentrations of calcium ions in the cell lead to a different degree of binding between the actin (thin) and myosin (thick) filaments of the heart muscle. Direct determination of cardiac contractility is not possible in the clinical setting. Therefore, surrogate parameters are used to evaluate or estimate the contractility.

Cardiac power index (CPI)

CPI represents the power of left ventricular cardiac output in watts. It is the product of pressure (MAP) and flow (CO). In clinical studies it has been found to be the strongest independent predictor of hospital mortality in cardiogenic shock patients.[27,28]

$$CPI = CI \times MAP \times 0.0022$$

Left ventricular contractility (dPmx)

From the arterial pressure curve, the pressure changes during the systolic phase can be analyzed and a measure of the pressure increase over time (analyzed in speed) is calculated. The steeper the upslope of the curve, the higher the contractility of the left ventricle. As the upslope also depends on the individual compliance of the aorta, the parameter should primarily be viewed and evaluated as part of the overall trend.

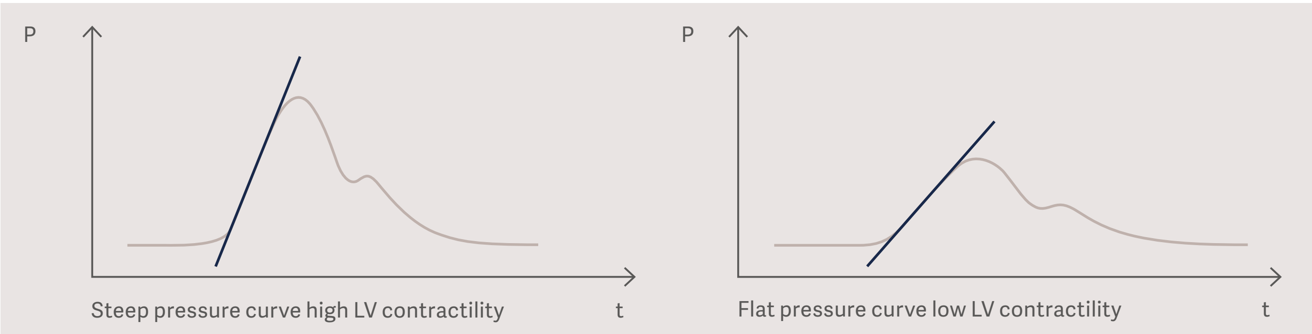


Diagram of steep / flat pressure increase with high / low contractility

OK

dPmx
mmHg/s trend information

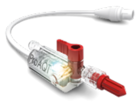
CPI
0.5 – 0.7 W/m^2

Advanced patient monitoring platform

The PulsioFlex monitor platform is equipped with the ProAQT technology.

You can easily extend the hemodynamic scope with modules featuring NICCI, PiCCO, CeVOX, and LiMON. This will give you the information you need to help assess the hemodynamic status for a broad range of patients, on-site.

The following table lists the parameters available with the current technologies:

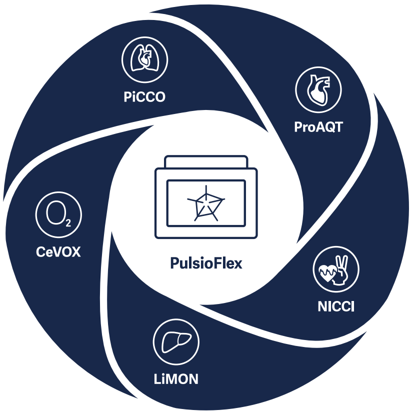




	NICCI	ProAQT	PiCCO	CeVOX	LiMON
Invasiveness	Noninvasive	Minimally invasive arterial line	Less invasive arterial catheter	Less invasive	noninvasive
Pulse contour analysis (continuous)					
Chronotropy	PR	HR	HR		
Blood Pressure	AP_{sys}, AP_{dia}, MAP	AP_{sys}, AP_{dia}, MAP	AP_{sys}, AP_{dia}, MAP		
Flow	$CI_{Trend/Cal}$**, SVI	$CI_{Trend/Cal}$**, SVI	CI_{PC}*, SVI		
Contractility	dPmx, CPI	dPmx, CPI	dPmx, CPI		
Afterload	SVRI	SVRI	SVRI		
Volume responsiveness	SVV, PPV	SVV, PPV	SVV, PPV		
Thermodilution (discontinuous)					
Flow			CI_{TD}***		
Preload			GEDI, ITBI		
Contractility			CFI, GEF		
Pulmonary edema			ELWI, PVPI		
Oxymetry					
Oxygen saturation				$ScvO_2$	
ICG elimination					
Liver function					PDR, R15
Besides the PulsioFlex, the Advanced Patient Monitoring Technologies are integrated into the following OEM platforms:					
		Nihon Kohden	Philips, Mindray, Drager Medical, General Electric, Nihon Kohden	Philips, Mindray, Nihon Kohden	

* Cardiac index derived from pulse contour ** Calibrated from internal or external reference value *** Cardiac index derived from thermodilution

Passion for life

Improving outcomes for critically ill patients



Advanced hemodynamic monitoring helps physicians understand complex conditions of patients in intensive care units and during high-risk surgeries and helps to optimize their hemodynamic condition.[2]

Pulsion's core competence is the development and production of medical devices for monitoring critically ill patients. Pulsion Medical Systems SE was founded in 1990 and is located in Feldkirchen, Greater Munich. Since 2014, Pulsion is wholly-owned by, and fully-integrated with, Getinge.

Getinge is a global provider of innovative solutions for operating rooms, intensive care units, sterilization departments and life science companies and institutions.

Based on our firsthand experience and close partnerships with clinical experts, healthcare professionals and medtech specialists, we are improving everyday life for people – today and tomorrow.

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