WHITE PAPER

The Role of Advanced Hemodynamic Monitoring in Enhanced Recovery After Surgery (ERAS) Initiatives

Using continuous hemodynamic monitoring as a tool to help maintain patient fluid balance and reduce postoperative complications.

INTRODUCTION

Patients undergoing major surgery are faced with an inherent risk of morbidity and mortality (See Table 1).These risks can increase depending on a patient's cardiovascular and hemodynamic condition and are known to contribute to a variety of postoperative complications and increased lengths of stay (LOS) in the hospital.[1,2] Specific factors that influence a patient's LOS during postoperative rehabilitation include the need for analgesia, intravenous fluids, and lack of mobility.[3] To minimize recovery time and reduce postoperative complications for a variety of high- to moderate-risk surgical patients, hospitals and surgical teams around the world have adopted a comprehensive set of perioperative practice guidelines known as Enhanced Recovery After Surgery (ERAS).

TABLE 1. POSTOPERATIVE COMPLICATION RATE[2]

SURGERY	MORBIDITY RATE
Esophagectomy	55%
Pelvic exenteration	45%
Pancreatectomy	35%
Colectomy	29%
Gastrectomy	29%
Liver resection	27%

ERAS guidelines consist of 22 preoperative, intraoperative, and postoperative protocols, which have been shown to lead to a reduction in complications and hospital LOS, improvements in cardiopulmonary function, earlier return of bowel function, enhanced mobilization, and earlier resumption of normal activities.[4,5,6] These practice guidelines represent a fundamental shift in perioperative care for numerous types of surgical interventions including colorectal surgery, vascular surgery, thoracic surgery, radical cystectomy, and orthopedic cases.[7,8,9,10,11]

One critical element of all ERAS programs is a protocol known as perioperative goal-directed therapy (PGDT), which helps ensure adequate hydration and maintain euvolemia, while avoiding hypervolemia or hypovolemia that can contribute to postoperative complications (See Figure 1).[12,13] To achieve optimal fluid balance for the surgical patient, PGDT relies on continuous monitoring of a variety of hemodynamic targets, which can all be derived from minimally invasive cardiac output (CO) monitoring technologies.

PERIOPERATIVE GOAL-DIRECTED THERAPY

PGDT is an integral element of ERAS and has been shown in multiple single-center studies, quality improvement studies, and published meta analyses to significantly improve patient outcomes.[14,15,16,17] By improving cardiovascular function and balancing fluid intake, PGDT helps clinicians maintain adequate oxygen supply perioperatively. As part of ERAS guidelines, PGDT helps decrease nausea, vomiting, and the incidence of ileus, or intestinal obstruction, while allowing patients to take solid food earlier, become more alert, and start walking sooner after surgery, ultimately reducing hospital LOS.[12,13]

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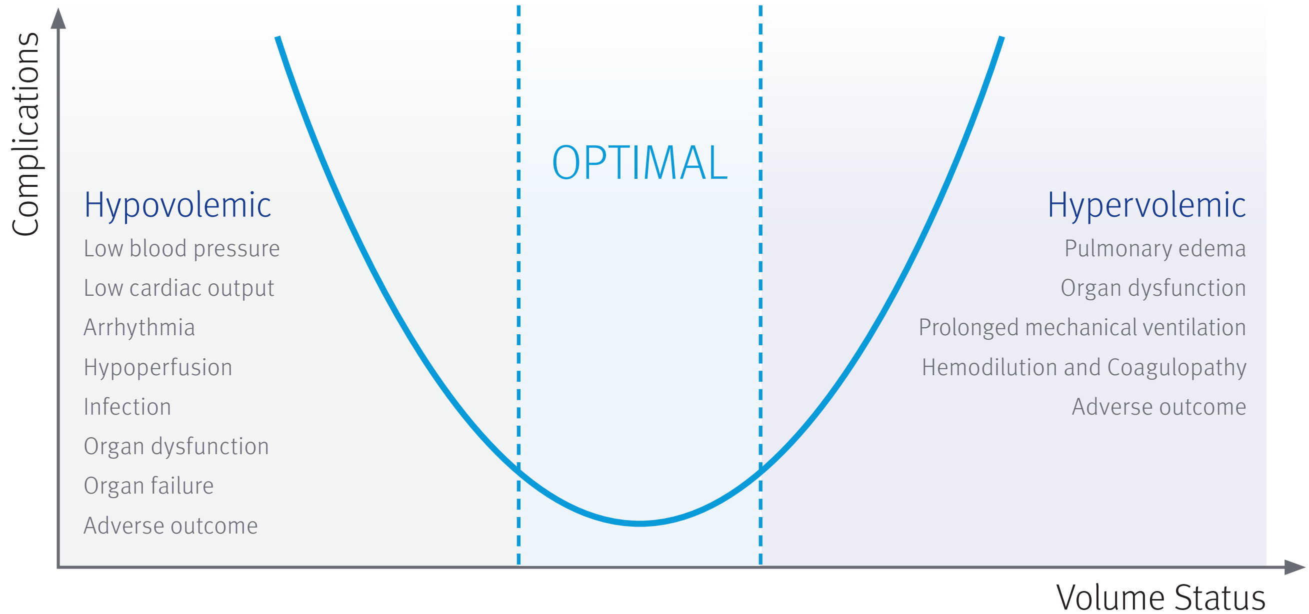
FIGURE 1. COMPLICATIONS ASSOCIATED WITH SUBOPTIMAL PERIOPERATIVE FLUID MANAGEMENT[13]



Intraoperative fluid management protocols are designed to maintain a patient's preoperative euvolemia, or properly hydrated state by avoiding excess salt and water as well as hypovolemia conditions known to increase postoperative complication rates.[18,19,20,21] Once optimal intravascular volume is established, intravenous fluid administration is controlled and increased only if clinically indicated.

Intravascular hypovolemia can lead to complications stemming from hypoperfusion of vital organs and the bowel. However, administering too much fluid can lead to bowel edema and increased interstitial lung water, resulting in complications and delayed return of gastrointestinal function.[18,20,22] As a result, intravascular volume is one of the key determinants of cardiac output (CO) and oxygen delivery to the tissues. Determining the correct amount of fluid required is simplified with the focus on easily accessible, flow-based hemodynamic parameters.

To achieve optimal fluid balance, clinicians must monitor a variety of hemodynamic targets, including cardiac index (CI), stroke volume (SV), stroke volume variation (SVV), and pulse pressure variation (PPV).

MAINTAINING FLUID BALANCE WITH ACCURATE HEMODYNAMIC MONITORING

Clinicians have studied both restrictive and liberal fluid regimens as a means to guide PGDT, finding that it is important to evaluate patients on the basis of being in a state of "fluid balance."[20] To achieve this optimal fluid balance, clinicians must monitor a variety of hemodynamic targets, including cardiac index (CI), stroke volume (SV), stroke volume variation (SVV), and pulse pressure variation (PPV).

Routine hemodynamic measurements, such as heart rate and mean arterial pressure (MAP), remain relatively unchanged despite reduced blood flow and are considered insensitive indicators of hypovolemia or changes in CI.[23,24] As a result, conventional fluid management is based on clinical assessment, vital signs, central venous pressure (CVP) monitoring, or a combination of these. However, recent studies have shown that CVP is not able to predict fluid responsiveness nor can changes in blood pressure be used to approximate changes in SV or CO.[25,26]

Many of the clinical parameters that help clinicians effectively manage patient fluids are considered dynamic due to their continuous updating and sensitivity to fluid volume changes in patients. These dynamic flow parameters, such as SV, SVV, and PPV, are needed to accurately predict fluid responsiveness.[27] More than two dozen randomized controlled studies and meta-analyses support the advantages of hemodynamic optimization over standard fluid management to achieve superior clinical outcomes.[12,28,29,30]

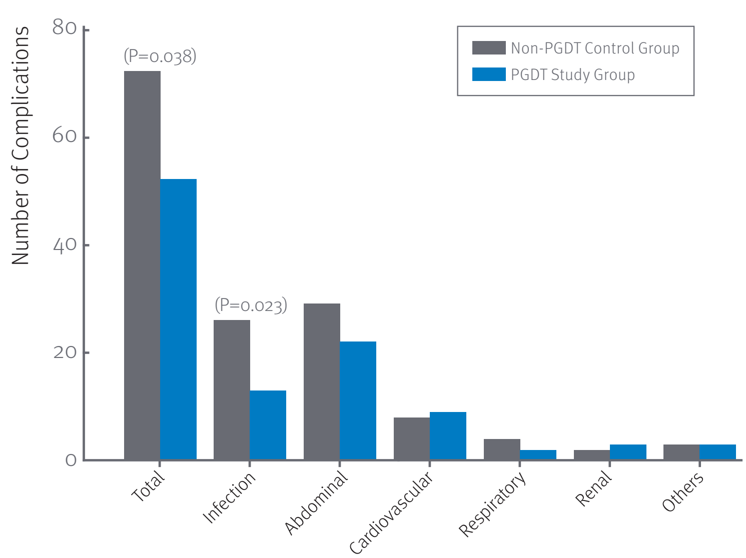
DEMONSTRATING THE CLINICAL EFFECTIVENESS OF PGDT

PGDT has proven to help improve outcomes for a variety of patient populations, including orthopedic cases, which often carry a significant burden of complications and mortality when performed in elderly patients. One study examining the effectiveness of PGDT protocols when used with total hip replacement (THR) surgery patients found that PGDT patients received a greater volume of fluids during the intraoperative period, exhibited higher urine output, achieved a more positive fluid balance and ultimately experienced fewer postoperative complications.[14] In this study, SV and CO were tracked continuously and oxygen delivery index (DO_2I) was calculated by inputting the hemoglobin concentration and SaO_2 into standard equations.

PGDT based on pulse pressure variation (PPV) has also been shown to improve patient outcomes while utilizing less invasive, pulse contour-based, arterial pressure monitoring devices to determine CO.[31,32,33] These devices provide a wide variety of dynamic parameters, are generally easier to use, and have exhibited the ability to adequately assess dynamic changes in CO.[34] PPV, which is inversely proportional to SV when attempting to maximize SV intraoperatively, has also been shown to accurately reflect volume responsiveness in a number of different high-risk surgical groups, helping avoid unnecessary and potentially harmful volume loading by reflecting the cyclic changes in preload induced by mechanical ventilation.[35,36,37,38]

A randomized, multi-center study of patients undergoing major abdominal surgery demonstrated that PGDT using PPV, radial artery pulse contour CI, and MAP leads to a reduction in postoperative complications (See Figure 2).[39] After an initial assessment, patients in the study were reassessed every 15 minutes intraoperatively to maintain hemodynamically stable values. Hemodynamic data were documented every 30 minutes, and ventilatory parameters every 60 minutes. Meanwhile, the treatment of patients in the control group was performed at the discretion of the care-giving anesthesiologist.

FIGURE 2. MULTI-CENTER COMPARISON OF COMPLICATIONS FOLLOWING MAJOR SURGERY BETWEEN PGDT AND NON-PGDT GROUPS[39]



Control group (basic anesthesia monitoring without PPV and CI information; treatment at the discretion of the caregiver); Study group (basic anesthesia monitor including continuous PPV and CI information; initial hemodynamic assessment/intervention based on PPV and CI treatment algorithms)

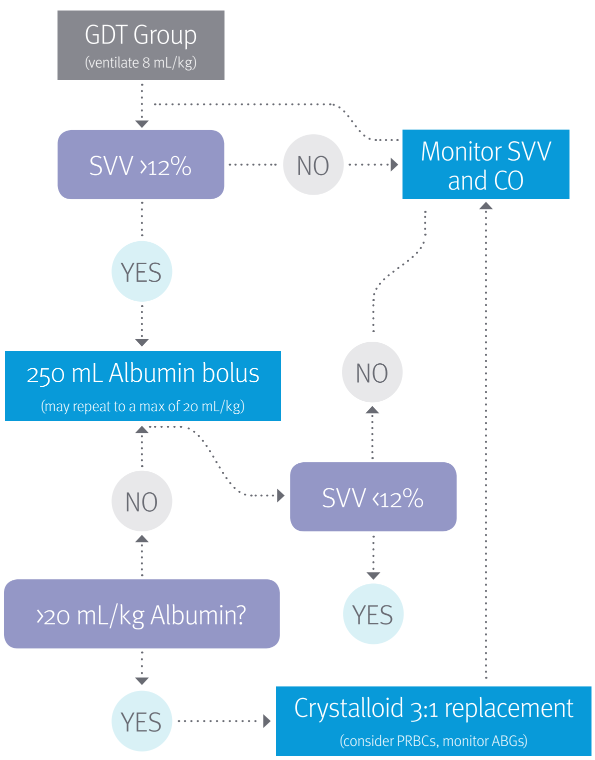
Studies show that applying ERAS practice guidelines reduces postoperative complications by up to 50% and hospital LOS by 2.5 days.[28,44]

Study data showed that the number of patients experiencing a complication, such as renal failure, respiratory failure, or wound infections was significantly lower in the PGDT study group.

One study examining the effects of PGDT based on an SVV-guided protocol (See Figure 3) showed that by maintaining an SVV of ‹12% helped reduce complications and LOS for moderate-risk patients following major surgery.[40] In the study, the PGDT group experienced earlier return of GI function (3 vs. 4 days) and oral intake (4 vs. 5 days), decreased hospital stay (5 vs. 7.5 days), and significantly higher recovery scores compared to the non-PGDT control group. Another study of patients undergoing major surgeries showed that monitoring SV increases greater than 10% with 250 mL boluses reduced total LOS by 3.6 days (See Figure 4).[41]

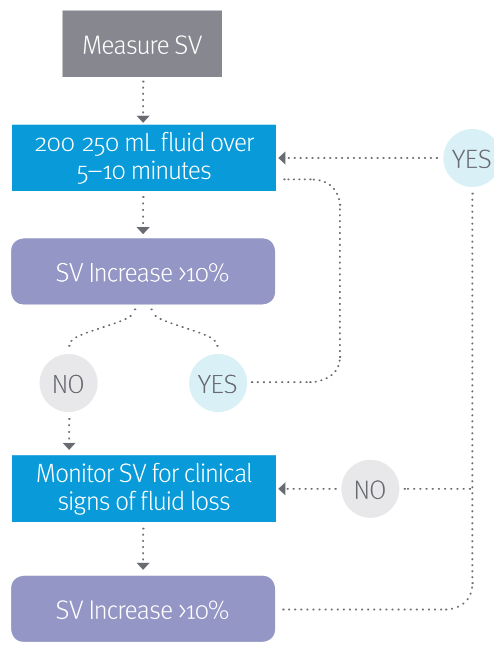
If large amounts of blood loss with severe hemodynamic instability are anticipated during the course of surgery, such as vascular surgery or liver transplant, arterial pressure-based hemodynamic monitoring may be warranted.[39] Research shows that, for some high-risk patients, the use of central venous oxygen saturation ($ScvO_2$) in the early postoperative period is an effective parameter to help guide fluid therapy.[42,43]

FIGURE 3. GDT FLUID MANAGEMENT PROTOCOL[40]



The above SVV-based GDT protocol was used to manage patients by maintaining an SVV ‹12%. Data from the study indicates this intraoperative protocol, guided by arterial pressure-based cardiac output monitoring, may impact postoperative outcomes and hospital LOS.

FIGURE 4. STROKE VOLUME OPTIMIZATION PROTOCOL[41]



Abbreviation: SV = Stroke Volume

The above SV optimization protocol has been associated with reduced postoperative complications and hospital LOS and is now officially recommended by the National Institute for Clinical Excellence in the UK and by the French Society of Anesthesiology & Intensive Care (SFAR).

One review of twenty-nine randomized controlled trials (4,805 patients) found that proactive hemodynamic intervention in the perioperative period for cardiovascular management of moderate- to high-risk patients was associated with a 52% reduction in mortality in studies using a pulmonary artery catheter as well as those that employed cardiac index or oxygen delivery as the end-point targets.[30] The meta-analysis also found that preemptive hemodynamic intervention was associated with a 57% reduction in overall rates of surgical complications.

ECONOMIC BENEFITS

> Although ERAS protocols were initially created for colorectal surgery, the concept has been studied and adapted for use across a wide range of medical specialties including gynecology, thoracic, vascular, pediatric, and orthopedic surgery.

Meta-analyses of published studies focused on major abdominal surgery show that applying ERAS practice guidelines reduces postoperative complications by up to 50% and hospital LOS by 2.5 days.[28,44] One study evaluating the economic impact of the clinical benefits of ERAS found that both direct medical and indirect non-medical costs were significantly lower in the ERAS group.[45] A similar published cost analysis of ERAS for colorectal sugery showed that the full financial burden of setting up and maintaining an ERAS program was significantly offset by the costs saved by reducing postoperative resource utilization.[46] For the 50 patients managed using ERAS protocols, clinicians documented a significant reduction in total hospital stay, intravenous fluid use, complications, and duration of epidural use, representing an overall cost-savings of roughly $345,000, or $6900 per patient—more than offsetting the $102,000 cost associated with implementing the ERAS program.

According to a study conducted at the University of Virginia Medical Center, ERAS patients undergoing colorectal surgery reduced their length of hospital stay to 4.5 days compared to 6.9 days for patients who didn't experience ERAS protocols.[47] The hospital also cut its surgical complication rate from 30% to 15% and saved an average of $7,000 per patient, totaling $700,000 over six months. ERAS programs also allowed the hospital to accept more transfer patients with added bed capacity resulting from shorter LOS. In addition, patient engagement and satisfaction increased significantly, and the 30-day readmission rate fell from 19% to 7%, suggesting the benefits of ERAS protocols extend beyond the hospital walls.

CONCLUSION

The implementation of PGDT protocols guided by continuous hemodynamic monitoring is associated with improved postoperative outcomes and decreased LOS. ERAS guidelines were initially created for colorectal surgery but have since been studied and adapted for use across a wide range of medical specialties, including gynecology, thoracic, vascular, pediatric, and orthopedic surgery. The current evidence base shows that perioperative management, specifically the use of PGDT guided by real-time, continuous hemodynamic monitoring, helps clinicians maintain a patient's optimal fluid balance. Clinical awareness of the impact of ERAS is continuing to grow with help from organizations and societies such as the Enhanced Recovery Partnership (ERP), the Association of Surgeons of Great Britain and Ireland, the French Society of Anesthesiology (SFAR), and the Enhanced Recovery After Surgery Society.[48,49,50,51]

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