VIA MEDICA

Biuletyn Polskiego
Towarzystwa Onkologicznego
NOWOTWORY
2023, tom 8, nr 5, 371–376

ISSN: 2543–5248, e-ISSN: 2543–8077
www.nowotwory.edu.pl

Artykuł przeglądowy / Review article

Nowotwory wątroby / Liver tumors

The influence of fluid therapy on short- and long-term outcomes in patients undergoing liver resection for malignant indications

Marta Dec[1], Wojciech Figiel[2], Paweł Andruszkiewicz[1], Michał Grąt[2]

[1]2nd Department of Anaesthesiology and Intensive Care, Medical University of Warsaw, Warsaw, Poland
[2]Department of General, Transplant and Liver Surgery, Medical University of Warsaw, Warsaw, Poland

Although fluid therapy in hepatic surgery affects the postoperative course and morbidity, there is a paucity of unequivocal guidelines in the literature as to which of three fluid strategies to use: liberal, restrictive or goal-directed. We performed a review of literature regarding fluid management strategies in major abdominal procedures, focusing on hepatic surgery. The quantity and quality of fluids infused perioperatively is often dependent on the preference of the physician, institutional experience and practices. A liberal fluid regimen carries the risk of impaired wound healing and prolonged ileus, furthermore in liver surgery it may increase blood loss. Restrictive fluid therapy is the mainstay of the anesthetic management in hepatic resections, keeping the central venous pressure low controls outflow from the liver and results in a decrease in intraoperative blood loss. In recent years, goal-directed fluid therapy (GDFT), as a component of enhanced recovery pathways after surgery (ERAS) programs, has gained in popularity. It is based on the concept of hemodynamic optimization in order to ensure optimal tissue perfusion and oxygen delivery. Furthermore, a fluid infusion strategy should be individualized in terms of the unique pathophysiology of the patient (e.g. cirrhosis) and the specific requirements of the surgical technique (laparoscopic procedures). Controversy regarding often contradictory data, leaves the clinician at a loss as to which fluid strategy will best serve the patient. Therefore, it is imperative to design and conduct clinical trials in a homogenous group of patients to define the optimal type and amount of fluid for patients undergoing hepatic surgery.

Key words: liver resection, fluid management, goal-directed therapy, restrictive therapy, enhanced recovery pathways after surgery

Fluid regimes in major abdominal surgery

Relevant articles were searched for using the Pubmed database with the following terms: "liver resection", "liver surgery", "goal-directed therapy", "fluid management" and "enhanced recovery after surgery". The results were independently assessed by the authors for scope and relevance.

Many factors influence the normal postoperative course of patients undergoing extensive liver surgery. One of those is a fluid infusion strategy; preoperatively – in urgent cases – intraoperatively and in the postoperative period. Transfusion of the optimal fluid volume during surgical procedures and in the postoperative period affects the course of the operation, as well as postoperative morbidity. Both excessive and insufficient fluid intake can be harmful [1, 2]. The main goal is to restore and maintain fluid volume to ensure homeostasis in terms of euvolemia, electrolyte balance and tissue perfusion.

Jak cytować / How to cite:
Dec M, Figiel W, Andruszkiewicz P, Grąt M. ***The influence of fluid therapy on short- and long-term outcomes in patients undergoing liver resection for malignant indications.*** *NOWOTWORY J Oncol* 2023; 73: 303–308.

[3]. Intra- and postoperative fluid transfusion strategies have been the subject of numerous studies. Both surgeons and anesthesiologists have different approaches to fluid management. The confirmation of the thesis that fluid therapy depends mainly on individual preferences of the physician is a study by Lilot et al., which included a group of 5,912 patients undergoing various abdominal procedures. The authors concluded that a patient weighing 75 kg can receive from 500 to 5400 ml of crystalloids depending on the physicians preference [4]. There are generally three main strategies of perioperative fluid therapy: "liberal", "restrictive" and "goal-directed". Each of these strategies has its supporters and opponents, and each has been the subject of randomized trials. After years of a "liberal" approach, a paper by Brandstrup et al. was published comparing "liberal" and "restrictive" strategies. The results of the study clearly indicated a statistically significant increase in the number of complications in the patients from the "liberal" group [5]. Over the following years, the "restrictive strategy" has gained popularity, as one of the components of the "enhanced recovery after surgery" (ERAS) protocols. In 2018, a multicenter study was published comparing the two strategies. The study included a group of 3,000 patients. One of the key results of the study was the finding of a statistically higher incidence of acute kidney injury in patients who received fluids according to restriction protocol [6].

The adopted perioperative fluid therapy strategies have been extensively studied especially in patients undergoing gastrointestinal procedures. Some researchers believe that excessive fluid loading impairs the healing of intestinal anastomoses, delays the return of gastrointestinal motility, increases the overall incidence of complications, increases the length of hospital stay and the cost of treatment [7–9]. While this is true in patients undergoing procedures on the large intestine [10], it has been shown that the use of restrictive fluid therapy does not bring such benefits in cases of pancreatoduodenectomy [11, 12]. With regards to abdominal surgery, it should be noted that the specificity of individual procedures (the number of intestinal anastomoses, the need to open the retroperitoneal space, the presence of vascular anastomoses) affects the movement of fluids between compartments. In order to recommend a "surgery specific" fluid strategy, studies should be carried out in homogeneous groups.

Evolution of aim-directed fluid protocols. Optimization of oxygen delivery to tissues

In addition to the restrictive and liberal strategies discussed so far, or rather, as a result of the inconclusive results of conducted studies, a third strategy named goal-directed therapy (GDT) was introduced.

This strategy was created not only in response to the contradictory results of studies on the previously mentioned liberal and restrictive strategies, but also stemmed from in-depth analysis of the pathophysiology of the phenomena leading to increased number of complications, prolonged hospitalization and postoperative deaths in patients undergoing non-cardiac surgery. It was proven that intraoperative tissue perfusion (tissue blood flow), arterial oxygen saturation, hemoglobin concentration and cardiac output – components of the parameter referred to as oxygen tissue delivery (DO_2) – affect mortality and morbidity. The conducted studies have shown that perioperative fluid therapy, optimized on the basis of hemodynamic parameters significantly reduces the number of postoperative complications and the risk of death. At the same time, it has been shown that traditional parameters monitored intra- and postoperatively, i.e., blood pressure and heart rate, are not sensitive enough to detect moderate hypovolemia, which may cause inadequate tissue perfusion, especially in the visceral bed [13–15]. Goal-directed therapy is based on the premise that perioperative fluid administration is essential to maximizing DO_2. Therefore, it should be based on dynamic flow-dependent parameters, i.e., stroke volume (SV) and its variability in response to fluid bolus (stroke volume variation – SVV) [16, 17]. The results of randomized trials, where the primary endpoint was the occurrence of postoperative complications (as in other studies evaluating the liberal and restrictive strategy) are contradictory. The FEDORA study showed a statistically significant lower complication rate in patients from the GDT group who underwent abdominal procedures [15]. However, the work of Pestania et al. (POEMAS study) showed no such relationship [18].

Concept of perioperative euvolemia

Most studies refer to intraoperative fluid administration. Some papers treat this topic more broadly and include the preoperative and postoperative period as well. The protocols regarding the intake of fluids before abdominal surgery clearly indicate the benefits of the lack of restrictions in oral administration up to 2 hours before the induction of anesthesia [19]. Postoperative fluid therapy should continue as long as the patient is unable to tolerate oral intake. Its primary goal is to maintain intravascular volume while avoiding a positive fluid balance which, among others, leads to delayed healing of the wounds and anastomoses, consequently leading to a longer hospital stay, prolonged ileus and other complications [20]. In recent years the term "goal-directed therapy" has been introduced in literature in relation to intraoperative infusions, and "zero balance" – in relation to postoperative management.

Fluid therapy in liver surgery

The incidence of liver tumors is on the rise [21]. Indications to liver resections are mainly oncological, with the majority of cases being hepatocellular carcinoma and metastatic tumors. The basic differences in the approach to intraoperative and postoperative fluid therapy in patients undergoing liver surgery will be presented below. Clinical situations related to patients who are hemodynamically unstable prior to emergency surgery will be intentionally omitted. Septic patients, as well as those receiving total parenteral nutrition will not be discussed either. Thus, we will concentrate on fluid therapy in ASA ≤3 patients undergoing elective liver procedures.

Liver surgery can be divided into hepatic parenchymal surgery, biliary tract surgery and cholecystectomy. The aim is to discuss the strategy of intra- and postoperative fluid therapy in large (including excision of more than 3 segments) liver resections.

Limitation of blood loss in liver surgery

One of the key aspects of liver surgery is the bloodless surgical field. The inflow to the liver may be controlled, e.g. by the Pringle maneuver (a temporary tightening of the hepatoduodenal ligament). Back bleeding from valveless hepatic veins is prevented by low central venous pressure. CVP of 5 mmHg is recommended to provide unobstructed outflow and limit blood loss. It has been shown that maintaining low central venous pressure effectively reduces bleeding, limiting the need for blood product transfusions, morbidity and postoperative mortality. At the same time, it has been shown that it does not significantly affect the incidence of postoperative acute kidney injury [22–27].

Looking for a silver bullet in fluid management

Recently, the role of central venous pressure (CVP) as a reliable parameter for assessing volemia has been increasingly questioned. Hemodynamic parameters as guides to volume management have gained popularity, although analysis of the literature reveals that these methods also have limitations. Problematic situations include mechanical ventilation and cardiac arrythmias to name a few [28].

Regardless of the monitoring methods used, the aim of the anesthetic technique is to maintain the free outflow of the blood through the hepatic veins. This is achieved by simultaneously employing several methods: fluid restriction, head-elevated patient positioning and ventilation techniques with pressure limitation in airways. Vasodilators (nitroglycerin) sublingually or intravenously are also used. It should be emphasized that these strategies are limited to the stage of parenchymal transection. Fluid infusion is being restricted to 1 ml/kg/h of buffered crystalloid plus additional volume to make up for the ongoing blood loss at a ratio 1:1. Intraoperative fluid therapy strategies are the subject of randomized trials. Correa-Galle et al. compared a conventional strategy with "goal-directed fluid therapy". Randomization was performed after the resection stage. The "conventional" group received an infusion of crystalloid at a dose of 6 ml/kg/h. The "goal-directed" group received infusion at a rate of 1 ml/kg/h with the simultaneous supplementation of albumin solution with an aim to restore stroke volume variation (SVV) to the level measured at the induction of anesthesia. In both groups, additional fluid volume was administered to maintain systolic blood pressure ≥90 mmHg or diuresis >25 ml/h. Red blood cell concentrate was also given to ensure hemoglobin concentration ≥7g/dl. In the postoperative period, conventional fluid therapy of 1.2 ml/kg/h was used with additional infusion in order to maintain the above-mentioned targets. There was no statistically significant difference in terms of the incidence of postoperative complications, the length of hospital stay or other variables specified in the study. A statistically significant difference was observed in the total volume of fluids infused during the post-hepatectomy phase. In the "goal-directed" group it was lower by an average of 900 ml [29]. Another study by Weinberg et al. compared the addition of a fluid restrictive intraoperative cardiac output-guided algorithm to standard fluid protocol. The "conventional care" group consisted of patients in whom the amount of fluid and catecholamines administration were at the discretion of the anesthesiologist. In both groups a higher incidence of postoperative complications was found, compared to the previously cited study, and these were mainly grade I and II complications according to the Clavien-Dindo classification. This trial showed a statistically significant lower fluid balance in the study group compared to the control group. There were no differences in the incidence of acute kidney injury between the groups [30].

Studies conducted by Kim Y. et al. [31] and Lilot M. et al. [32] showed that despite the recommendations regarding intraoperative fluid therapy in patients undergoing abdominal procedures, including liver resections, there is a very large discrepancy regarding the amount of fluids administered between individual centers and even physicians. Hepatic resections are procedures that can significantly affect hemodynamics, e.g. by compressing the inferior vena cava during surgical maneuvers, which causes a decrease in venous return and consequently cardiac output. In addition, the liver because of its metabolic function, i.e., contributing to lactate clearance, affects the acid-base balance.

Taking into account these facts and the protocols of enhanced recovery after surgery (ERAS) [33], which recommend intraoperative fluid restriction but not at the cost of organ hypoperfusion, the following can be suggested: the most appropriate approach to perioperative fluid therapy in liver resections should be goal-directed therapy with fluid restriction until transection completion (low central venous pressure) with subsequent volemia restoration under SVV guidance. Indicators of organ perfusion, e.g. serum lactate concentration should be monitored and included in decision-making regarding fluid therapy in the postoperative period with the aim to stabilize hemodynamic parameters, maintain diuresis and improve metabolic hemostasis [34, 35].

In the postoperative period, methods based on techniques that assess the diameter of the inferior vena cava, its collapsibility, extensibility and the Doppler spectrum of the portal vein and hepatic veins can be used to guide fluid therapy [36, 37]. To date, there are no reports on the effectiveness of these methods in liver surgery.

There are no data concerning the impact of the applied fluid strategy on early and long-term prognosis in resections performed for oncological reasons. Restrictive and goal-oriented therapy facilitates visualization in the operating field, which may improve the radicality of the procedure. No studies have investigated the relation between the type of perioperative fluid regimen used as regards tumor recurrence risk. Further research in this direction is warranted.

Laparoscopic techniques

Laparoscopic liver resections have been gaining popularity. There are no randomized prospective studies comparing different strategies (liberal, restrictive and goal-directed) in resections performed laparoscopically. Nevertheless, in the published trials, the technique of maintaining low central venous pressure in the transection phase was adopted as a standard, with the aim of reducing bleeding. However, low central venous pressure together with increased intra-abdominal pressure increases the risk of gas embolism (carbon dioxide) [38, 39]. It seems prudent to use SVV rather than CVP monitoring as an indicator of vascular bed filling and use it as a guide to fluid therapy during the transection phase. In laparoscopic procedures, central venous pressure is notoriously unreliable due to the influence of the pneumoperitoneum on the inferior vena cava pressure [40, 41].

Challenges in cirrhosis

Data on fluid therapy in extensive resections in patients with cirrhosis is lacking. Published trials describe anesthesia complexity in this population, including strategies of fluid therapy [42, 43]. Taking into account the detailed data on the multi-organ consequences of cirrhosis and liver failure, it can be assumed that goal-directed therapy should be adopted.

Depending on the severity of cirrhosis and abnormal liver function (assessed according to the MELD or Child–Pugh scale), organ dysfunctions will vary, e.g. the presence of hepatorenal syndrome or the severity of hyperkinetic circulation with a relative or absolute intravascular volume deficit. Portal hypertension with collateral circulation, independently of other causes of coagulopathies, may increase the risk of bleeding at the stage of abdominal cavity incision. Multifactorial coagulopathy complicates anesthesia management. Vigilance over blood loss is essential with thresholds for red blood cells, platelets and plasma transfusions to maintain homeostasis. Fluid strategy, other than goal-directed, may exacerbate pathologies present in cirrhosis. The restrictive strategy may lead to hypoperfusion of vital organs, including the liver, intestines and kidneys, and as a result, lead to their failure. The liberal strategy, in addition to preexisting hypoalbuminemia, may lead to edema of the liver and the intestinal wall. Removal of the excess fluid may prove difficult, and, in some cases, impossible without implementing renal replacement therapy.

Performing major abdominal surgeries in patients with hepatic insufficiency, requires balancing the risk of exacerbation of liver failure and its organ consequences with expected benefits. Mortality in cirrhotic patients decreased due to advances in surgical techniques, anesthesia and postoperative care. In group C according to the Child–Pugh scale, it is expected to be 12%, in comparison to previous years, when it was estimated at 82% [44, 45]. However, these estimates do not refer to hepatic surgeries. Scheduled liver resections in C group are contraindicated.

Types of fluids

An increase in lactate concentration in patients undergoing liver resection is a common phenomenon. This is due to impaired lactate liver clearance but can also be caused by increased anaerobic metabolism associated with maintaining low central venous pressure and subsequent organ hypoperfusion. It is widely accepted to use balanced crystalloid solutions. A study by Weinberg et al. showed that acetate buffered crystalloids are recommended. Better biochemical and hematological indices are obtained in terms of electrolyte balance, acid-base balance and coagulation parameters compared to solutions buffered with lactates [46]. Data on the safety of hydroxyethyl starch solutions are conflicting and mainly drawn from studies of intensive care patients. However, most authors indicate a potentially higher risk of acute kidney injury and coagulation disorders in patients receiving these solutions [47–49]. No definitive conclusions can be drawn on gelatin solution use. Conclusive data from randomized trials is lacking. Acute kidney injury, coagulation disorders and remnant failure may complicate liver resection. Thus, in the author's opinion, the use of the above-mentioned solutions should not be encouraged during liver resection and in the postoperative period. Postoperative fluid therapy in patients undergoing laparoscopic liver resections does not differ significantly from what has been discussed previously. This technique results in fewer complications, faster recovery of gastrointestinal function, which encourages earlier oral fluid intake and a shorter hospital stay. The published results of studies on the safety of using albumin solutions cover mainly critically ill patients and patients undergoing abdominal surgery, not specifically liver resection [50, 51]. Although there are no studies on this group of patients, being aware of the possibility of liver failure after the procedure (sometimes before) and the physiological role of albumin i.e. in maintaining oncotic pressure, preventing the occurrence of edema, it can be assumed that their administration both intra- and postoperatively is beneficial – especially when large volumes of crystalloids would have to be used otherwise.

Conclusions

Fluid transfusion in the perioperative period in major liver resections is a complex topic. The chosen fluid strategy has an impact on morbidity and the length of hospital stay. It is of the utmost importance to detect features of cirrhosis and its complications which may largely determine the type of strategy adopted. In extensive liver resections without cirrhosis, restrictive fluid therapy is most often used. During liver resection in cirrhotic livers, goal- directed therapy is preferred. It should be emphasized that only close cooperation between the surgeon and the anesthesiologist during the procedure enables the rational implementation of the adopted strategy, depending on the progress of surgery and clinical situation. The type of fluid is equally as important as the volume. The use of balanced crystalloid solutions is recommended with the exception of lactate-buffered solutions. In cirrhotic liver resection, it is important to maintain an adequate concentration of albumin in the serum, which is justified by the pathophysiology of cirrhosis and its consequences.

Article information and declarations

Author contributions

Marta Dec, Wojciech Figiel – writing of the manuscript.
Paweł Andruszkiewicz, Michał Grąt – review of the manuscript.

Funding

None declared

Conflict of interest

None declared

Wojciech Figiel
Medical University of Warsaw
Department of General, Transplant and Liver Surgery
ul. Banacha 1a
02-097 Warszawa
e-mail: wojciech.figiel@wum.edu.pl

Received: 19 Jul 2023
Accepted: 25 Sep 2023

References

1. Bellamy MC. Wet, dry or something else? Br J Anaesth. 2006; 97(6): 755–757, doi: 10.1093/bja/ael290, indexed in Pubmed: 17098724.
2. Minto G, Mythen MG. Perioperative fluid management: science, art or random chaos? Br J Anaesth. 2015; 114(5): 717–721, doi: 10.1093/bja/aev067, indexed in Pubmed: 25794505.
3. Miller TE, Myles PS. Perioperative Fluid Therapy for Major Surgery. Anesthesiology. 2019; 130(5): 825–832, doi: 10.1097/ALN.0000000000002603, indexed in Pubmed: 30789364.
4. Lilot M, Ehrenfeld JM, Lee C, et al. Variability in practice and factors predictive of total crystalloid administration during abdominal surgery: retrospective two-centre analysis. Br J Anaesth. 2015; 114(5): 767–776, doi: 10.1093/bja/aeu452, indexed in Pubmed: 25586725.
5. Brandstrup B, Tønnesen H, Beier-Holgersen R, et al. Danish Study Group on Perioperative Fluid Therapy. Effects of intravenous fluid restriction on postoperative complications: comparison of two perioperative fluid regimens: a randomized assessor-blinded multicenter trial. Ann Surg. 2003; 238(5): 641–648, doi: 10.1097/01.sla.0000094387.50865.23, indexed in Pubmed: 14578723.
6. Myles PS, McIlroy DR, Bellomo R, et al. Australian and New Zealand College of Anaesthetists Clinical Trials Network and the Australian and New Zealand Intensive Care Society Clinical Trials Group. Restrictive versus Liberal Fluid Therapy for Major Abdominal Surgery. N Engl J Med. 2018; 378(24): 2263–2274, doi: 10.1056/NEJMoa1801601, indexed in Pubmed: 29742967.
7. Marjanovic G, Villain C, Juettner E, et al. Impact of different crystalloid volume regimes on intestinal anastomotic stability. Ann Surg. 2009; 249(2): 181–185, doi: 10.1097/SLA.0b013e31818b73dc, indexed in Pubmed: 19212167.
8. Kulemann B, Timme S, Seifert G, et al. Intraoperative crystalloid overload leads to substantial inflammatory infiltration of intestinal anastomoses-a histomorphological analysis. Surgery. 2013; 154(3): 596–603, doi: 10.1016/j.surg.2013.04.010, indexed in Pubmed: 23876362.
9. Holte K, Sharrock NE, Kehlet H. Pathophysiology and clinical implications of perioperative fluid excess. Br J Anaesth. 2002; 89(4): 622–632, doi: 10.1093/bja/aef220, indexed in Pubmed: 12393365.
10. Irish Surgical Research Collaborative. PERioperative Fluid Management in Elective ColecTomy (PERFECT)-a national prospective cohort study. Ir J Med Sci. 2019; 188(4): 1363–1371, doi: 10.1007/s11845-019-02003-w, indexed in Pubmed: 30982155.
11. Martin D, Lykoudis PM, Jones G, et al. Impact of postoperative intravenous fluid administration on complications following elective hepato-pancreato-biliary surgery. Hepatobiliary Pancreat Dis Int. 2018; 17(5): 402–407, doi: 10.1016/j.hbpd.2018.09.001, indexed in Pubmed: 30243876.
12. Chen BP, Chen M, Bennett S, et al. Systematic Review and Meta-analysis of Restrictive Perioperative Fluid Management in Pancreaticoduodenectomy. World J Surg. 2018; 42(9): 2938–2950, doi: 10.1007/s00268-018-4545-6, indexed in Pubmed: 29464346.
13. Bundgaard-Nielsen M, Holte K, Secher NH, et al. Monitoring of perioperative fluid administration by individualized goal-directed therapy. Acta Anaesthesiol Scand. 2007; 51(3): 331–340, doi: 10.1111/j.1399-6576.2006.01221.x, indexed in Pubmed: 17390421.
14. Lobo SM, de Oliveira NE. Clinical review: What are the best hemodynamic targets for noncardiac surgical patients? Crit Care. 2013; 17(2): 210, doi: 10.1186/cc11861, indexed in Pubmed: 23672840.
15. Calvo-Vecino JM, Ripollés-Melchor J, Mythen MG, et al. FEDORA Trial Investigators Group. Effect of goal-directed haemodynamic therapy on postoperative complications in low-moderate risk surgical patients: a multicentre randomised controlled trial (FEDORA trial). Br J Anaesth. 2018; 120(4): 734–744, doi: 10.1016/j.bja.2017.12.018, indexed in Pubmed: 29576114.
16. Grocott MPW, Mythen MG, Gan TJ. Perioperative fluid management and clinical outcomes in adults. Anesth Analg. 2005; 100(4): 1093–1106, doi: 10.1213/01.ANE.0000148691.33690.AC, indexed in Pubmed: 15781528.
17. Price HL, Deutsch S, Marshall BE, et al. Hemodynamic and metabolic effects of hemorrhage in man, with particular reference to the splanchnic circulation. Circ Res. 1966; 18(5): 469–474, doi: 10.1161/01.res.18.5.469, indexed in Pubmed: 5937539.
18. Pestaña D, Espinosa E, Eden A, et al. Perioperative goal-directed hemodynamic optimization using noninvasive cardiac output monitoring in major abdominal surgery: a prospective, randomized, multicenter, pragmatic trial: POEMAS Study (PeriOperative goal-directed thErapy in Major Abdominal Surgery). Anesth Analg. 2014; 119(3): 579–587, doi: 10.1213/ANE.0000000000000295, indexed in Pubmed: 25010820.
19. Pędziwiatr M, Mavrikis J, Witowski J, et al. Current status of enhanced recovery after surgery (ERAS) protocol in gastrointestinal surgery. Med Oncol. 2018; 35(6): 95, doi: 10.1007/s12032-018-1153-0, indexed in Pubmed: 29744679.
20. Malbrain ML, Langer T, Annane D, et al. Intravenous fluid therapy in the perioperative and critical care setting: Executive summary of the International Fluid Academy (IFA). Ann Intensive Care. 2020; 10(1): 64, doi: 10.1186/s13613-020-00679-3, indexed in Pubmed: 32449147.
21. Wojciechowska U, Barańska K, Miklewska M, et al. Cancer incidence and mortality in Poland in 2020. Nowotwory. Journal of Oncology. 2023; 73(3): 129–145, doi: 10.5603/NJO.2023.0026.
22. Cunningham JD, Fong Y, Shriver C, et al. One hundred consecutive hepatic resections. Blood loss, transfusion, and operative technique. Arch Surg. 1994; 129(10): 1050–1056, doi: 10.1001/archsurg.1994.01420340064011, indexed in Pubmed: 7944934.
23. Melendez JA, Arslan V, Fischer ME, et al. Perioperative outcomes of major hepatic resections under low central venous pressure anesthesia: blood loss, blood transfusion, and the risk of postoperative renal dysfunction. J Am Coll Surg. 1998; 187(6): 620–625, doi: 10.1016/s1072-7515(98)00240-3, indexed in Pubmed: 9849736.
24. Jones RM, Moulton CE, Hardy KJ. Central venous pressure and its effect on blood loss during liver resection. Br J Surg. 1998; 85(8): 1058–1060, doi: 10.1046/j.1365-2168.1998.00795.x, indexed in Pubmed: 9717995.
25. Chen H, Merchant NB, Didolkar MS. Hepatic resection using intermittent vascular inflow occlusion and low central venous pressure anesthesia improves morbidity and mortality. J Gastrointest Surg.

2000; 4(2): 162–167, doi: 10.1016/s1091-255x(00)80052-9, indexed in Pubmed: 10675239.
26. Smyrniotis V, Kostopanagiotou G, Theodoraki K, et al. The role of central venous pressure and type of vascular control in blood loss during major liver resections. Am J Surg. 2004; 187(3): 398–402, doi: 10.1016/j.amjsurg.2003.12.001, indexed in Pubmed: 15006570.
27. Eid EA, Sheta SA, Mansour E. Low central venous pressure anesthesia in major hepatic resection. Middle East J Anaesthesiol. 2005; 18(2): 367–377, indexed in Pubmed: 16438011.
28. Huntington JT, Royall NA, Schmidt CR. Minimizing blood loss during hepatectomy: a literature review. J Surg Oncol. 2014; 109(2): 81–88, doi: 10.1002/jso.23455, indexed in Pubmed: 24449171.
29. Marik PE, Monnet X, Teboul JL. Hemodynamic parameters to guide fluid therapy. Ann Intensive Care. 2011; 1(1): 1, doi: 10.1186/2110-5820-1-1, indexed in Pubmed: 21906322.
30. Correa-Gallego C, Tan KS, Arslan-Carlon V, et al. Goal-Directed Fluid Therapy Using Stroke Volume Variation for Resuscitation after Low Central Venous Pressure-Assisted Liver Resection: A Randomized Clinical Trial. J Am Coll Surg. 2015; 221(2): 591–601, doi: 10.1016/j.jamcollsurg.2015.03.050, indexed in Pubmed: 26206652.
31. Weinberg L, Ianno D, Churilov L, et al. Goal directed fluid therapy for major liver resection: A multicentre randomized controlled trial. Ann Med Surg (Lond). 2019; 45: 45–53, doi: 10.1016/j.amsu.2019.07.003, indexed in Pubmed: 31360460.
32. Kim Y, Ejaz A, Gani F, et al. Crystalloid administration among patients undergoing liver surgery: Defining patient- and provider-level variation. Surgery. 2016; 159(2): 389–398, doi: 10.1016/j.surg.2015.06.037, indexed in Pubmed: 26263833.
33. Lilot M, Ehrenfeld JM, Lee C, et al. Variability in practice and factors predictive of total crystalloid administration during abdominal surgery: retrospective two-centre analysis. Br J Anaesth. 2015; 114(5): 767–776, doi: 10.1093/bja/aeu452, indexed in Pubmed: 25586725.
34. Warner SG, Jutric Z, Nisimova L, et al. Early recovery pathway for hepatectomy: data-driven liver resection care and recovery. Hepatobiliary Surg Nutr. 2017; 6(5): 297–311, doi: 10.21037/hbsn.2017.01.18, indexed in Pubmed: 29152476.
35. Giustiniano E, Nisi F, Rocchi L, et al. Perioperative Management of Complex Hepatectomy for Colorectal Liver Metastases: The Alliance between the Surgeon and the Anesthetist. Cancers (Basel). 2021; 13(9), doi: 10.3390/cancers13092203, indexed in Pubmed: 34063684.
36. Yoshino O, Perini MV, Christophi C, et al. Perioperative fluid management in major hepatic resection: an integrative review. Hepatobiliary Pancreat Dis Int. 2017; 16(5): 458–469, doi: 10.1016/S1499-3872(17)60055-9, indexed in Pubmed: 28992877.
37. Charbonneau H, Riu B, Faron M, et al. Predicting preload responsiveness using simultaneous recordings of inferior and superior vena cavae diameters. Crit Care. 2014; 18(5): 473, doi: 10.1186/s13054-014-0473-5, indexed in Pubmed: 25189403.
38. Rola P, Miralles-Aguiar F, Argaiz E, et al. Clinical applications of the venous excess ultrasound (VExUS) score: conceptual review and case series. Ultrasound J. 2021; 13(1): 32, doi: 10.1186/s13089-021-00232-8, indexed in Pubmed: 34146184.
39. Jin D, Liu M, Huang J, et al. Gas embolism under standard versus low pneumoperitoneum pressure during laparoscopic liver resection (GASES): study protocol for a randomized controlled trial. Trials. 2021; 22(1): 807, doi: 10.1186/s13063-021-05678-8, indexed in Pubmed: 34781988.
40. Dunki-Jacobs EM, Philips P, Scoggins CR, et al. Stroke volume variation in hepatic resection: a replacement for standard central venous pressure monitoring. Ann Surg Oncol. 2014; 21(2): 473–478, doi: 10.1245/s10434-013-3323-9, indexed in Pubmed: 24150192.
41. Tranchart H, Dagher I. Laparoscopic liver resection: A review. Journal of Visceral Surgery. 2014; 151(2): 107–115, doi: 10.1016/j.jviscsurg.2013.10.003.
42. Abbas N, Makker J, Abbas H, et al. Perioperative Care of Patients With Liver Cirrhosis: A Review. Health Serv Insights. 2017; 10: 1178632917691270, doi: 10.1177/1178632917691270, indexed in Pubmed: 28469455.
43. Kiamanesh D, Rumley J, Moitra VK. Monitoring and managing hepatic disease in anaesthesia. Br J Anaesth. 2013; 111 Suppl 1: i50–i61, doi: 10.1093/bja/aet378, indexed in Pubmed: 24335399.
44. Mansour A, Watson W, Shayani V, et al. Abdominal operations in patients with cirrhosis: still a major surgical challenge. Surgery. 1997; 122(4): 730–5; discussion 735, doi: 10.1016/s0039-6060(97)90080-5, indexed in Pubmed: 9347849.
45. Telem DA, Schiano T, Goldstone R, et al. Factors that predict outcome of abdominal operations in patients with advanced cirrhosis. Clin Gastroenterol Hepatol. 2010; 8(5): 451–7, quiz e58, doi: 10.1016/j.cgh.2009.12.015, indexed in Pubmed: 20036761.
46. Weinberg L, Pearce B, Sullivan R, et al. The effects of plasmalyte-148 vs. Hartmann's solution during major liver resection: a multicentre, double-blind, randomized controlled trial. Minerva Anestesiol. 2015; 81(12): 1288–1297, indexed in Pubmed: 25407026.
47. Perel P, Roberts I, Ker K. Colloids versus crystalloids for fluid resuscitation in critically ill patients. Cochrane Database Syst Rev. 2013(2): CD000567, doi: 10.1002/14651858.CD000567.pub6, indexed in Pubmed: 23450531.
48. Bagshaw SM, Chawla LS. Hydroxyethyl starch for fluid resuscitation in critically ill patients. Can J Anaesth. 2013; 60(7): 709–713, doi: 10.1007/s12630-013-9936-4, indexed in Pubmed: 23604905.
49. Mutter TC, Ruth CA, Dart AB, et al. Hydroxyethyl starch (HES) versus other fluid therapies: effects on kidney function. Cochrane Database Syst Rev. 2010(1): CD007594, doi: 10.1002/14651858.CD007594.pub2, indexed in Pubmed: 20091640.
50. Roberts I, Blackhall K, Alderson P, et al. Albumin Reviewers (Alderson P, Bunn F, Li Wan Po A, Li L, Blackhall K, Roberts I, Schierhout G), Albumin Reviewers, Cochrane Injuries Group Albumin Reviewers. Human albumin administration in critically ill patients: systematic review of randomised controlled trials. BMJ. 1998; 317(7153): 235–240, doi: 10.1136/bmj.317.7153.235, indexed in Pubmed: 9677209.
51. Finfer S, Bellomo R, Boyce N, et al. SAFE Study Investigators. A comparison of albumin and saline for fluid resuscitation in the intensive care unit. N Engl J Med. 2004; 350(22): 2247–2256, doi: 10.1056/NEJMoa040232, indexed in Pubmed: 15163774.