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Perioperative haemodynamic optimisation in patients undergoing non-cardiac surgery — a position statement from the Cardiac and Thoracic Anaesthesia Section of the Polish Society of Anaesthesiology and Intensive Therapy. Part 1

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GENERAL CONSIDERATIONS

In 2009, an article was published in the opinion-leading *New England Journal of Medicine* which documented even two-fold differences in mortality between hospitals concerning patients undergoing vascular and abdominal surgery [1]. The authors indicated that hospitals existed which were characterized by high or low perioperative mortality (3.5% vs 6.9%). An analysis of demographic parameters, concomitant conditions, and the type of surgery being performed allowed additional comparisons. It was shown that the complication rate in the perioperative period did not differ between hospitals, with a difference being seen only regarding mortality. It was previously suggested that the reason for high mortality was ineffectiveness of the treatment that had been undertaken (failure to rescue), with treatment effectiveness depending mostly on the early diagnosis and the targeted treatment of complications. The place where the patient is treated is also of importance. Optimal timing of patient transfer to an intensive care unit (ICU) may have a major effect on treatment outcomes. The timing of treatment, type of therapy and the settings of care are not the only determinants of treatment success. The number of specialists employed and nurse staffing of the post-anaesthesia care unit (PACU) or the ICU have an unquestionable effect of treatment outcomes [2]. These factors underlie the differences in the level of care.

The criteria for patient selection and admission to an ICU have been defined in the Polish Society of Anaesthesiology and Intensive Care guidelines [3]. Postoperative care for high-risk patients is considered a first priority in these guidelines. The continuous presence of a physician is an important advantage of these settings of care. The concept of shared care was first introduced in the United States. American authors documented clinically significant hypotension lasting on average 150 minutes if patients were managed in surgical wards in the early postoperative period. In operating room settings, this period was 10 times shorter. It was also shown that nurses identify only 5% of hypoxemic episodes in this patient group. Both hypotension and hypoxemia may lead to complications. The appropriate organization of the postoperative care that involved the continuous presence of a physician contributed to a reduction in mortality. This specific analysis focused on the surgical treatment of hip fractures with a geriatrician's input into postoperative care [4].

The scope of the problem is indicated by the sheer numbers. Worldwide, the estimated annual number of surgical procedures is 230 million. About 15% of surgical procedures are performed in high-risk patients, and 80% of all postoperative deaths occur in this patient group [5]. Major cardiovascular complications are the cause of one third of these deaths [6]. Moreover, perioperative myocardial infarction is becoming an increasingly important problem. This may be caused by typical vessel occlusion secondary to atherosclerotic plaque rupture (type 1 infarction) or prolonged abnormal myocardial oxygen balance (type 2 infarction) [7]. The most common cause of type 2 infarction is tachycardia. This type is also more common in patients with diastolic heart failure, developing due to volume overload [8]. If postoperative deaths were considered a separate category, this would be the third most common cause of mortality in the United States [4]. Thus, the scope of this problem is enormous.

The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) showed that the 30-day postoperative complication rate is a more important predictor of early mortality and long-term outcomes (survival time) than the preoperative risk estimate and surgery-related risk [9]. Despite effective treatment during hospitalization, complications such as pneumonia, deep surgical wound infections, pulmonary embolism, and acute kidney injury lead to decreased survival. Audit conclusions indicate the need to concentrate staff and resources in order to prevent postoperative complications, diagnose impending complications early and, ultimately, institute effective treatment. It also seems reasonable to increase the duration of postoperative follow-up.

Risk evaluation is fundamental for preoperative management. It helps inform the patient precisely about the existing risks, which allows for an informed decision and consent for anaesthesia. It also guides the physician's team regarding the choice of the optimal treatment method, including consideration of hybrid, minimally invasive and palliative approaches. When planning management strategies, the extent of intra- and postoperative monitoring should be included, as should be the place of further postoperative care. An action plan based on a carefully selected risk score, prepared by an interdisciplinary team, increases the chance of treatment success and reduces suffering and costs. It should be stressed, however, that the overestimation of risk leads to delaying, or even denying surgical treatment which may be the only effective treatment approach [10]. Thus, the patient is deprived of the prospect of an improved quality of life.

Drug treatment used in a patient scheduled for surgery must be carefully analysed [11]. As hypertension and ischemic heart disease are major diseases of civilization, drug treatment of these conditions most commonly requires modifications [11, 12]. Beta-blocker use was carefully evaluated in the PeriOperative ISchemic Evaluation (POISE) study [13]. The findings of this study indicate that chronic beta-blocker therapy should be continued in the perioperative period, although the dose may be modified (reduced). This treatment should be initiated at least one week before the surgery in patients with a revised cardiac risk index (RCRI) of 2 or more, or American Society of Anesthesiologists (ASA) class III or higher [11]. The recommended drugs are bisoprolol and atenolol. The beta-blocker dose should be increased slowly and titrated individually to achieve the target heart rate (60–70 bpm) and blood pressure (systolic blood pressure >100 mm Hg). Other drug classes worth mentioning are angiotensin-converting enzyme inhibitors and angiotensin receptor blockers. These drugs increase the risk of intraoperative hypotension (vasoplegic syndrome). In patients with hypertension, they should be temporarily withdrawn (two days before surgery), while the treatment should be continued in patients with heart failure [11, 14].

Intensive care already begins in the operating room. The optimal condition for appropriate tissue oxygen supply is normovolaemia. Inappropriate correction of the volume status leads to hypo- or hypervolaemia. Both these clinical situations are dangerous, as they lead to inadequate perfusion and cellular hypoxia (Fig. 1). In addition, hypervolaemia results in the development of oedema. Fluid shifts between the compartments are inevitable in such circumstances as trauma, surgery, and sepsis. The underlying cause are mediators released during the systemic inflammatory response along with lymphatic system insufficiency. Poorly controlled fluid replacement aggravates fluid shifts. The importance of fluid therapy is directly related to the extent of the surgery. In high risk surgical procedures, restrictive fluid therapy has been shown to reduce the rates of anas-

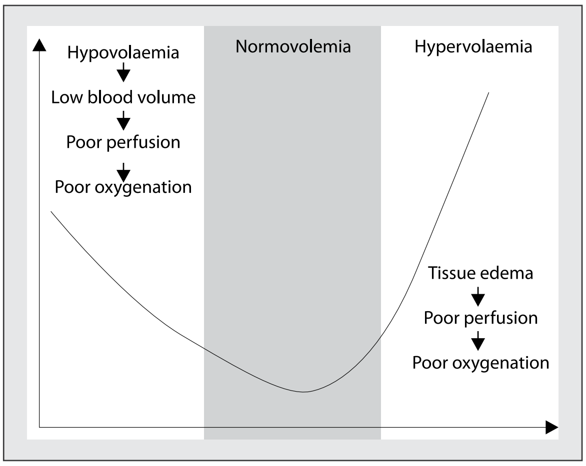

Figure 1. Volume optimization in the perioperative period [based on: 15]

tomosis leakage, pneumonia and surgical wound infection, leading to a reduced duration of hospital stay. Such benefits have not been shown for low risk surgical procedures. Of note is the fact that liberal fluid therapy may be beneficial in the latter case. These benefits include reduction in the rate of postoperative nausea and vomiting, as well as less postoperative pain [15].

The concept of fluid compartment integrity assumes that two types of fluid shifts exist. The first type is a physiological shift between intravascular water and the interstitial space. The fluid is protein-free and the capillary barrier is preserved. These shifts are rapidly reversible due to normal functioning of the lymphatic system. The second type is clinically more important. This is associated with impaired endothelial integrity, and the thus the fluid shifting between the compartments is rich in protein. Reversal of these changes requires a long time, which may have an adverse effect on the function of organs affected with fluid overload. An increased susceptibility to infections and impaired wound healing, including that of surgical anastomoses, are observed [16]. Fluid shifts are increased by using inappropriate (unbalanced) fluids, not observing indications for their use, and inappropriate dosing. Crystalloids should be used to correct fluid losses related to perspiration and diuresis while colloids should be administered in cases of active bleeding. Fluid shifts are limited by the avoidance of both hypo- and hypervolaemia. The persistence of hypovolaemia, despite fluid therapy, results from underestimation of bleeding or damage to the natural barrier of the vessel wall [17].

Perioperative fluid therapy means fluid substitution. Using the terms of "restrictive" and "liberal" fluid therapy is an oversimplification. Volume status should be optimized individually (patient-oriented medicine/personalised medicine/theranostic approach) in all high-risk patients or scheduled for a high risk surgery. Optimization may be understood as monitoring volume status in the context of providing oxygen supply and maintaining its positive balance (goal-directed therapy, GDT). Hypovolaemia is a condition associated with symptoms of hypoperfusion that are resolved following fluid administration. The situation is complicated by the fact that only 50% of patients with symptoms of hypoperfusion respond positively to fluid therapy (fluid responders), while the remaining 50% are considered non-responders. Fluid administration should expand intravascular volume leading to an increase in cardiac output. In a haemodynamically unstable patient, it is necessary to answer the basic question as to whether cardiac output has increased following fluid administration. If the answer is positive, such treatment should be continued. It should be noted that this information is not provided by conventionally evaluated haemodynamic "macroparameters" (systemic blood pressure, heart rate, central venous pressure, oxygen saturation). An increase in systemic blood pressure following fluid administration does not equal an increase in cardiac output. Most controversies are related to central venous pressure (CVP) which has been used for years to evaluate volume status. An increase in CVP is clearly not synonymous with an increase in cardiac output — it is only the price we pay for an increase in intravascular volume and it is closely associated with organ dysfunction/failure. Obviously, this parameter is useful for calculating the optimal organ perfusion pressure which is the difference between the mean arterial pressure (MAP) and CVP. Measurement of CVP is also necessary for calculating systemic vascular resistance (SVR), a parameter important to guide treatment in patients with an unstable cardiovascular status. Only very small CVP values, up to 5 mm Hg, may reliably suggest hypovolaemia [18].

Taking into account all the limitations of the various parameters of volume status, the GDT algorithm seems a quite comprehensive tool to optimize cardiac output. The latter may be evaluated using non-invasive, minimally invasive or invasive methods. The approach should be tailored to the patient and the planned surgery. Some help is provided by companies that manufacture equipment for haemodynamic measurements, as physicians are provided with systems that allow swift changes of the monitoring method depending on the changing clinical status of the patients. When evaluating cardiac output, it is worth analysing stroke volume (SV), as we do not focus on the heart rate when we assess cardiac output or cardiac index, while tachycardia may be a compensatory mechanism in hypovolaemia (bleeding) or heart failure. However, an attempt at fluid resuscitation is always the first therapeutic measure. In hypovolaemia, it is free from adverse effects (in fluid-responders).

Regardless of what haemodynamic monitor is used by the anaesthesiologist, there is no single parameter that would be sufficient for the evaluation of the oxygen balance, even with continuous recording. Parameters of fundamental importance for the evaluation of cardiovascular system function include blood lactate level, central or mixed venous blood oxygen saturation, venous-to-arterial pCO_2 difference, as well as regional oximetry. When monitoring lactate level, it should be remembered that lactates are metabolized at a rate of about 10% per hour. Thus, effective treatment should lead to this rate of lactate level reduction. Venous-to-arterial pCO_2 difference above 5 mm Hg suggests inadequate cardiac output. Venous pCO_2 depends on flow, and thus analysing this parameter together with venous blood oxygen saturation allows one to differentiate between low cardiac output syndrome and cellular respiration disturbances (e.g., in sepsis) [19].

Cardiovascular system functioning depends on many factors which hinders interpretation of the research results. Due to patient heterogeneity, it is difficult to determine clearly benefits from the use of the GDT algorithm in all patients undergoing surgical treatment. Patients evaluated before anaesthesia may have different disease conditions, risk factors, and physiological abnormalities. In 1988, Shoemaker was the first to report a significant mortality reduction with the use of a pulmonary artery catheter and supranormal oxygen flow rates [20]. In the later years, however, these findings were not confirmed by other authors and this approach was questioned. Only meta-analyses showed that it was the time factor that contributed significantly to the treatment success. Thus, early initiation of haemodynamic optimization prior to organ damage results in a significant reduction of mortality among those patients in whom the risk exceeds 20% [21].

The use of cardiovascular optimization algorithms reduces the rate of postoperative complications. In a meta-analysis that included 3,410 patients undergoing major abdominal surgery, Giglio *et al.* [22] showed a significantly reduced rate of life-threatening gastrointestinal complications that required reoperation or ICU treatment. In an analysis of 20 studies (4,220 patients), Brienza *et al.* [23] showed a reduction in the rate of acute kidney injury among high-risk patients in whom cardiovascular optimization was undertaken using protocols than included adequate fluid therapy and the use of positive inotropic agents throughout the perioperative period. In an analysis of 26 studies (4,188 patients), Dalfino *et al.* [24] evaluated the effect of early haemodynamic optimization on the rate of infective complications. In high-risk patient groups, this approach significantly reduced the rate of surgical wound infections, hospital-acquired pneumonia and urinary tract infections. In another meta-analysis published in 2013, Grocott *et al.* [25] included 31 studies (5,292 patients) that used haemodynamic optimization protocols targeted at increasing blood flow based on an evaluation of stroke volume, cardiac output, oxygen supply, oxygen consumption, venous blood oxygen saturation, lactate level or oxygen extraction. These authors showed significant reductions in the rates of postoperative kidney injury, respiratory failure and surgical wound infections. The duration of hospital stay was also shorter in this group. One of the most recent meta-analyses was published in 2014. Based on 14 studies that included 961 patients, Benes *et al.* [26] evaluated the effect of cardiovascular optimization using an algorithm based on dynamic parameters on the rate of postoperative complications. This approach significantly reduced infective, cardiovascular and gastrointestinal complications. Moreover, a meta-analysis published in 2011 showed that pre-emptive intraoperative goal-oriented haemodynamic optimization reduced complications and mortality in high-risk patients [27]. This study showed that the benefits in patients being monitored using a Swan-Ganz catheter were the same as in those being monitored using less invasive cardiac output measurement methods. This reduction of complications translated to better long-term outcomes. The observed benefits outweigh the small costs of haemodynamic monitoring. The most important factor is the belief that haemodynamic monitoring is justified. When this opinion is shared, the equipment available in ICU, where monitoring is a common practice, may be used.

Could the suggested management approach, including intraoperative haemodynamic monitoring, be recommended [in Poland? The answer is short — it should be. The above data confirm the effectiveness of intraoperative haemodynamic monitoring in reducing complications and treatment costs [20–27]. Unfortunately, operating rooms in our country lack adequate equipment. The authors are advocates of haemodynamic monitoring and hope that the above-mentioned arguments might help convince the decision makers that such equipment should be available in operating rooms. Clearly, a different (better) financial reimbursement of anaesthesia with haemodynamic monitoring would lead to an increased availability of dedicated equipment. The strategy of intraoperative management based on haemodynamic monitoring should be used in high-risk patients and/or those undergoing a high-risk surgery. Although recommendations regarding haemodynamic monitoring have been published in Western Europe [28–30], their implementation in routine clinical practice has also proven difficult in the developed countries. These methods are mostly used in university hospitals. A survey published in 2011 showed that only 35% of anaesthesiologists in the United States and Europe use cardiac output monitoring in high-risk patients [31]. Problems with adopting this strategy stem from the lack of clear indications for monitoring (i.e., in which patient population), the lack of a clear universal algorithm, as well as financial and staffing issues. On the other hand, a retrospective analysis of anaesthesia records showed that during 4 hours of anaesthesia for a procedure with negligible blood loss, patients with a body weight of 75 kg received 700 to 5400 mL of crystalloids depending on the anaesthesiologist's preference [32]. Such findings quite clearly indicate that monitoring is definitely indicated. By analogy, we do not administer insulin without measuring blood glucose levels!

An increased serum creatinine level in the early postoperative period is a predictor of reduced survival, while patients treated due to postoperative acute kidney injury more frequently require dialysis treatment in the long term [33]. Thus, it seems that reducing complications that have no effect on early mortality but contribute to worse long-term outcomes is clearly beneficial for both the individual patient and society as a whole. Developing an optimally functioning surgical treatment program requires novel approaches in several dimensions. A good example is the Enhanced Recovery After Surgery (ERAS) strategy [34]. A patient's encounter with an anaesthesiologist in a clinic immediately after the decision is made to proceed with an elective surgery might lead to optimization of the patient's status, including correction of anaemia, improving diabetes control, nutrition status, and oral hygiene, as well as modification of drug therapy. Close collaboration with the family GP would allow optimal preoperative patient preparation. With the current advances in medical interventions, every surgical procedure should be theoretically possible in any patient. Exceptions are rare. Unfortunately, the number of postoperative complications is increasing at a worrying rate.

The intention of the authors is to popularize knowledge regarding the proven benefits of intraoperative haemodynamic monitoring and to increase the number of proponents of this approach. As Wallace D. Wattles once said, the way we work is a direct consequence of the way we think. The current statement of the Cardiac and Thoracic Anaesthesia Section of the Polish Society of Anaesthesiology and Intensive Care is intended to "optimize" thinking about intraoperative cardiovascular monitoring. In the introduction, we summarized the approach to surgical treatment in a broad context, including preoperative patient preparation and postoperative management. Intraoperative haemodynamic monitoring is one of the many elements being introduced that are intended to improve surgical treatment outcomes in various conditions and regardless of the location of a pathology. The net effect of the proposed strategy is improved patient safety. We present a universal approach that requires individualization in specific cases. The basis for creating the proposed management model is the team work of physicians, nurses, physiotherapists, dieticians, social workers, as well as all other personnel involved in patient care.

Below, we present simple risk scores in order to predict complications and estimated mortality and/or early morbidity, which are the basis for identifying high-risk patients and procedures. The second part discusses available intraoperative haemodynamic monitoring methods and provides suggestions to implement these when optimizing perioperative cardiovascular status.

RISK ESTIMATION

The choice of an appropriate monitoring method must be preceded by an evaluation of risk [6, 35, 36]. This should be done already during preoperative anaesthesiology consultation (in an anaesthesiology clinic and/or following patient admission) and individualized. It is suggested to discuss the potential implications of the estimated perioperative risk by the whole team involved in the treatment (primarily the surgeon, anaesthesiologist and physiotherapist) as it helps one optimize perioperative management (improving nutritional status, treatment of anaemia, improving cardiovascular status, increasing muscle mass, the choice of method, the level of invasiveness, as well as the type of anaesthesia, pain control, early mobilization, etc.). High-risk patients require periodic re-evaluation of the planned and used diagnostic and therapeutic methods in order to individualize goal-oriented therapy, with the goal being patient safety [6, 35, 36].

For research purposes, risk is usually defined as cardiovascular morbidity (fatal or non-fatal acute coronary syndrome, cerebrovascular events, life-threatening arrhythmia, cardiovascular decompensation) or mortality (regardless of the cause of death). However, predicting softer endpoints (any postoperative complications, primarily including wound infection or dehiscence, bleeding, thromboembolic event, need for admission to an ICU, duration of hospital stay) is equally important [37].

The risk of complications is mostly related to the patient's age, functional status, underlying disease, concomitant conditions, abnormal laboratory test findings, as well as the surgical intervention itself [37]. It should be noted that the quality of life in all its dimensions (physical, mental, social, and community-oriented) and long-term outcomes are more related to the occurrence and severity of postoperative complications that the risk estimated preoperatively [1, 38, 39].

INDIVIDUAL PATIENT RISK

Multiple methods are available to evaluate risk. These are mostly complex calculators based on mathematical equations, including the Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM), the P-POSSUM score, and the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) algorithm (Table 1) [40–42]. In addition to physiological parameters, they often include variables related to the invasive procedure. More practical systems are based on a simple evaluation of concomitant conditions and their control (ASA Physical Status Classification System, Shoemaker's criteria, RCRI) [11, 20, 43, 44] (Tables 2, 3), evaluation of the functional status (6-minute walk test, exercise test, Duke Activity Status Index) [11, 45], or the frailty score [46–48].

The decision regarding the choice of the risk estimation system should be made by the anaesthesiologist, taking into account his or her knowledge and clinical experience, details of the surgery and anaesthesia, as well as local conditions (equipment availability, organizational and staffing policy). Until local procedural standards are developed, use of the ASA score, the (P)POSSUM score, or the Shoemaker's criteria (Table 4) seems reasonable.

Table 1. The Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity [(P)POSSUM] score

Physiological parameters	Operative parameters
Age	Operation type
Cardiac conditions and their drug therapy	Number of procedures
Respiratory conditions	Intraoperative blood loss
Electrocardiogram	Peritoneal contamination
Systolic blood pressure	Malignancy status
Resting heart rate	Procedure urgency
Haemoglobin level	
Leukocyte count	
Urea level	
Sodium level	
Potassium level	
Glasgow Coma Scale	

Source: http://www.riskprediction.org.uk/index-pp.php

Table 2. The American Society of Anesthesiologists (ASA) Physical Status Classification System)

	Criterion	Example
I	A normal healthy patient (without concomitant conditions)	Healthy, non-smoking, no or minimal alcohol use
II	A patient with mild/moderate systemic disease without substantive functional limitations	Current smoker, social alcohol drinker, pregnancy, well-controlled hypertension, diabetes, obstructive lung disease, obesity (BMI 30–39.9 kg m^{-2})
III	A patient with severe systemic disease with substantive functional limitations	Poorly controlled hypertension, diabetes, obstructive lung disease, morbid obesity (BMI ≥ 40 kg m^{-2}), active hepatitis, alcohol dependence or abuse, implanted pacemaker, moderate reduction of ejection fraction, end-stage renal disease requiring dialysis therapy, history (> 3 months) of a coronary or cerebrovascular event (myocardial infarction, stroke, coronary stent implantation)
IV	A patient with severe systemic disease that is a constant threat to life	Recent (< 3 months) coronary or cerebrovascular event (myocardial infarction, stroke, coronary stent implantation), unstable coronary artery disease, symptomatic valvular heart disease, left ventricular ejection fraction < 30%, sepsis, disseminated intravascular coagulation, poorly controlled uraemia
V	A moribund patient who is not expected to survive without the operation	Ruptured aortic aneurysm, massive trauma, intracranial bleed with mass effect, massive pulmonary embolism, multiorgan failure

BMI — body mass index

Table 3. Shoemaker's criteria

	Criterion
1	Severe cardiopulmonary disease with significant dysfunction (acute myocardial infarction, severe obstructive lung disease, stroke)
2	Extensive surgery for malignancy (including gastrointestinal anastomosis, cystectomy, gastrectomy)
3	Age > 70 years with severely limited reserve of one or more organs
4	Advanced vascular disease involving the aorta
5	Acute abdomen with evidence of shock (acute pancreatitis, perforation, peritonitis)
6	Expected massive blood loss (need to transfuse > 8 units of packed red blood cells)
7	Sepsis (positive blood culture or septic focus)
8	Respiratory failure (PaO_2 < 60 mm Hg; FiO_2 > 0.4; or mechanical ventilation > 48 hours)
9	Acute kidney injury (urea > 20 mmol L^{-1}, creatinine >260 µmol L^{-1})

Table 4. Evaluation of the individual patient risk

Risk estimation score	Definition	Risk
ASA class	ASA I, II	Low
	ASA III, IV, V	High
(P)POSSUM score	< 5%	Low
	≥ 5%	High
Shoemaker's criteria	At least one criterion present	High

Abbreviations — see text

Table 5. Risk related to the type of surgical procedure

Type of surgery or intervention	Risk
Superficial surgery	Low
Breast surgery	
Dental surgery	
Thyroid surgery	
Eye surgery	
Reconstructive surgery	
Asymptomatic carotid artery disease (endarterectomy/stenting)	
Minor gynaecologic surgery	
Minor orthopaedic surgery (meniscectomy)	
Minor urological surgery (transurethral resection of the prostate)	
Intraperitoneal surgery (splenectomy, hiatal hernia repair, cholecystectomy)	Moderate
Symptomatic carotid artery disease (endarterectomy/stenting)	
Peripheral arterial angioplasty	
Endovascular aneurysm repair	
Head and neck surgery	
Major orthopaedic and neurological surgery (hip and spine surgery)	
Major urological and gynaecological surgery	
Kidney transplantation	
Non-major thoracic surgery	
Aortic and major vascular surgery	High
Open lower limb revascularization, amputation, or thromboembolectomy	
Duodeno-pancreatic surgery	
Liver resection, bile duct surgery	
Oesophagectomy	
Repair of perforated bowel	
Adrenal resection	
Total cystectomy	
Pneumonectomy	
Lung or liver transplantation	

SURGERY-RELATED RISK

Surgical factors that affect the perioperative risk are associated with the urgency, invasiveness, type, and duration of surgery. A classification of surgical risk related to the type of surgery or intervention was developed by the European Society of Cardiology and the European Society of Anaesthesiology [11]. According to these guidelines, surgical interventions may be categorized as low, moderate, and high risk, associated with an estimated 30-day myocardial infarction and fatal cardiovascular event risk of < 1%, 1–5%, and > 5%, respectively (Table 5).

The risk of complications is also related to the urgency of surgery and increases with fewer opportunities to prepare the patient for a surgical intervention (Table 6), with the urgency of surgery defined as per the ordinance of the Minister of Health [49].

GLOBAL RISK

Ultimately, although evaluation of the operative risk requires consideration of its all components, it is not a simple averaging of these components. With the presence of a high-risk factor in any category (patient/procedure), the patient is categorized at a high global risk. As a result, patients with high individual risk or high surgery-related risk (due to the type or urgency of the surgery) are candidates for more advanced monitoring. The initiation of monitoring does not reduce the risk of perioperative complications but allows appropriately early and successful institution of adequate treatment.

One component that is difficult to measure, but nevertheless clinically important, is the risk related to the experience of the surgical treatment team. The lower the experience, the higher the risk of adverse events and complications (learning curve). Thus, high-risk patients should be managed by anaesthesiologists with adequate clinical experience. According to the ordinance of the Minister of Health [49], a physician with a grade I board certification in anaesthesiology and intensive care may

Table 6. Risk related to the urgency of surgery

Urgency of surgery	Definition	Risk
Elective	Intervention in a patient in an optimal general condition, with timing to suit the patient and the surgeon	Low
Expedited	Intervention performed within days of the decision to operate, in a patient who requires early intervention, although the effect of the condition on the patient's status does not fulfil the criteria of an urgent or immediate procedure	Low
Urgent	Intervention performed within 6 hours of the decision to operate, in a patient with acute onset or clinical deterioration of conditions that are potentially life-threatening or may threaten the survival of a limb or an organ, or with other health problems that cannot be managed by medical care	High
Emergent	Intervention performed immediately after the decision to operate in a patient with a condition that is immediately life-threatening or threatens the survival or function of a limb or an organ; stabilization of the patient's condition is undertaken in parallel to the intervention	High

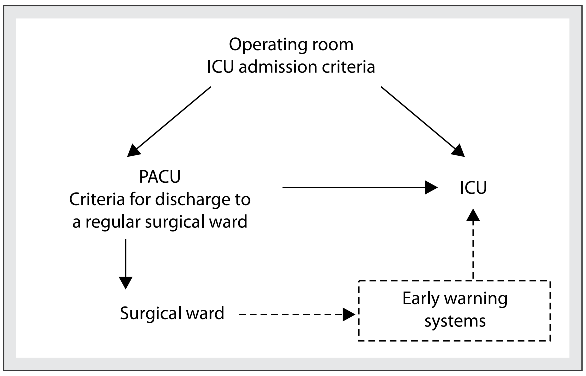

Figure 2. Postoperative management algorithm in relation to the risk of complications

independently provide anaesthesiology services in patients above 3 years of age in ASA class I, II, or III, and upon approval by the physician in charge of the clinical unit — in patients in ASA class IV or V. A physician during specialist training in anaesthesiology and intensive care must be directly supervised by a specialist and may provide anaesthesia to patients in ASA class I, II, or III if he or she has at least 2 years of experience during specialist training and has been proved to possess adequate knowledge and skills.

The decision to transfer a patient to the PACU, or directly to ICU should be based on an evaluation of the general status of the patient and the risk of organ failure, primarily cardiorespiratory failure (first priority) (Fig. 2) [3]. As the occurrence of adverse effects and postoperative complications is the most important factor determining long-term outcomes, the patient's condition should be regularly evaluated during the immediate postoperative period in the PACU [modified Aldrete score, Post-Anaesthesia Discharge Scoring System (PADSS), Danish Society of Anaesthesiology and Intensive Care Medicine (DASAIM) score, Brown criteria, Song criteria] [50–52]. The PACU should be supervised by an anaesthesiologist.

Achieving optimal scores in the above systems Aldrete score ≥9, PADSS score ≥ 9, DASAIM score ≤ 4, ≥ 12 points according to Song criteria, Brown criteria met) during one's stay in the PACU is a signal to terminate extended (advanced) haemodynamic monitoring and discharge the patient to a surgical ward. The choice of the scoring system is at discretion of the treating anaesthesiologist. If a decision is made to transfer the patient to an ICU [3], haemodynamic monitoring should be continued and used to guide appropriate treatment (Fig. 3). Any doubts regarding interpretation of haemodynamic parameters should be settled based on acid-base balance parameters in arterial and mixed venous or right atrium blood (acid-base balance parameters, pCO_2 gap, central venous blood oxygen saturation) and lactate level [6, 35, 36].

In the regular (surgical) ward, the role of enhanced nursing personnel surveillance is of particular importance. If providing direct postoperative supervision is difficult (1 nurse for up to 4–6 patients) [53], it is beneficial to monitor patients using available early warning systems (EWS) (Table 7) [54–56]. A score of at least 4 by the Modified Early Warning Score (MEWS), 4 by the Standardized Early Warning Score (SEWS), or 8 by the VitalPAC Early Warning Score (ViEWS) should prompt the nurse to notify the physician of a patient's worsening condition and the risk of complications. If the score increases at follow-up evaluations despite

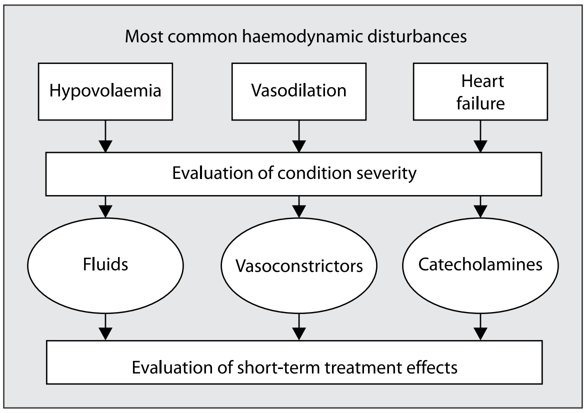

Figure 3. Basic principles of goal-oriented therapy

Table 7. Selected early warning scores (EWS) [31–33]

Score	3	2	1	0	1	2	3
Modified Early Warning Score (MEWS)							
Respiratory rate (breaths min^{-1})	–	< 9	–	9–14	15–20	21–29	> 29
Heart rate (beats min^{-1})	–	< 40	41–50	51–100	101–110	111–129	> 129
Systolic blood pressure (mm Hg)	< 70	71–80	81–100	101–199	–	> 199	–
Temperature (°C)	–	< 35	–	35–38.4	–	> 38.4	–
Neurological status (AVPU)	–	–	–	Alert	Voice	Pain	Unresponsive
Standardized Early Warning Score (SEWS)							
Respiratory rate (breaths min^{-1})	< 9	–	–	9–20	21–30	31–35	> 35
Oxygen saturation (%)	< 85	85–89	90–92	93–100	–	–	–
Heart rate (beats min^{-1})	< 30	30–39	40–49	50–99	100–109	110–129	> 129
Systolic blood pressure (mm Hg)	< 70	70–79	80–99	100–199	–	> 199	–
Temperature (°C)	< 34	34–34.9	35–35.9	36–37.9	38–38.9	> 38.9	–
Neurological status (AVPU)	–	–	–	Alert	Voice	Pain	Unresponsive
VitalPAC Early Warning Score (ViEWS)							
Respiratory rate (breaths min^{-1})	< 9	–	9–11	12–20	–	21–24	> 24
Oxygen saturation (%)	< 92	92–93	94–95	96–100	–	–	–
Oxygen therapy	–	–	–	Not required	–	–	Required
Heart rate (beats min^{-1})	–	< 41	41–50	51–90	91–110	111–130	> 130
Systolic blood pressure (mm Hg)	< 91	91–100	101–110	111–249	> 249	–	–
Temperature (°C)	< 35.1	–	35.1–36	36.1–38	38.1–39	> 39	–
Neurological status (AVPU)	–	–	–	Alert	–	–	Voice/pain/ /unresponsive

institution of appropriate treatment, it is an immediate indication to notify the early response (resuscitation) team and evaluate the criteria of admission to an ICU.

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