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Perioperative Assessment of High-Risk Abdominal Surgery: A Case Study

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Abstract

Objectives

• To outline the key components of a pre-operative cardiac risk assessment.

• To review the major guidelines utilized to assess patients' surgical risks.

• To discuss the perioperative management of surgical patients to prevent cardiac and pulmonary complications.

• To review the utility of biomarkers in the pre- and post-operative period.

Keywords

perioperative evaluation; non-cardiac surgery; surgical risk calculator; revised cardiac risk; medication management; red flags; functional capacity; pulmonary risk assessment; post-operative pulmonary complications

1. Case Presentation

A 71-year-old female with a past medical history of smoking, hypertension, hyperlipidemia, and type 2 diabetes mellitus (T2DM) controlled on oral medications presented to the surgery clinic for evaluation of a pancreatic mass with new onset cough with hemoptysis. Previous chest computerized tomography (CT) ordered by her primary care physician for cancer screening revealed pulmonary nodules and an incidental mass in the tail of the pancreas. The patient also reported a 12-pound weight loss over the last 6 months, including five pounds in the last month, as well as frequent night sweats. She denied other constitutional symptoms such as fever, malaise, chest pain, shortness of breath, or abdominal pain.

The patient's past surgical history was significant for hysterectomy, lithotripsy, and laparoscopic cholecystectomy. Home medications included ramipril, torsemide, atenolol, amlodipine, hydralazine, rosuvastatin, glipizide, mirtazapine, and oxycodone/acetaminophen.

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The patient had a 58 pack-year smoking history with occasional alcohol and marijuana use. She described herself as "functional", but she was not able to walk long distances, carry heavy bags, or perform strenuous house-work. The patient was able to climb four flights of stairs but was limited by bilateral thigh and knee pain. She had never performed a cardiac stress test.

On physical examination, the patient's BMI was 22.7 kg/m^2. Vitals were significant for hypertension at 177/110 mmHg and tachypnea at 27 breaths/minute. Pulse oximetry revealed oxygen saturation of 98% on room air. The patient was afebrile with a temperature of 98.2° F and had a heart rate of 70 beats/minute. Her examination also revealed well healed Pfannensteil and laparoscopic scars. The abdomen was soft and nontender. She was admitted for a pancreatic mass with new onset hemoptysis.

Laboratory values are in Table 1. Bloodwork was significant for brain natriuretic peptide (BNP) of 91 pg/mL, Carbohydrate Antigen 19–9 of 2572 U/mL and Calcium of 11.8 mg/dL. Pulmonary was consulted for hemoptysis and the patient underwent bronchoscopy with bronchioalveolar lavage which revealed normal vocal cords and no endobronchial lesions or masses. She also underwent CT of the chest, which revealed stable pulmonary nodules within the bilateral apical regions, as well as persistent scarring, mild fibrosis at the right lung base with mild paraseptal and mild/moderate centrilobular emphysematous changes. Evidence of dilation of the main pulmonary artery was also observed, suggestive of pulmonary arterial hypertension. Abdominal CT revealed a non-contrasting pancreatic mass at the tail of the pancreas with solid and cystic components, as well as nephrolithiasis.

On hospital day 2, subsequent fine needle aspiration of the pancreatic mass revealed pancreatic adenocarcinoma. Upper endoscopic ultrasound of the pancreatic mass revealed a hypoechoic homogenous lesion in the tail of the pancreas that was invading the spleen. The surgical service kept the patient informed of the results of the work-up and extent of the disease. Consults were placed to the Oncology, Cardiology and Medicine services. A decision was made for distal subtotal pancreatectomy, possible splenectomy, left nephrectomy, and left adrenalectomy.

As part of the pre-operative risk assessment an electrocardiogram (ECG) was obtained which revealed sinus bradycardia, possible left atrial enlargement, left ventricular hypertrophy, and T-wave abnormality consistent with anterolateral ischemia (inverted T waves on leads V3-V6, flattened T waves in V1–2). 2D-echocardiogram revealed a left ventricular ejection fraction 65%, grade 1 diastolic dysfunction, trivial mitral valve regurgitation, aortic valve calcification, and pulmonary artery hypertension at 25 mm-Hg.

2. What are the Risks of Surgery?

A surgical operation is widely understood to contribute to perioperative mortality. This can be accounted for by both the surgical stress response as well as physiologic changes due to anesthesia management [1]. The stress response can be characterized by a predictable set of endocrinologic, immunologic, and hematologic effects (pro-thrombotic state) leading to an initial decrease and subsequent increase of metabolic activity. Anesthetic and analgesic usage modulate this stress response and have additional hemodynamic effects on blood pressure and heart rate. Intraoperative changes on blood pressure and heart rate have been correlated with an increased risk in perioperative mortality [2]. Furthermore, there are risks associated with the specific surgical sites, the level of surgical urgency, and the duration of the surgical intervention.

2.1. Surgery-Site Specific Risk

Surgery-specific risks depend on the operative sites and the physical trauma and hemodynamic alterations to which the tissues will be subjected. As such, surgical sites and tissues have various degrees of risk of tissue loss, fluid shifts and hemodynamic shifts, all of which affect the stress responses [3]. Some surgeries are known to cause massive hemodynamic and fluid dynamic shifts, which can increase the risk of cardiovascular events. Table 2. shows different types procedures and sites. Cardiovascular events have been found to account for roughly half of the perioperative mortality of noncardiac surgery [4]. Cardiac risk can be categorized as the risk of major adverse cardiovascular events (MACE), often defined as in-hospital death, myocardial infarction (MI), or ischemic stroke. An analysis of MACE in noncardiac surgery revealed a rate of 3.0%, which were most commonly seen in vascular, thoracic, and transplant surgery [5].

2.2. Urgency

The urgency of an operation is also a contributing factor to perioperative mortality risk. Level of surgical urgency can reflect risk, as a more emergent surgical case has intrinsically elevated risk for mortality and morbidity. The American College of Cardiology (ACC)/ American Heart Association (AHA) developed a commonly used classification scheme for assessing surgical urgency for non-cardiac surgery. The scheme guidelines four categories: emergent, urgent, time-sensitive, and elective as shown below in Table 3 [7]. Perioperative mortality for a surgery such as pancreatectomy for resection of pancreatic neoplasm may be considered time-sensitive, needing intervention within 6 weeks. A procedure such as a pancreatectomy has been noted to have a 5.9% inpatient mortality [8].

2.3. Length of the Intraoperative Time

Operative duration may additionally contribute to perioperative complications. Prolonged surgery (ranging from three to four hours) has been shown to be an independent predictor of post-operative pulmonary complications [9]. This is especially important among the elderly; in a meta-analysis review, it was shown that a 30-minute increment of intra-operative time increased the odds of mortality by 17% in patients over the age of 80. The length of the surgical procedure among adults of various age categories has been found to predict complications such as cardiovascular events, renal injury and wound infections [10]. Furthermore, occurrence of venous thromboembolism was shown to be associated with increased surgical duration across all types of surgeries [11]. While operative duration may reflect the surgical complexity, intraoperative complications, surgeon experience, or technical skill, it is not explicitly considered a risk factor among the commonly used risk calculators.

3. How do Patient-specific Medical Conditions Influence Surgical Risk?

Chronic medical conditions are accounted for in the preoperative assessment within the American Society of Anesthesiologists (ASA) Physical Status classification system. Risk is stratified by severity of existing systemic disease using the ASA score from class I to VI [12,13] as shown in Table 4. Increasing ASA class indicates increased risk of perioperative morbidity and mortality. In the case of the patient, her chronic medical conditions included non-insulin dependent type II diabetes mellitus, hypertension, hyperlipidemia, chronic obstructive pulmonary disease and an abdominal malignancy with local spread. Without any intervention, our patient's ASA score was class IV, as she had severe systemic disease (metastatic malignancy) that was a constant threat to her life due to extensive local invasion with poor functional capacity [14].

4. How do Patient Functional Limitations and Lifestyles Influence Surgical Risk?

Decreased patient functional status is an important risk factor for adverse perioperative cardiovascular events, due to reduced functional capacity. Functional capacity is typically assessed using activities of daily living (ADLs), which can be measured using metabolic equivalents, one of which is a basal oxygen consumption of a 40-year-old male with a body mass of 70 kg, or 1 Measurement of Exercise Tolerance before Surgery (METS) [16]. Correlation examples of METS to ADLs are shown in Table 5. Patients can be categorized as excellent (>10 METS), good (7–10 METS), moderate (4–6 METS), or poor (<4 METS). Patients who have poor functional ability are placed into risk strata which have separate management options to preoperatively optimize surgical condition. Our patient was unable to perform strenuous housework or walk long distances. She was otherwise functional with intact independent ADLs. This categorized her as having poor functional capacity with <4 METS.

Another validated measurement of functional capacity is the Duke Activity Status Index (DASI). The DASI is a self-administered questionnaire meant to correlate with METS [17,18]. It includes 12 questions regarding specific activities including performing yardwork, walking a block, and participating in strenuous sports. Increased DASI score corresponds with an increased number of METS and higher functional capacity and it has been found to correlate with peak oxygen uptake during exercise.

Obesity is additionally a functional and lifestyle limitation that increases perioperative complication risk. Patients undergoing gastric bypass demonstrated that increasing levels of obesity increased their mortality risk [19]. Preoperative reduction of BMI has been subsequently shown to decrease surgical morbidity, particularly in the superobese [20].

Smoking is a lifestyle choice that is associated with perioperative complications, and smoking cessation has been noted to decrease postoperative complications [21]. Cessation as late as the day before surgery has been shown to decrease these complications as well. Our patient had a 58-pack-year smoking history and had quit 2 months prior to admission.

5. What are the Elements of a Preoperative Evaluation?

5.1. History and Physical

All patients scheduled for a surgery are considered for a preoperative evaluation. A preoperative evaluation typically involves a complete history and physical evaluation, including a review of systems. The goal is to identify factors that may increase a patient's risk of a perioperative complication [22]. The history includes: the condition requiring surgery, comorbid conditions (notably cardiac and pulmonary conditions), overall health and functional status, past reactions to surgery and anesthesia, and the use of medications, tobacco, alcohol and illicit substances. The review of systems is important to identify cardiopulmonary complaints including shortness of breath, exertional symptoms, chest pain, light headedness and palpitations [6]. Notably, comorbid conditions such as recent myocardial infarction (MI), unstable angina (within last 2 months), and recent stent placement are indications for delaying an elective surgery. The cardiopulmonary physical assessment and review of systems together identify features that warrant further cardiopulmonary testing [22]. Pertinent exam findings that also indicate delaying an elective surgery may include elevated blood pressure, arrythmias, severe valvular disease and signs of congestive heart failure or lung disease.

5.2. Laboratory

Laboratory testing should be guided by patient-specific comorbid conditions, history and physical exam, and the specific planned surgical procedure. Healthy patients undergoing minor procedures such as cataract removal would not require routine laboratory work [6]. However, patients with long standing comorbid conditions who are undergoing major procedures, such as the patient in this case presentation, should undergo routine laboratory work which includes basic metabolic panel, complete blood count, liver function tests and coagulation studies. Baseline BNP and troponins may be obtained depending on the cardiopulmonary history and physical assessment.

In our patient, the concerning factors identified in the pre-operative evaluation included the past medical history of hypertension and type II diabetes, tobacco use, extensive medication list, hemoptysis, unintentional weight loss and poor functional status as discussed above. The physical exam was only notable for elevated blood pressure. Laboratory work was significant for BNP of 91 pg/mL (within normal limits), Carbohydrate Antigen 19–9 of 2572 U/mL (elevated), and Calcium of 11.8 mg/dL (elevated). Additionally, important laboratory values to note were the patient's hemoglobin/hematocrit in anticipation of a procedure with potential blood loss, BUN/Creatinine to assess renal function in the context of the patient's diabetes and hypertension, and glucose given the patient's diabetes. The patient had a slightly elevated glucose level at 138 mg/dL. Prothrombin (PT) and activated partial thromboplastin time (aPTT) are typically ordered to monitor either anticoagulation or bleeding disorders, though the patient had no history of these disorders. She additionally did not require liver function tests as she had no history of cirrhosis or other liver disease. However, coagulation and liver function panels were obtained as part of routine laboratory testing and revealed results within normal limits.

6. When is Preoperative Cardiac Stress Testing Indicated?

Preoperative cardiac stress testing may be indicated in a patient to assess the risk of MACE, particularly in patients with signs and/or symptoms of cardiac ischemia [6]. Symptoms of cardiac ischemia include dyspnea and/or chest pain on exertion, which may or may not persist during rest. Stress testing is also indicated for patients with previously diagnosed coronary artery disease. Additionally, patients with a cardiac arrhythmia, severe valve disease, or recent PCI should be evaluated. In patients with stable angina, additional workup is not necessary [6]. According to the AHA guidelines, the use of 1 of 3 tools is necessary to categorize a patient in low (<1%) or high (≥1%) risk strata for postoperative cardiac complications such as MACE. These tools include the revised Cardiac Risk index, American National College of Surgeons National Surgical Quality Improvement (ACS NSQIP), or the Gupta Perioperative Risk Calculator [23]. The revised Cardiac Risk Index is most widely used. High risk patients with good exercise capacity as well as low risk patients can proceed without preoperative stress testing. Patients who have elevated risk and poor exercise capacity may be further evaluated with stress testing.

Our patient did not have any symptoms of cardiac ischemia but had poor functional capacity and ECG revealing anterolateral ischemia. The patient underwent a dobutamine stress echocardiogram with stress ECG that demonstrated evidence of stress-induced ischemia of the inferior and inferoseptal myocardial wall with no wall motional abnormalities at rest. There was no chest pain, palpitations, or shortness of breath during the test. Her good baseline ejection fraction as well as a possible reversible small ischemic area was not expected to cause hemodynamically significant complications during surgery.

7. Do Preoperative Medications Need Adjustments?

7.1. Hypertensive Medications

Long-term hypertensive medications such as beta-blockers, calcium channel blockers, and nitrates are recommended to be continued the day of surgery. Beta blockers are well studied in the perioperative setting [24]. The Preoperative Ischemic Evaluation (POISE) trial demonstrated that perioperative beta blocker therapy reduced the risk of cardiovascular complications but increased the risk of stroke and overall mortality. It is recommended to continue beta blockers in patients already undergoing beta blocker therapy, which must have been initiated at least 24 hours preoperatively, and optimally 2–7 days prior [7]. Beta blockers should not be started the day of surgery. Similar recommendations exist for the continuation of statin medications. Statins may be additionally considered in patients who are not currently taking them but have medical indication to begin [7]. A table describing various preoperative medications and their respective recommended actions are found in Table 6 as outlined by the AHA guidelines [7]. Chronic ACE-inhibitors/ARB medications may be discontinued 24 hours prior to the surgery to prevent intra-operative hypotension [25]. Diuretics are typically discontinued for hypertension, though continued in patients receiving a diuretic for heart failure [26].

7.2. Diabetic Medications

There is currently no clear HbA_1C cutoff for diabetic patients to continue serum glucose-lowering medications preoperatively; however, increased levels of HbA_1C are associated with an increased risk of perioperative complications [6]. It is recommended that patients frequently monitor their glucose before meals and at bedtime in the preoperative period. Long-acting insulin can be discontinued 24–48 hours before the surgery, while adjusting the intermediate and short-acting insulin dosages [27]. Newer long-acting insulin, such as Glargine, may be continued the day before surgery while adjusting intermediate acting insulin in a patient with well-controlled diabetes. Notably, type I diabetic patients should always continue their basal insulin dose. On the day of surgery, short acting insulin and oral hypoglycemic medications such as biguanides, GLP-1 agonists, DPP-4 inhibitors, thiazolidinediones, sulfonylureas, and alpha-glucosidase inhibitors, are held [28]. Long acting sulfonylureas are discontinued 48–74 hours before the operation [27].

7.3. Antiplatelet Medications

For patients without previous cardiac stenting undergoing non-cardiac, non-urgent or emergent operations, it is considered reasonable to discontinue Aspirin seven days prior to surgery when the risk of bleeding outweighs the risk of cardiac events. For patients 4–6 weeks after stent placement undergoing an urgent, non-cardiac surgery, dual antiplatelet therapy should be continued, unless the risk of bleeding outweighs the risk of stent thrombosis prevention. Ideally, surgery should be delayed until the patient receives the complete dual antiplatelet therapy duration of >30 days for bone metal stent (BMS) and >365 days for drug eluting stent (DES). Overall, the use of perioperative anti-platelet therapy is determined by consensus between the cardiologist, anesthesiologist, surgeon, and patient [7]. Nonselective non-steroidal anti-inflammatory drugs (NSAIDs) are held 3–7 days prior to surgery due to the risk of bleeding [29].

7.4. Anticoagulation

If there is minimal surgical risk of bleeding, a patient currently on anti-coagulant medications may continue. Patients with prosthetic valves on warfarin may require bridging therapy with either unfractionated heparin or low-molecular weight heparin [7]. Patients who have mechanical aortic or mitral valves with additional thromboembolism risk factors may bridge unfractionated heparin when anticoagulation interruption is required in the perioperative period to control bleeding.

7.5. Psychiatric Medications

Antidepressants such as selective serotonin reuptake inhibitors, serotonin/norepinephrine reuptake inhibitors, and benzodiazepines are well tolerated and may be taken the day of surgery [29]. Tri-cyclic antidepressants may enhance sympathomimetic actions of serotonin and norepinephrine during surgery and may interfere with physiologic hemodynamic changes intraoperatively; however, they are frequently continued the day of surgery. The decision to change monoamine oxidase inhibitor management is typically discussed with a patient’s psychiatrist due to its potential risk for hypertensive crisis and multiple drug-drug interactions [29].

7.6. Opioids

Patients who are on opioids for pain management may continue their medications the day of surgery and should notify the Surgery and Anesthesia services [30].

Our patient continued her atenolol, rosuvastatin, hydralazine, amlodipine, and mirtazapine on the day of surgery. Torsemide was discontinued as she did not have congestive heart failure, indicated by her echocardiogram, history, and physical exams. Glipizide was discontinued the day of surgery to prevent hypoglycemia and she was placed on blood sugar checks every 6 hours with regular insulin sliding scale.

8. What Comorbidities Require Special Preoperative Considerations?

Comorbid conditions are known to affect perioperative mortality. Perioperative management of various conditions such as hypercoagulability and other systemic diseases such as diabetes and hypertension have been noted to decrease perioperative mortality [31]. A study performed in 2017 investigated mortality in 13 non-surgical interventions including glycemic control, hemodynamic optimization, and noninvasive ventilation; the study demonstrated that these interventions decreased perioperative mortality [32]. Additionally, preexisting conditions may alter the validity of the use of risk assessment tools and should be evaluated and managed separately [7].

8.1. Cardiac

Patients may have preexisting coronary artery disease before undergoing a noncardiac surgery. Preoperative cardiac testing may also reveal extensive cardiac ischemia and may warrant preoperative CABG or PCI for coronary revascularization. The latest recommendations indicate revascularization before noncardiac surgery in specific cases [7]. These include patients with left main coronary artery disease with preexisting morbidities precluding previous coronary intervention as well as patients with unstable coronary artery disease who would otherwise undergo revascularization procedures. Similarly, patients undergoing myocardial infarction as denoted by non-ST elevation or ST elevation may have separate indication to undergo coronary revascularization. Based on the Coronary Artery Revascularization Prophylaxis (CARP) trial, only patients with left main coronary artery disease showed benefit to preoperative coronary revascularization [33].

In patients with previous PCI, elective noncardiac surgery should be delayed after balloon angioplasty for at least 2 weeks and delayed one month after BMS placement [7]. If using a DES, elective noncardiac surgery should be delayed for one year. Additionally, if a patient is taking dual antiplatelet therapy, elective noncardiac surgery should not be performed within one year after DES placement or within one month after BMS placement, as previously mentioned.

8.2. Pulmonary

Pulmonary risk accounts for a large proportion of perioperative morbidity and mortality in noncardiac operations [3]. Thoracic and upper abdominal surgery have been noted to impact lung physiology and result in reduction in Vital Capacity and Functional Residual Capacity in a restrictive pattern [34]. These risks are substantiated by presence of chronic lung disease such as smoking, asthma, and pulmonary hypertension. Additionally, obstructive sleep apnea has been noted to lead to cardiopulmonary complications in surgery, which is related to obesity [35]. The patient's chronic lung disease, smoking status, and advancing age will contribute to post-operative complications including atelectasis and increased hospital stay duration.

Preoperative incentive spirometry has been shown to improve postoperative lung function. Incentive spirometry should be done before surgery to ensure that the patient can adequately ventilate the lungs [36]. This is also a technique widely used postoperatively for upper abdominal surgery in order to prevent postoperative atelectasis and subsequent complications [37]. Atelectasis is an independent risk factor for pneumonia along with increased hospital stay [37,38]. However, there is evidence that incentive spirometry has no effect on the development of complications [39,40].

8.3. Endocrine

Endocrine effects constitute a large portion of the surgical stress response [1]. Various endocrine dysfunctions are theorized to have adverse effects on intraoperative hormonal fluctuations, including adrenal insufficiency and thyroid hormone dyscrasia [41]. Diabetic patients should have glucose well-controlled, though there is no consensus on whether an elective surgery should be cancelled by an elevated HbA1C [42]. Similarly, thyroid and adrenal function should be well-controlled perioperatively similar to that of a non-perioperative setting.

9. What Are Common Risk Calculators and Biomarkers Used for Risk Assessment?

9.1. Surgical Risk Calculation

Perioperative risk management is an important step in optimizing a patient for surgery with the goal of minimizing perioperative morbidity and mortality. Risk can be assessed through patient case-specific factors including existing morbidities, surgery-specific factors, and urgency of the operation. As previously mentioned, there are several methods used to assess specific cardiac risk, including the revised Cardiac Risk Index, the Gupta Perioperative Risk for Myocardial Infarction (MICA), and the American College of Surgeons National Surgery Quality Improvement Program (ACS NSQIP) [3]. Table 7 includes information about each of these risk assessment tools, and the relevant risk factors incorporated in each tool.

Advantages of the Lee Cardiac Risk Index include its requirement of limited patient information in order to calculate a risk (i.e. troponins) and is well validated [43]. However, it is based on data for emergent and urgent surgeries, which leads to underprediction of cardiac risk [44]. The Gupta MICA score incorporates more information, including specific operative region [23]. The MICA falls short when considering that the calculator does not incorporate all cardiac complications during its analysis, and that surgical risk does not calculate specific to procedures (i.e. length of procedure, specific operative technique). The ACS NSQIP, which is widely validated by numerous studies, is created using a wider dataset including additional pre-operative risk factors and operative operation-specific data. Even though the NSQIP has operation-specific surgery data, it does not incorporate data such as patient-specific operational variables (i.e. length of surgery etc.).

NSQIP is a risk calculator developed with data from about 4.3 million operations, including 1500 codes for specific surgeries, making it a commonly used peri-operative risk assessment tool [3,45]. The ACS NSQIP calculator has been validated by multiple studies and its use is recommended by the ACC and AHA. [45,46].

Our patient's risk factors included: abdominal malignancy, systemic disease, T2DM on oral medications, hypertension, chronic obstructive pulmonary disease, current smoker, and age between 65–74. She had METS <4 and an ASA score of IV. The scheduled procedure was distal subtotal pancreatectomy with or without splenectomy without pancreatojejunostomy. The patient's calculated NSQIP risk for any serious complication (defined as cardiac arrest, myocardial infarction, pneumonia, progressive renal insufficiency, etc.) was 31.9%, and any complication at 35.5%, both of which were above average (18.3% and 20.1% respectively). Specifically, she had a 3.4% risk for cardiac complication which included cardiac arrest and myocardial infarction. This was designated as intermediate risk according to the 2014 ACC/AHA guidelines [7]. Other risks included pneumonia 8.7% (2.3% average), surgical site infection 17.0% (10.9% average) and readmission 22.9% (14.7% average).

Similar to those for cardiac risk assessment, there are pulmonary risk calculators such as the Gupta Respiratory Failure and Post-operative Pneumonia calculator, Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT), ACS NSQIP, STOP-Bang questionnaire (**S**noring, **t**iredness, **o**bserved apnea, high blood **p**ressure, **B**MI, **a**ge, **n**eck circumference, and male **g**ender), and Sleep Apnea clinical score [35,47,48]. Each of these methods measures a variety of characteristics which can aid in characterizing pulmonary morbidity and mortality peri-operatively. The Gupta Post-operative Pneumonia Risk calculator calculated our patient's pneumonia risk at 18.0%, which was considerably elevated from the 8.7% risk calculated by the NSQIP. The Gupta Post-operative Respiratory Failure Risk calculator also estimated a 13.2% risk for mechanical ventilation for >48 hours post-operatively or reintubation within 30 days for the patient. Our patient was encouraged to perform incentive spirometry in the pre-operative period to prevent post-operative pulmonary complications.

9.2. Biomarkers

The Canadian Cardiovascular Society (CCS) now recommends measuring baseline BNP or N-terminal fragment of pro-BNP (NT-pro-BNP), both of which can aid assessment of cardiac risk in patients above 65, between 45 and 64 with significant cardiovascular disease, or those with revised Cardiac Risk index score of >1 [25,44]. According to the CCS, baseline BNP can be used to assess peri-operative risk. If the pre-operative BNP is >92 ng/L, there should be an EKG ordered with trended troponins. This patient had a BNP of 91 ng/L, which indicates no more than routine post-operative cardiac monitoring. With BNP<92 ng/L (or NT-Pro-BNP >300 ng/L), the rate of 30-day post-operative non-fatal MI or death was 4.9%, as opposed to 21.8% in those with BNP >92 ng/L (or NT-Pro-BNP>300 ng/L).

Post-operative BNP may be trended if there are signs and/or symptoms of impending heart failure and myocardial stress. Post-operative changes in BNP levels >91 ng/L would warrant trended troponins, particularly if accompanied by clinical signs (such as arrhythmia and/or dyspnea). Type 2 MI, defined as nonischemic myocardial injury due to oxygen supply/demand mismatch without atherothrombosis, may be a cause of myocardial injury (and subsequent troponemia) in patients with no previous history of coronary artery disease undergoing noncardiac surgery [49]. It is important to monitor troponemia that does not reach levels of ST-segment elevation myocardial infarction. According to the AHA, ST-segment elevation is defined as a new ST-segment elevation at the J point in two contiguous leads ≥0.1 mV in all leads other than V2-V3 on ECG, or in leads V2-V3 ≥0.2 mV in men ≥40 years old, ≥0.25 mV in men <40 years old, or ≥0.15 mV in women [50]. Elevated troponins with sub-threshold ST-elevation are linked to higher short and long-term risk of morbidity and mortality [51]. Additionally, there is some evidence that suggests elevated post-operative troponin independently predicts 30-day mortality in noncardiac surgery, defined as Myocardial Injury after Noncardiac Surgery (MINS) [52]. This is with exclusion of non-cardiac elevation of troponin, such as cerebrovascular accident, sepsis, and pulmonary embolism.

10. Conclusions

Our patient understood the above than average surgical risk given her medical comorbidities and underlying malignancy. Her beta blocker, calcium channel blocker, and hydralazine were continued throughout the peri-operative period. ACE-inhibitor was held for 24 hours before the surgery. Incentive spirometry training began 36 hours prior to the operation. Her oral anti-diabetic medications were held on the morning of surgery, and blood glucose was checked every 6 hours with corrective scale insulin. The patient underwent the planned procedures of laparoscopic converted laparotomic distal subtotal pancreatectomy, splenectomy, left nephrectomy, and left adrenalectomy, along with lysis of adhesions.

The patient had a pre-induction thoracic epidural catheter for intraoperative analgesia and postoperative pain management. There were no intra-operative adverse events. Estimated blood loss was 400 mL and the patient received 4400 mL of IV normal saline intraoperatively. Intra-operative urine output was 450 mL. The patient received 1 unit of packed red blood cells (pRBCs) and occasional phenylephrine pushes for hypotension. Post-operatively, patient remained normotensive and did not require any vasopressor support but received another unit of pRBCs. The patient was transferred to the medical intensive care unit for ventilator and blood pressure support due to low tidal volumes and tachypnea. She remained on fentanyl and propofol for sedation.

In the post-operative period, she was extubated on post-operative day 2 after a satisfactory weaning trial. There were no clinical signs or symptoms suggestive of cardiac events. Venous thromboembolism prophylaxis, pain control, and transition to oral intake were key components of her post-operative care.

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Table 1.

Patient's laboratory data

Laboratory	Patient	Reference Range
WBC (K/uL)	5.95	[3.50–10.80]
RBC (M/uL)	4.44	[4.10–5.40]
Hemoglobin (g/dL)	13.5	[12.0–16.0]
Hematocrit (%)	40.7	[37.0–47.0]
MCV (fL)	91.6	[78.0–98.0]
Platelets (K/uL)	191	[130–400]
Sodium (mmol/L)	139	[136–145]
Potassium (mmol/L)	4.0	[3.5–5.1]
Chloride (mmol/L)	104	[98–107]
Bicarbonate (mmol/L)	24	[21–31]
Blood Urea Nitrogen (BUN) (mg/dL)	14	[7–25]
Creatinine (mg/dL)	1.05	[0.70–1.30]
Calcium (mg/dL)	11.8	[8.2–10.0]
Total Protein (g/dL)	7.9	[6.0–8.3]
Albumin (g/dL)	4.83	[3.50–5.70]
AST (u/L)	20	[13–39]
ALT (u/L)	16	[7–52]
Alkaline Phosphatase (u/L)	94	[34–104]
Total Bilirubin (mg/dL)	0.50	[0.30–1.00]
Glucose (mg/dL)	138	[70–99]
Magnesium (mg/dL)	2.1	[1.9–2.7]
Phosphorus (mg/dL)	2.2	[2.5–5.0]
PT (s)	12.4	[10.8–13.7]
aPTT (s)	32.3	[25.4–38.6]
Lipase (mmol/L)	19	[11–92]
Carbohydrate Antigen 19–9 (u/mL)	2572	[<34]
BNP (pg/mL)	91	[≤100]

Table 2.

[*] Risk of major adverse cardiovascular events associated with surgical site

Risk Strata for MACE	Location/Procedure Examples
Low (<1%)	Superficial surgery, breast, dental, ocular, thyroid, minor gynecologic, minor urologic
Intermediate (1–5%)	Carotid, endovascular aneurysm repair, renal transplantation, head and neck surgery, intraperitoneal, nonmajor intrathoracic
High (>5%)	Aortic, major vascular surgery, major abdominal surgery with large fluid shifts, esophagectomy, adrenal resection, lung/liver/pancreatic transplantation, pneumonectomy

[*] As adapted from [6].

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Table 3.

Time frame categories for surgical interventions

Category	Time Frame	Example
Emergent	Within 6 hours	Acute limb ischemia
Urgent	6–24 hours	Appendicitis
Time Sensitive	Within 6 weeks	Rapidly aggressive tumor
Elective	6 weeks – 1 year	Stable inguinal hernia

Table 4.

[*] American Society of Anesthesiology physical status classification system

ASA Classification	Definition	Examples (not limited)
I	Normal healthy patient	Healthy, non-smoker, minimal to no alcohol use
II	Mild systemic disease	Well controlled diabetes mellitus/hypertension, pregnancy, current smoker
III	Severe systemic disease	Poorly controlled diabetes mellitus/hypertension, COPD, reduced ejection fraction
IV	Patient with severe systemic disease	End stage renal disease (no dialysis), cerebrovascular accidents, myocardial infarction, sepsis, metastatic cancer with poor prognosis
V	Patient not expected to survive without procedure	Intracranial bleed with mass effect, ruptured aortic aneurysm, massive trauma
VI	Brain dead patient, organ donation	--

[*]As adapted from [15].

Table 5.

Simplified Metabolic Equivalent Tasks

METS	ADLs
≥4 METS (at least moderate functional capacity)	Walk >4 mph, climb stairs, walk >2 blocks
<4 METS (poor functional capacity)	Can perform light housework, walk <2 blocks

Table 6.

Peri-operative management of commonly prescribed medications

Medication Therapy	Recommendation	Class*, Evidence Level**
Beta blockers	-Continue in patients already taking for secondary disease indication	1, B
Statin	-Continue in patients already taking for secondary disease indication	1, B
Alpha 2 agonists	-Continue in patients already taking to avoid any withdrawal	3, B
Angiotensin-converting Enzyme Inhibitors/Angiotensin 2 Receptor Blockers	-Continue in patients already taking for secondary disease indication -If held, restart when clinically appropriate	−2a, B −2a, C
Calcium Channel blockers	-Continue in patients already taking for secondary disease indication	--***
Anticoagulation	-Tailored to risk benefit of thrombosis versus bleeding risk -Oral anticoagulants should continue if no significant risk of surgical bleeding	--***
Antiplatelet	-Should not begin if not already taking -It is not beneficial to continue aspirin therapy in vascular surgery unless undergoing carotid endarterectomy. -For recent PCI with DES or BMS, elective surgery should be delayed until the patient receives the optimal duration of DAPT (i.e. ≥ 30 days in the case of BMS and ≥ 12 months in the case of DES -If the surgery demands discontinuation of $P2Y_{12}$ inhibitors then continue aspirin, stop the $P2Y_{12}$ inhibitor and restart it as soon as possible after surgery.	−3, B −1, C

* - strength the Guideline Writing Committee assigns a recommendation. Class 1: procedure, treatment should be performed. Class 2a: procedure, treatment is reasonable, additional studies with focused objectives needed. Class 2b: procedure, treatment may be considered, additional studies with broad objectives needed. Class 3: no benefit or harm

** - a rating for the scientific evidence supporting the intervention. Level A: multiple populations studied/ multiple randomized clinical trials or meta-analysis. Level B: limited populations studied- data obtained from single randomized trial. Level C: very limited populations studied- only consensus opinion of experts, case studies, standard of care

*** - insufficient evidence for classification.

Table 7.

*Comparison of Surgical Risk Calculators

Tool	Risk Factor Entry
Revised Cardiac Risk Index	Location of operation, history of ischemic heart disease, history of congestive heart failure, history of cerebrovascular disease, insulin use for diabetes, creatinine >2 mg/dL
ACS NSQIP	Specific surgical procedure, acute renal failure, dialysis, congestive heart failure (<30 days), diabetes, age, functional Status, ASA class, steroid use, ascites, sepsis, ventilator dependence, metastatic cancer, BMI, hypertension requiring medication, severe COPD, dyspnea, smoking (within past year), sex, wound class, urgency of surgery
Gupta Peri-Operative Risk (MICA)	Age, ASA class, functional status, creatinine (3 categories), type of procedure

*As adapted from [3]