Complications in Robotic Urologic Surgery

René Sotelo
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Introduction

Robotic surgery is one of the century's great technological advances. High quality evidence continues to grow demonstrating the benefits and superiority of this technology compared to open or pure laparoscopic techniques for urological procedures. With the wide acceptance of robotic surgery, it is estimated that a robotic procedure is begun every 60 s worldwide, and one out of every five cases is urological surgery.

It is imperative with the adoption of any new technology that surgeons and operating room staff are trained appropriately in order to ensure excellent outcomes and minimize medical complications. Specifically, surgical team training should emphasize the early recognition and management of complications. Endoscopic video equipment allows robust video databases to be created and maintained for this purpose.

In this book, pioneers and experts in the field of robotic urologic surgery provide detailed descriptions of possible surgical complications. Focusing on specific procedures, these experts describe how to avoid and manage surgical complications as they arise and provide a blueprint for planning a surgery free from complications. Being prepared to manage complications will ultimately increase the safety and efficiency of robotic urologic surgery.

I am sure this book will be indispensable for any surgeon who wants to perform safe robotic urologic surgery.

Part I

Complications Related to Robotic Surgery

Patient's Own Risk Factors

1

Shadi Dowlatshahi, Wei-I Vickie Wu,
and Michael Donald Wang

Abbreviations

ABG	Arterial blood gas
AC	Anticoagulation
ACEI	Angiotensin-converting enzyme inhibitor
ACS-NSQIP	American College of Surgeons National Surgical Quality Improvement Program
ACS-NSQIP MICA	ACS-NSQIP Gupta MI Cardiac Arrest
AP	Antiplatelet
ARB	Angiotensin receptor blocker
ASA	American Society of Anesthesiology
ASA	Aspirin
BMS	Bare-metal stent
CABG	Coronary artery bypass graft
CAM	Confusion Assessment Method
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
CrCl	Creatinine clearance
DAPT	Dual antiplatelet therapy
DES	Drug-eluting stent
DOAC	Direct oral anticoagulant
DSE	Dobutamine stress echocardiogram
DVT	Deep vein thrombosis
IOP	Intraocular pressure
IS	Incentive spirometry
LMWH	Low molecular weight heparin
MACE	Major adverse cardiac event
METS	Metabolic equivalents
MI	Myocardial infarction
MPH	Miles per hour
MPI	Myocardial perfusion imaging
NGT	Nasogastric tube
OSA	Obstructive sleep apnea
PCI	Percutaneous coronary intervention
PE	Pulmonary embolism
PFTs	Pulmonary function tests
PPCs	Postoperative pulmonary complications
RCRI	Revised Cardiac Risk Index
UFH	Unfractionated heparin

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Introduction

Recent technological advances have made many surgical procedures possible with minimally invasive techniques, including urologic robotic surgeries. These techniques have improved patient satisfaction and recovery times, leading to reduced morbidity. However, it is important to recognize that these procedures are not without risk and require a careful preoperative assessment in order to minimize complications.

During the preoperative assessment, the goal is to identify patients at intermediate or high clinical risk for adverse events and whether modifiable medical conditions exist. In addition, we evaluate the surgical urgency and assess whether the delay in an untreated underlying urologic disease will pose a greater risk over an untreated non-urological clinical condition.

In general, a thorough preoperative evaluation includes a full review of the patient's medications, in addition to any cardiac, pulmonary, thromboembolic, or bleeding risks. Also, an assessment of delirium and frailty may be beneficial in the prediction of the elderly patients' outcome.

Postoperative complications related to robotic surgeries can include cardiopulmonary events related to insufflation and decompression, postoperative ileus, and increased intraocular pressure in the steep Trendelenburg position [1].

Perioperative Cardiac Assessment

Cardiac complications are an area of significant concern for any patient undergoing a procedure. Risk factors include coronary artery disease, heart failure, valvular disease, arrhythmias, pulmonary vascular disease, diabetes, and renal disease [2]. Several scoring systems have been devised to simplify the process including the Revised Cardiac Risk Index (RCRI) [3], the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) risk model [4], and the ACS-NSQIP Gupta MI Cardiac Arrest (ACS-NSQIP MICA) calculator [5], to predict the risk of a major cardiac event (i.e., myocardial infarction (MI), pulmonary edema, ventricular fibrillation, complete heart block). The RCRI scoring system is widely used as it is simple to use and has been validated in several studies [6, 7]. The RCRI scoring system encompasses six predictors of risk for major adverse cardiac event (MACE). An RCRI score of 0 indicates a MACE risk of 0.4%; RCRI 1, 1%; RCRI 2, 2.4%; and RCRI ≥3, 5.4% (Table 1.1).

Table 1.1 Revised Cardiac Risk Index (RCRI)

RCRI	MACE rate	Risk
0	0.4% (0.1–0.8)	Low
1	1% (0.4–1.5)	Low-elevated[a]
2	2.4% (1.3–3.5)	Elevated
3+	5.4% (2.8–7.9)	Elevated

MACE indicates major adverse cardiac event
[a]Low risk is <1% per ACC/AHA 2014 guidelines

Functional status is also imperative to cardiac risk assessment and is a prognostic determinant in the decision for further cardiac risk stratification [8, 9]. It is quantified by the use of metabolic equivalents (METS). One MET is equal to the resting/basal oxygen consumption of a 40-year-old, 70 kg man. Functional status is classified as excellent (>10 METS), good (7–10 METS), moderate (4–6 METS), poor (<4 METS), or unknown. Patients with METS >4 are able to climb a flight of stairs or walk up a hill, walk on level ground at 4 miles per hour (MPH), or perform heavy work around the house. Activities requiring METS <4 include slow ballroom dancing, golfing with a cart, playing a musical instrument, or walking at approximately 2–3 MPH.

Patients with poor functional status have been shown to have an increased risk for perioperative morbidity and mortality [10]. These patients, in addition to those with elevated cardiac risk, may benefit from further risk stratification with cardiac stress testing [11]. The decision to pursue further evaluation depends on whether this testing will impact the decision-making or care of the patient perioperatively (i.e., perform original surgery or undergo cardiac intervention). If stress testing will change management, then the patient should undergo further cardiac testing with well-validated stress-testing modalities, such as

dobutamine stress echocardiogram (DSE) or myocardial perfusion imaging (MPI) [12–14]. Currently, there are no randomized controlled trials comparing the two stress test modalities; therefore, which test to pursue should be based on local expertise performing the test, in addition to patient characteristics [2].

Patients with a moderate to large area of myocardial ischemia noted on stress test imaging are at increased risk for perioperative MI and/or death. They may be considered for preoperative revascularization if they are deemed to have unstable angina and/or left main disease and would otherwise need to undergo emergent/urgent revascularization [15, 16]. Patients who require revascularization secondary to an ST elevation MI or non-ST elevation MI usually benefit from percutaneous coronary intervention (PCI). Due to the shorter need for ongoing dual antiplatelet therapy (DAPT), bare-metal stent (BMS) may be preferred over a drug-eluting stent (DES) if surgery is time sensitive [16]. The Coronary Artery Revascularization Prophylaxis (CARP) trial – the largest randomized trial of its kind – showed that there was no mortality benefit to coronary artery revascularization, either with PCI or coronary artery bypass grafting (CABG), prior to elective vascular surgery, in patients with known stable coronary artery disease [17]. Only patients with left main disease showed a benefit to preoperative coronary artery revascularization [18].

Patients who undergo PCI should have surgery delayed by 14 days after balloon angioplasty and 30 days after BMS implantation. Those who undergo DES placement should have surgery delayed by at least 365 days, though surgery may be considered after 180 days if the risks of delaying the surgery further are greater than the risk of stent thrombosis [2, 19–21].

Perioperative Cardiac Medications

Beta-Blocker Therapy

Patients currently on beta-blockers should be continued on these medications throughout the perioperative period. Studies [22, 23] have shown that sudden withdrawal of beta-blocker may be harmful. However, they may need to be decreased in dose or temporarily discontinued due to hypotension, bradycardia, or bleeding.

There is conflicting data however on the benefits versus risks of initiating beta-blocker therapy. Initial data supported the use of beta-blockers to prevent postoperative cardiac complications; however, these trials were limited by small sample sizes with low power [2]. A favorable outcome has been observed in patients who preoperatively are at intermediate or high risk for myocardial ischemia, as determined by pharmacological stress test [24], or if the patient has an RCRI of ≥3 [25]. The POISE trial showed that beta-blockers had a potentially harmful effect, including increased risk of stroke and death. Criticism of the POISE trial included use of high-dose long-acting beta-blockers, initiating beta-blocker immediately before surgery, and lack of a titration protocol before or after surgery [26].

A risk-benefit analysis should be performed before deciding if a beta-blocker should be initiated. If a decision is made to start a beta-blocker, it should be initiated at least 1 day prior to surgery and titrated safely to lower the resting heart rate [2].

Statin Therapy

Patients currently taking a statin should be continued on the statin throughout the perioperative period. Further, patients may be started on statins if deemed to be higher risk (i.e., history of diabetes, hypertension, coronary artery disease). Data from statin trials suggests there is a reduction in cardiovascular events in the perioperative period in high-risk patients [27, 28]. The general recommendation is to start statin therapy 1 week prior to surgery and to continue for 30 days after, if not already indicated. Regardless, patients who meet criteria for initiation of a statin may benefit long term from its introduction.

Angiotensin-Converting Enzyme Inhibitor (ACEI)/Angiotensin Receptor Blocker (ARB) Therapy

ACEI/ARB may be continued throughout the perioperative period; however, there is increased risk for transient intraoperative hypotension

[29]. If they are held preoperatively, they may be restarted postoperatively when the blood pressure is able to tolerate the addition of the medication.

Anticoagulants and Antiplatelet Therapy

See anticoagulation/antiplatelet section for further details.

Perioperative Pulmonary Assessment

The frequency of postoperative pulmonary complications (PPCs) varies from 5% to 70%, with the wide discrepancy explained by the definition used in each study, patient selection, and procedure-related risk factors [30].

PPCs include atelectasis, cough, dyspnea, bronchospasm, hypoxemia, hypercapnia, adverse reaction to pulmonary medication, pleural effusion, pneumonia, pneumothorax, and ventilatory failure. Those that are particularly at increased risk are persons with preexisting lung disease, medical comorbidities, poor nutritional status, overall poor health, and current smokers. PPCs are not only detrimental to the patient (account for about 25% of deaths occurring within 6 days of surgery [30]), but they are also costly to the hospital (i.e., can increase length of stay by 1–2 weeks). Similar to cardiac complications, the patient's own risk factors, as well as the procedure itself, may increase the risk for pulmonary complications.

Patient Risk Factors

There are several patient-related risk factors that are associated with increased risk for PPCs. Age has been shown to be an independent risk factor for PPCs, specifically, in patients greater than age 50 [31]. The general health status is usually predicted by the American Society of Anesthesiology (ASA) classification system, and class two or higher is associated with an increased pulmonary risk [31]. In addition, patients with poor functional status, as well as those with low albumin (<3.5 g/dL) and weight loss, are at increased risk for PPCs [32].

Patients with at least a 20 pack-year smoking history are at increased risk for PPCs, compared to those with a lesser smoking history. Risk for PPCs is reduced when patients stop smoking at least 4 weeks prior to surgery [33]; however, data has shown that even briefer durations of smoking cessation have been associated with a reduction in PPCs [34, 35].

Chronic obstructive pulmonary disease (COPD) is an important risk factor for PPCs. Patients with severe COPD have an increased risk for pneumonia, unplanned intubation, and prolonged ventilatory support [36]. Similar to COPD, patients with asthma are at increased risk for PPCs when it is not well controlled [37, 38]. Patients should be medically optimized prior to surgery (Table 1.2).

Obesity causes decreased lung volumes, ventilation-perfusion mismatch, and relative hypoxemia, which one would expect to increase the risk for PPCs. However, available data is inconsistent regarding this matter, and the consensus currently is that obesity is not a predictor of PPCs [38, 39]. Patients with suspected obstructive sleep apnea (OSA) should undergo screening with one of the available screening tools such as the STOP-BANG questionnaire. Early identification of these patients will allow for possible intraoperative and postoperative modifications to be made, such as minimizing the use of sedatives and opioid analgesics [40, 41]. An arterial blood gas should be considered in patients with suspected or known OSA and suspicion for obesity hypoventilation syndrome [40].

Table 1.2 General perioperative strategies in reduction of postoperative pulmonary complications

Preoperative	Postoperative
Immediate smoking cessation	Incentive spirometer and deep breathing
Optimization of underlying lung disease	Early mobilization
Optimization of nutrition	Pain control in thoracic/abdominal surgeries
–	Nasogastric decompression when indicated

Procedure Risk Factors

Procedure risk factors include surgical site (the closer the incision site is to the diaphragm, the greater the risk for PPCs) [31], duration of surgery (longer than 3–4 h) [38], type of anesthesia, and type of neuromuscular blockade. Patients undergoing intra-abdominal surgeries are at an increased risk for pulmonary complications. While robotic urologic procedures are minimally invasive, they have been associated with a decrease in pulmonary compliance and tidal volume due to pneumoperitoneum and steep Trendelenburg position. Further, these patients are also at increased risk for facial, pharyngeal, and laryngeal edema leading to re-intubation [1].

Preoperative Testing

A complete history and physical exam are important in evaluating a patient's risk for PPCs. These elements should be directed toward eliciting any findings that may be concerning for underlying lung or cardiac disease. Based on the history and physical exam, further preoperative testing may be warranted which may include pulmonary function testing, an arterial blood gas, and a chest radiograph.

Pulmonary Function Tests (PFTs)

Patients typically do not require PFTs to be performed prior to surgery, unless they have an unexplained history of dyspnea or exercise intolerance. PFTs do not predict the risk for pulmonary complications, and therefore patients should not have surgery withheld based on PFTs only. If a patient has a history of COPD/asthma and it is unclear if the patient is at their baseline, PFTs may be beneficial in determining whether the patient requires more aggressive treatment for optimization prior to surgery [42].

Arterial Blood Gas (ABG)

Although patients with hypercapnia are at increased risk for PPCs and mortality, there is no strong evidence to suggest that patients should have an ABG performed prior to surgery; however, this can be considered if obesity hypoventilation syndrome is suspected [42, 43].

Chest Radiographs

Despite routine ordering of chest radiographs prior to surgery, they have been shown to add little clinical significance in predicting PPCs [44]. It is therefore suggested that chest radiographs not be obtained in low-risk patients, unless the patient is over the age of 50 years with known history of cardiopulmonary disease undergoing a high-risk surgery involving the upper abdomen, esophagus, thoracic cavity, or aorta [45].

Postoperative Strategies to Reduce Pulmonary Complications

Strategies to reduce postoperative pulmonary complications include lung expansion maneuvers, early mobilization, adequate pain control, use of nasogastric decompression, and venous thromboembolism prophylaxis (Table 1.2).

Lung Expansion Maneuvers

Lung expansion maneuvers include incentive spirometry (IS), deep breathing exercises, chest physical therapy, intermittent positive pressure breathing, and continuous positive airway pressure (CPAP). IS is widely used postoperatively given its cost-effectiveness and safety. However, whether there is benefit to preventing PPCs is controversial. In a meta-analysis by Overend et al. [46], there was no reduction in PPCs in patients using IS who had undergone cardiac or upper abdominal surgery. Conversely, in a systemic review by Ireland et al. [47], it was suggested that CPAP may reduce PPCs; however, the quality of the evidence was low.

Early Mobilization

The sooner the patient is able to ambulate after surgery, the less risk they have for PPCs [48]. Minimize bedrest orders and tethers that discourage mobility. Physical therapy and occupational therapy can be consulted soon after surgery to help aid in early mobilization of the patient.

Adequate Pain Control

Ensuring good pain control for the patient postoperatively helps reduce PPCs. Patients are able to take deeper breaths, as well as ambulate earlier [42, 49].

Nasogastric Decompression

Patients who have undergone abdominal surgery with subsequent routine placement of a nasogastric tube (NGT) for prophylactic reasons have an increased risk for PPCs [49]. NGTs should only be used when indicated (i.e., unable to tolerate oral intake due to nausea and vomiting, postoperative ileus).

Venous Thromboembolism (VTE) Prophylaxis

Surgery is a known risk factor for deep vein thrombosis (DVT) and subsequent pulmonary embolism (PE). Patients should be started on adequate prophylactic anticoagulation postoperatively, once deemed safe to do so.

Perioperative Anticoagulation Assessment

As the patient population continues to age, more patients are taking oral anticoagulants and antiplatelet agents. Patients requiring anticoagulation include patients with atrial fibrillation, prosthetic valves, and DVT/PE, while those requiring antiplatelet therapy include patients with cardiovascular, cerebrovascular, or peripheral arterial disease. The goal is to balance the risk for a thromboembolic event against the excess risk of bleeding. Data is limited regarding the risks and benefits of interrupting anticoagulation and/or antiplatelet therapy. As such, each patient should be evaluated separately in regard to when to hold or continue these therapies.

In general, patients undergoing invasive procedures should discontinue their anticoagulation in a timeframe that allows the drug effect to wear off prior to surgery – generally five half-lives of the medication. If the patient is at high risk for thromboembolic events, then the interruption period should be as short as possible (e.g., restart after hemostasis is established and the bleeding risk is acceptable). Those undergoing low bleeding risk procedures may be able to continue anticoagulation throughout the procedure though this is usually at the discretion of the operator.

Commonly used antiplatelet agents include aspirin (ASA) and the $P2Y_{12}$ inhibitors (clopidogrel, prasugrel, and ticagrelor). Despite its short half-life, ASA irreversibly inhibits thromboxane A1 and prostacyclin synthesis, thereby preventing platelet aggregation for the life of the platelet. These effects are maintained up to 5–7 days after cessation of ASA. $P2Y_{12}$ inhibitor also prevents platelet aggregation through the inhibition of the adenosine diphosphate receptor, which returns to normal after 5–7 days of cessation of the $P2Y_{12}$ inhibitor.

For decades, warfarin was the most commonly used anticoagulant; however, the development of direct oral anticoagulants (DOACs) has led to their increased use in many conditions in lieu of warfarin. DOACs include dabigatran (direct thrombin inhibitor) and the factor Xa inhibitors apixaban, edoxaban, and rivaroxaban.

Management of Anticoagulation (AC)/Antiplatelet (AP) Therapy

Robotic urologic surgery is associated with decreased bleeding and decreased transfusion rates compared to traditional open urologic surgery [50]. However, data is limited regarding the management of AC/AP therapy in the perioperative period for robotic surgeries. Decisions regarding AC/AP management have been based on prior studies involving other surgical procedures, including traditional urologic surgery [51].

Anticoagulant Therapy

Patients with mechanical valves at high risk for thromboembolism (Table 1.3) should stop warfarin 5 days prior to surgery and be bridged with either low molecular weight heparin (LMWH) or unfractionated heparin (UFH) once the INR falls below 2 [52]. LMWH may be stopped 24 h prior to surgery, while UFH may be stopped 6 h beforehand (Fig. 1.1) [52–54]. Once surgery is com-

Table 1.3 Thromboembolic risk conditions

	Low thromboembolic risk (*Bridging generally not required*)	High thromboembolic risk (*Bridging generally required*)
Mechanical valves	Bileaflet aortic valves (most common)	All right-sided valves (rare) All mitral valves Certain aortic valves Tilting disc Caged ball Other risk factors for thromboembolism[a]
Atrial fibrillation	Low CHA_2DS_2-VASc score	High CHA_2DS_2-VASc score[b] Prior stroke
DVT/PE	Remote	Recent (<3 months)

[a]Risk factors include: previous thromboembolic event, concurrent atrial fibrillation, hypercoagulable condition, left ventricular systolic dysfunction (ejection fraction <30%), or more than one mechanical valve
[b]Not well defined in the literature

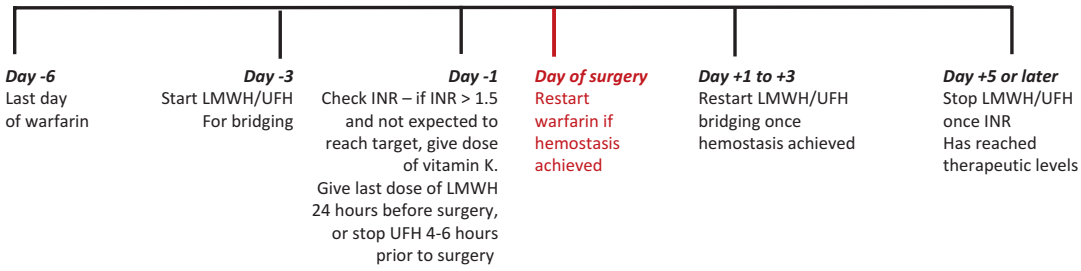

Fig. 1.1 Warfarin dosing in setting of high thromboembolism risk

pleted and hemostasis has been achieved, the patient should be restarted on LMWH or UFH, as a bridge to warfarin. Similarly, patients with atrial fibrillation and at high risk for thromboembolism (Table 1.3) should be restarted on warfarin after surgery, with a LMWH/UFH bridge, as soon as possible once the bleeding risk and hemostasis have been addressed (Fig. 1.1) [52].

Patients with low-risk mechanical valves or atrial fibrillation with low- or intermediate-risk CHA_2DS_2-VASc score (Table 1.3) should consider stopping warfarin 5 days before surgery and be restarted on anticoagulation after surgery, with no need for full-dose bridging with LMWH or UFH (Fig. 1.2) [55]. Note that VTE prophylaxis is still indicated in these patients.

Patients on a DOAC undergoing robotic urologic procedure should have their last dose of the drug held 2–5 days prior to surgery, based on the DOAC used and their creatinine clearance (CrCl). Patients on dabigatran and CrCl >50 ml/min should stop the drug 2–3 days before surgery, while those with a CrCl of 30–50 mL/min should stop the drug 3–5 days prior to surgery, depending on bleeding risk [56]. Similarly, patients on apixaban and rivaroxaban should stop the drug 2–3 days before surgery, with the longer duration for those undergoing high bleeding risk procedures. Patients with high risk for thromboembolism may benefit from bridging with LMWH or UFH; however, there is an associated increased risk of bleeding [57, 58]. If the patient has a low thromboembolic risk with low bleeding risk, DOACs may be restarted 24 h postoperatively; if there is a high bleeding risk, it may be restarted with a delay: 48–72 h postoperatively (Table 1.4).

If the patient is at a high risk for thromboembolic event and underwent a high bleeding risk surgery, it is suggested to restart the DOAC at a reduced dose on the evening of the surgery and continue this dose the following day (postopera-

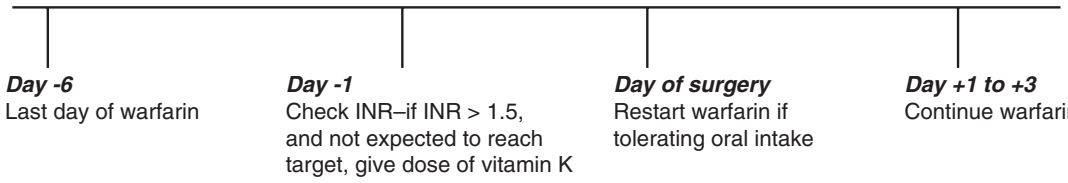

Fig. 1.2 Warfarin dosing in setting of low thromboembolism risk

Table 1.4 Direct oral anticoagulants and interval dosing

Drug	Mechanism of action	Half-life (t1/2) (h)	Patient renal function	Dosing	Interval from last dose to day of surgery	
					Low bleeding risk surgery	High bleeding risk surgery
Dabigatran	Factor IIa inhibitor	~15	CrCl >50 mL/min	Twice daily	Last dose 2 days before surgery (i.e., skip 2 doses)	Last dose 3 days before surgery (i.e., skip 4 doses)
			CrCl 30–50 mL/min		Last dose 3 days before surgery (i.e., skip 4 doses)	Last dose 5 days before surgery (i.e., skip 8 doses)
Apixaban	Factor Xa inhibitor	~12	CrCl >50 mL/min	Twice daily	Last dose 2 days before surgery (i.e., skip 2 doses)	Last dose 3 days before surgery (i.e., skip 4 doses)
			CrCl 30–50 mL/min			
Edoxaban	Factor Xa inhibitor	~10	CrCl >50 mL/min	Once daily	Last dose 2 days before surgery (i.e., skip 1 dose)	Last dose 3 days before surgery (i.e., skip 2 doses)
			CrCl 30–50 mL/min			
Rivaroxaban	Factor Xa inhibitor	~9–12	CrCl >50 mL/min	Once daily	Last dose 2 days before surgery (i.e., skip 1 dose)	Last dose 3 days before surgery (i.e., skip 2 doses)

tive day 1). Resumption of the full dose of the DOAC may occur on postoperative days 2–3, once hemostasis has been achieved (Table 1.4) [59].

Antiplatelet Therapy

Patients who require dual antiplatelet therapy (DAPT) for a BMS or DES should be continued on therapy for no less than 30 days for a BMS and no less than 365 days for a DES to minimize risk of in-stent thrombosis. Ideally surgery should be delayed until it is safe to stop the $P2Y_{12}$ inhibitor [2, 19–21]; however, if surgery cannot be delayed, then the patient should be continued on DAPT during the perioperative period, if surgically permissible [52]. On the other hand, if a patient has no prior history of cardiac stenting, recent MI, or stroke, it is reasonable to stop ASA prior to surgery. The POISE-2 study demonstrated that patients who were at increased risk for cardiovascular events who stopped ASA prior to surgery did not have an increased risk for postoperative cardiovascular events. Bleeding risk was higher on ASA until postoperative days 7–8 [60].

Perioperative Assessment of the Geriatric Patient

More and more adults over the age of 60 years are undergoing surgical procedures. With the increase in comorbidities and complexity of care, the risk for complications and medical errors may be increased. As with all patients, a thorough review of their medication list should be performed, with all nonessential medications

stopped days prior to surgery. Medications that are medically indicated or that have the potential for withdrawal should be continued in the perioperative period. Similar to their younger counterparts, patients should be assessed for cardiac and pulmonary risk factors prior to surgery and should be managed for these risk factors postoperatively in a similar manner.

Older patients are also at increased risk for postoperative delirium and deconditioning [61]. Patients at increased risk for postoperative delirium include those over 65, chronic cognitive decline/dementia, poor vision/hearing, severe illness (i.e., ICU admission), and presence of an infection [62]. One-third to one-half of delirium cases are preventable, and perioperative management is targeted toward delirium prevention. Careful review of the patient's medications will aid in reducing the risk for postoperative delirium. Further, optimal pain control, optimizing the physical environment (minimizing overnight interruptions, frequent reorientation, encouraging family at bedside), having vision and hearing aids accessible, use of earplugs during sleep, removal of catheters, and daily physical activity all promote delirium risk reduction. Several screening tools have been adapted to evaluate and diagnose patients with delirium. The Confusion Assessment Method (CAM) is one of the most widely used screening tools [63, 64]. Once a patient has been diagnosed with delirium, the healthcare team should identify any precipitating factors and treat accordingly [65, 66]. Patients may benefit from systematic intervention (interdisciplinary team approach, ongoing educational programs) and/or consultation with a geriatrician [64].

Frailty can be defined as a state of decreased physiological reserve and vulnerability to stressors [67]. Elderly patients are at particular risk for frailty, which can be a prognostic marker in patients with underlying cardiovascular disease. Awareness of this fact can provide optimal patient-centered care. Studies have correlated frailty with a threefold increased risk for 1-year mortality [68] and a 30% risk of developing new heart failure [69]. A frail patient with heart failure can be particularly at risk during robotic surgeries. When a frail patient is exposed to stressors, the effects can be a disproportionate decompensation [70], leading to adverse events and prolonged recovery. Furthermore, in studies that looked at frail patients after cardiac surgery, frail patients were more likely to require rehabilitation and/or institutionalization [71]. There are several frailty assessment tools, which evaluate the main phenotypes of frailty: slowness, weakness, low physical activity, exhaustion, and shrinking. A simple evaluation is a 5-meter gait speed: a performance over 6 s indicates frailty.

Intraoperative Risks

Pneumoperitoneum/ Retroperitoneum

Patients with cardiopulmonary disease can be particularly susceptible to the effects of pneumoperitoneum during robotic surgeries. Insufflation will decrease venous return and preload, thereby lowering cardiac output while increasing the afterload due to compression of the aorta. At the same time, the increased intra-abdominal pressure from insufflation can decrease functional residual capacity and vital capacity, which can further compromise patients with underlying restrictive lung disease or decreased pulmonary reserve, leading to a hypercarbic condition [1]. Intraoperative compensatory maneuvers to augment blood pressure, such as volume administration, can potentiate pulmonary edema at the end of the case, particularly once insufflation is withdrawn, with a corresponding large increase in preload [1].

Clinical Risk Factors in Patient Positioning

Intraocular Pressure

Steep Trendelenburg position, with abdominal insufflation, leads to increased intraocular pressure (IOP) [72]. Glaucoma patients generally have decreased outflow through the trabecular meshwork and at baseline have increased

intraocular pressure; therefore, these patients should be identified during preoperative evaluation. During surgery, IOP is increased in a time-dependent fashion while in the steep Trendelenburg position, with 25% of the studied population reaching IOP ≥30 mmHg at 5 h [72]. Serious complications, although rare, can include postoperative visual loss.

Treatment to control the IOP is not routinely used for non-glaucoma patients. However, in glaucoma patients with underlying optic nerve damage or severe disease, full discussion of concerns should be communicated among the patient, ophthalmologist, urologist, and anesthesiologist. Prophylactic treatments have been documented in the literature, including the use of systemic acetazolamide and mannitol to lower IOP [73–76]. Mannitol is not appropriate for everyone, particularly in the elderly patient with cardiopulmonary disease, and an alternative procedure may be necessary in this situation.

Conclusions

Patients undergoing robotic surgery should have a thorough preoperative medical evaluation to minimize risk factors that may lead to perioperative complications. A multidisciplinary team approach incorporating hospitalists, internists, geriatricians, and ancillary staff (physical therapy and occupational therapy) can help achieve this goal.

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Anesthetic Implications of Robotic Surgery

2

Pete Roffey

Medical Comorbidities

Oftentimes, patients coming for robotic procedures have medical comorbidities that place them at a higher risk for anesthesia themselves. The appropriate preoperative workup of these issues is discussed in another chapter, but a brief overview of relevant topics follows.

In general, the age of surgical patients is increasing. Elderly patients often have cardiovascular disorders such as coronary artery disease, cardiomyopathies with low ventricular ejection fractions, diastolic dysfunction with or without preserved ejection fraction, peripheral vascular disease such as carotid stenosis, and/or hypertension, which may in turn lead to chronic kidney disease.

Hypertension, seemingly nearly ubiquitous in these patients, is associated with intravascular depletion from chronic vasoconstriction, which tends to cause exaggerated swings in blood pressure until corrected. In addition, though controversial, many anesthesiologists feel that patients who are on angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARB) often show hemodynamic instability intraoperatively due to resistant reduction in afterload [1–3]. ACE inhibitors prevent breakdown of bradykinin, leading to increased levels of nitric oxide (NO) [2]. This in combination with decreased venous return from insufflation can cause severe hypotension that may not be responsive to fluid challenges. Once adequate fluid administration has occurred, if hypotension persists, it may be necessary to institute an infusion of norepinephrine or vasopressin to increase afterload. It is this author's opinion that both ACE inhibitors and ARB agents should be withheld for 24 h prior to surgery, though this does not guarantee this reaction will not still occur.

Smoking results in a significant increase in urologic cancers including transitional cell carcinoma of the bladder, with smokers having approximately three times the risk of bladder cancer relative to nonsmokers [4]. Therefore, a significant number of patients presenting for cystectomy will have this history, whether active or not, often with the associated comorbidities of COPD, productive cough, and coronary artery disease.

Due to the presence of these comorbidities or merely the advanced age of the patient, these patients may have various degrees of chronic kidney disease. It is important to remember that serum creatinine level does not necessarily reflect glomerular filtration rate (GFR), which is also related to age, race, and sex, and may remain normal until significant impairment of GFR exists.

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Patient home medications, such as ACE inhibitors, may also induce renal injury. Additionally, patients with renal cell carcinoma have a 3.1 relative risk of developing disease of the contralateral kidney in the future [5]. Therefore, patients presenting for partial or radical nephrectomy may have already undergone a similar operation on the contralateral side.

Obesity patients are known to have a high incidence of comorbidities such as hypertension and diabetes and present many challenges to the anesthesiologist. These include issues with mask ventilation, intubation, and intravenous and arterial line placement. Their large size may also have a negative impact on intraoperative ventilation, especially in cases of steep Trendelenburg.

Intraoperative Concerns

Pneumoperitoneum

In order to obtain surgical exposure, carbon dioxide is insufflated into the abdomen. This leads to a number of physiologic changes affecting different organ systems that the anesthesiologist must be aware of. These changes tend to be insufflation pressure-dependent, such that the greater the insufflation pressure, the greater the effect on various organ systems. At this time, it is recommended to maintain insufflation pressures below 15 mmHg if possible and below 12 mmHg in cases of steep Trendelenburg [6].

Insufflation has several effects on the cardiovascular system. There can be many reactions to initial insufflation, including tachycardia and hypertension. Response to insufflation includes release of catecholamines and vasopressin with renin-angiotensin activation [7]. Also of great concern is the potential for a vasovagal reaction resulting in severe bradycardia and hypotension, which may be significant enough to lead to asystole and cardiac arrest. This may respond to anticholinergic agents such as glycopyrrolate or in more severe cases atropine or vasopressors such as ephedrine. In cases of hemodynamic instability, the surgeons should be notified to desufflate the abdomen immediately and allow the patient time to recover prior to reinsufflation. Following treatment with anticholinergic agents and adequate recovery time, insufflation can be attempted again slowly; usually subsequent attempts do not lead to such significant hemodynamic consequences. Other complications associated with initial insufflation include hemorrhage due to blood vessel injury during trocar placement and carbon dioxide embolism, resulting in cardiovascular collapse. The latter complication has been shown to occur with a much higher frequency than would be thought, though the incidence of clinically significant embolism is low [8]. The diagnosis can be made by transesophageal echocardiography, along with a high degree of suspicion from the timing of events.

Cardiovascular

Venous return is altered during insufflation. While initially there is an increase in venous return due to compression of the splanchnic circulation, subsequently there is a decrease, due to interference of venous flow from the lower extremities, ultimately leading to a drop in cardiac output and potential hypotension. Patients who are already intravascularly depleted are more at risk for this complication.

Transesophageal echo evaluation during pneumoperitoneum has shown conflicting results with regard to left ventricular ejection fraction (EF). Though some studies have shown no overall effect on EF, a more recent study documented an initial decrease felt to be related to increased afterload followed by a subsequent recovery, often facilitated by positioning in the Trendelenburg position [9]. The author has noted direct distortion of the cardiac profile during pneumoperitoneum, with compression of the right ventricle and rotation of the cardiac axis. Though usually tolerated, this may be of significance in a patient with already compromised cardiac function. The release of catecholamines secondary to the pneumoperitoneum may add stress to patients with preexisting coronary artery disease and, combined with increased afterload and tachycardia in the presence of diastolic

dysfunction, may lead to ischemia and cardiac decompensation [9].

Airway/Respiratory System

Many aspects of the respiratory system are affected during robotic procedures. Functional residual capacity, already compromised by anesthesia, undergoes further reduction as a result of the pneumoperitoneum, causing diaphragmatic elevation, lung compression, and decreased pulmonary compliance. This in turn can lead to high peak pressures and an increased risk of barotrauma. Carbon dioxide is used to create the pneumoperitoneum, which is absorbed by patients to a varying degree and leads to a variable rise in $PaCO_2$, necessitating increased minute ventilation. It is estimated that between 14 and 48 mL/min of CO_2 is absorbed during laparoscopic procedures [10]. Just over 5% of the time, $PaCO_2$ rises at a greater rate than can be removed and severe hypercapnia results. This in turn results in a significant respiratory acidosis. The use of bicarb is contraindicated here due to the ultimate rise in CO_2. Though patients often tolerate some degree of respiratory acidosis well, rises in potassium can be seen with this technique and can be significant [11]. One also must bear in mind the effects of hypercarbia on pulmonary artery pressures, especially in those with preexisting pulmonary hypertension. It is important to remember that as $PaCO_2$ rises, $PetCO_2$ can become a less reliable reflection of $PaCO_2$ (difference increases) due to increased dead space or V/Q mismatch, or both.

Various measures can be taken to overcome these issues. Most easily, minute ventilation (tidal volume × respiratory rate) can be increased to assist in blowing off the extra CO_2 present. If peak pressures rise relative to tidal volume (decreased compliance) to what is deemed an unacceptable level, pressure control mode can be utilized, with the caveat that under pressure control, tidal volume is not guaranteed. This means that any sudden change in compliance (increase or decrease) can lead to significant changes in tidal volume. If changing to pressure control mode does not suffice in improving compliance, an alteration in the I:E ratio may be of use: by allowing more time for inspiration each breath, peak pressures may be lowered. Traditionally longer I:E ratios allow for greater removal of CO_2 due to longer expiratory times; however, in these robotic cases, a shorter I:E ratio may allow for improved removal of CO_2 through resulting larger tidal volumes for the same peak pressure. If despite all measures, severe hypercarbia or hypoxemia persists, or if peak pressures remain unacceptably high or blood pressure too low, it is warranted to ask the surgeons to lower the CO_2 insufflation pressure or, in extreme cases, convert to an open procedure.

A major risk factor for development of hypercarbia is the presence of subcutaneous emphysema, which has been shown to occur in 0.4–2.3% of patients [10]. In turn, many factors influence whether or not subcutaneous emphysema develops. These include insufflation pressure, number of ports used, and length of operation, among others. One patient at the author's institution developed such severe subcutaneous emphysema that the patient's EKG voltage diminished significantly. Clearly, patients with preexisting pulmonary disease, who may already have issues with elimination of CO_2, are also at higher risk of hypercarbia.

It is important to be mindful of the degree of hypercarbia present prior to extubation. First, mandatory ventilation should be continued for several minutes following desufflation to allow for adequate expansion of atelectasis and improved removal of carbon dioxide. However, those with higher levels of CO_2 retention intraoperatively may need prolonged ventilation in the postoperative period until their CO_2 levels reach an acceptable range.

In procedures such as prostatectomy and cystectomy, steep Trendelenburg is initiated to optimize surgical access and view. Not only does this position exacerbate the aforementioned issues with pulmonary compliance, but airway edema is often a major concern at the conclusion of these cases. While most patients can be extubated without issue, caution should be exercised in patients who have developed significant facial

swelling. A leak test and visual upper airway assessment can be performed, keeping in mind that this edema may make an initially relatively straightforward intubation and/or mask ventilation almost impossible to perform if reintubation is necessary. This edema tends to resolve over the first few hours of surgery.

Renal System

Robotic surgeries affect the renal system via several mechanisms. These include direct effects of the pneumoperitoneum as well as indirect responses such as catecholamine release and activation of the renin-angiotensin-aldosterone system. Though generally transient, with urine output returning to acceptable levels soon after desufflation, patients who are older with less reserve or those with preexisting renal dysfunction are at higher risk of prolonged sequelae in the postoperative period due to these changes. Ultimately, these changes lead to decreased renal blood flow, decreased creatinine clearance, and oliguria [12].

The pneumoperitoneum results in a high intra-abdominal pressure, to the extent that it may mimic abdominal compartment syndrome, leading to compression of renal vasculature and parenchyma, decreasing renal blood flow and urine output intraoperatively. Renal blood flow is additionally reduced due to a decrease in cardiac output secondary to the peritoneum as discussed above [13].

Furthermore, this direct compression mimics hypovolemia to the renal system, resulting in the stimulation of the renin-angiotensin-aldosterone system, as well as antidiuretic hormone release. These substances will further decrease renal blood flow and urine output, respectively.

Other mechanisms of intraoperative renal dysfunction have been examined, and it has recently been demonstrated that both endothelin-1 and nitric oxide systems are involved [13]. In fact, blockade of these systems was shown to result in exacerbation of pneumoperitoneum-induced renal hypoperfusion, whereas the preemptive addition of a nitroglycerin infusion significantly reduced these adverse effects [13]. Additionally, it has been shown that with volume loading, renal blood flow and oliguria can be reversed; however, creatinine clearance remains reduced [12].

There is evidence that renal injury, a serious morbidity on its own, has significant negative effects on many distant organ systems [14]. Thus, it is prudent to take steps to minimize the risk of perioperative acute kidney injury. The author utilizes a multimodal approach to accomplish this.

Given the fact that, as mentioned, many of the negative effects on renal blood flow during pneumoperitoneum appear to involve dysfunction of the nitric oxide system, it can be of benefit to administer a nitric oxide donor intraoperatively in patients who are high risk of perioperative renal dysfunction. For this, we have found nitroglycerin to be of great use. Nitroglycerin is primarily a preload reducer with minimal effects on afterload. It allows for the additional volume loading possibly necessary for improved renal blood flow while minimizing the reflex tachycardia often seen with the use of afterload reducers.

Diuretics are also of use in this setting. Mannitol, an osmotic diuretic, may have renal protective effects, primarily through improvement of renal blood flow and decreased renal vascular resistance [15]. Additionally, furosemide, a loop diuretic, helps to decrease oxidative stress on the kidney. Loop diuretics block the functioning of the Na-K-2Cl pump, an ADP-dependent pump, thereby reducing the kidney's oxygen utilization and increasing oxygen availability [16]. This can be particularly important in cases of partial nephrectomy, which necessitates some element of warm ischemia time during resection.

Central Nervous System

Due to the nature of the position during robotic prostatectomy or cystectomy, there can be concern about any compromise in cerebral blood flow due to elevated intracranial pressure and/or decreased venous return from positioning. Of course, this position does through gravity increase arterial pressure. However, a small study has shown that while zero perfusion pressure (the pressure at which cerebral blood flow ceases) does rise during steep Trendelenburg, the rela-

tionship between mean arterial pressure, intracranial pressure, and cerebral perfusion pressure is preserved, and MAP increases adequately to prevent ischemia [17]. There have been anecdotal reports of patients awakening from anesthesia somewhat mentally altered for a brief period after being in this position for some time however.

Optical

Though rare, cases of postoperative blindness following operations requiring steep Trendelenburg have been reported [18]. Intraocular pressure rises from baseline significantly in a time-dependent manner. If mean arterial pressure is low during this time, then blood flow through the optic artery can be compromised, leading to vision loss. Patients with preexisting conditions such as glaucoma who already have elevated intraocular pressure will be at increased risk of this unfortunate occurrence.

Nerve Injury

As with any operative procedure, care must be taken to prevent nerve injury resulting from compression. As both arms are tucked during supine robotic surgeries, proper padding must be placed to prevent ulnar injury. Improper bracing of the shoulders during prolonged steep Trendelenburg or severe stretching while in lateral decubitus can lead to brachial plexus injury. Additionally, though rare, patients in lithotomy and Trendelenburg for extended periods of time can lead to rhabdomyolysis, or even compartment syndrome, reflected in extremely elevated creatine kinase levels and swelling of the affected extremity.

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Robot Failure

3

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Introduction

With advances in technology, new machines and devices have been developed, bringing great advances in modern medicine; the use of such a high-technology machine should not only be based on its advantages but also on its shortcomings, and clinicians should be aware of the risks of untoward or unexpected events. Malfunction of the da Vinci robotic system is one of the shortcomings that might result in variable outcomes, depending on the severity.

The potential technical advantages of the robotic approach are delivered through sophisticated engineering that is significantly more complex in both hardware and software than laparoscopic instruments. Additionally, the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) is an entire system solution for surgery instead of a set of instruments. Therefore, by its nature, the robotic system might be more prone to dysfunction than a simpler surgical solution. With the increased use of robotics, surgeons are increasingly reliant on a computerized system to function properly to complete cases. The potential for malfunctions leading to complications, aborted procedures, or open conversions is a concern due to the reliance on this system.

According to the annual report issued by Intuitive Surgical in 2013, since 2000, 1.75 million procedures have been practiced in the United States in different specialties [1]. Surgical robots enable performing complex minimally invasive procedures with improved visualization, greater precision, and skill improvement compared with laparoscopy.

The da Vinci surgical robot is the only surgical robot currently approved by the US FDA (Food and Drug Administration) for performing various types of urological, gynecological, cardiothoracic, and head and neck surgical procedures [2].

The intention of this text is to give a consolidated assessment of the safety and efficacy of robotic surgical systems. We have practiced a review of current medical literature indexed in PubMed to date (US National Library of Medicine National Institutes of Health).

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Adverse Events Facts in Robotic Surgery According to FDA MAUDE

The Manufacturer and User Facility Device Experience ("MAUDE") database is a published public collection belonging to the FDA, in which suspected adverse events derived from the device are recorded and mandatorily reported by producers and distributors, while health professionals and customers make them voluntarily [3].

As a spontaneous reporting system database, FDA MAUDE suffers from underreporting and inconsistencies [4–6]. However, it provides valuable information about actual incidents that occurred during robotic procedures and how they impacted on the safety of the patients. The data reported in deaths, injuries, and poor performance of the devices, provided by the MAUDE, can be treated as a sample to estimate the lower limits of the prevalence of adverse events and identify their causes and impacts on patients and surgeries.

Adverse events during robotic surgery in United States since 2000 have been recovered from the FDA MAUDE [3] database; analysis has been made from this data collection about security incidents experienced during the procedures made by this approach, so preventable and not preventable events can be detected and analyzed. In several texts it has been estimated prevalence of incidents, including deaths, injuries, and poor function of the device during different periods of time. With this information potential causes of the incidents, of the impact on patients, and of the surgery process have been defined.

Several analyzes of the FDA-MAUDE database have been performed at different periods of time, the biggest was recently practiced and 2.9 million records were analyzed [1]. The relationship of these studies can be seen in Table 3.1 [7–13].

Instrument or Robotic Device Malfunction: Mortality and Injury Association

Malfunctions are infrequent, and the need to abort or convert to another modality is rare. The types and outcomes of these device malfunctions have changed with time and robotic system.

Overall rates of equipment malfunction occurred among 0.5–4.6%, this percentage varied according to the experience and the number of cases performed by the group of surgeons [14–16]. In the review group at the University of Illinois [1], five main categories of malfunctioning devices and instruments were identified, either that they

Table 3.1 Data review

Study	No. reports (years)	System under study	Surgical specialties
Murphy et al. [7]	38 system failures, 78 adverse events (2006–2007)	da Vinci system	N/A
Andonian et al. [8]	189 (2000–2007)	ZEUS and da Vinci	N/A
Lucas et al. [9]	1,914 (2003–2009)	da Vinci system models dV and dVs	N/A
Fuller et al. [10]	605 (2001–2011)	da Vinci system	N/A
Friedman et al. [11]	565 (2009–2010)	da Vinci instruments	N/A
Gupta et al. [12]	741 (2009–2010)	da Vinci system	Urology, gynecology
Manoucheri et al. [13]	50 injuries/deaths (2006–2012)	da Vinci system	Gynecology
Alemzadeh et al. [1]	10,624 (2000–2013)	da Vinci robotic systems and instruments	Gynecology, urology, general, colorectal, cardiothoracic, and head and neck surgery

had an impact on patients, either by injuries and complications or by interrupting the progress of surgery and/or prolonging operative times. This division also has the highest impact for the analysis of robot failures, since it covers the largest number of cases studied (2.9 million records) and cases of adverse events reported (10,624).

As the da Vinci robotic system is made up of several parts of software and hardware, the shortcoming is that each part might cause an unexpected failure.

System Errors and Video/Image Problems

- These are the most reported with 7.4% of the adverse events and were the main cause of interruptions of any surgery. Including system reboots, the conversion of proceedings to a non-robotic (59.2% of all conversions) approach, and need to abort/rescheduling of procedures (81.8% of all cases).
- System errors have increased by robot's existing security mechanisms after troubleshooting detection that cannot be recovered autonomously; most of the time, it is corrected with a manual system reset (recoverable error), even though there are cases in which the robotic procedure requires to be stopped (unrecoverable error).
- The most common failure component was the robotic arm and joint system malfunction (71.4%) [16]. The arm and optical systems were the two main causes of malfunction [17].

Falling Pieces or Burnings in the Patient's Body

- They constituted approximately 1557 (14.7%) of adverse events. In almost all these cases, the procedure is interrupted, and the surgical team spent some time looking for the missing pieces to be recovered from the patient (in 119 cases an injury to the patient was informed, and 1 death was informed).

Instruments Electrical Arcs, Sparks, or Burning

- Concerning burns or holes on tip covers, they constituted 1111 reports (10.5%) of the events, which led to almost 193 injuries such as burn tissue.
- Failures of instrument tip insulation accessories such as the monopolar scissors are included in this category. Studies showed 25–33% of insulation failure accessories after a single surgical use. Single use of each isolation device is recommended to prevent unnecessary patient morbidity [18].

Unintended Operation of Instruments

- Uncontrolled movements and spontaneous switch On or Off occurred in 1078 adverse events (10.1%), including 52 injuries and 2 deaths.

Malfunctions That Could Not Be Classified into Another Criteria, such as Breaking of Cable and Instruments

It is found in the medical literature that despite a relatively high number of reports, the vast majority of procedures were successful and no problems were present. In the analysis with most reports, the number of injuries/death events per procedure has remained relatively stable since 2007. However, the total number of failures reported per procedure (0.46%) was six times below the average number of malfunction by the procedure (3%). Also the total number of injuries and deaths reported by procedure (0.08%) was almost the same as the predicted for robotic surgery complications [19], but in a less magnitude than the lower rate of complications reported for robotic surgery in previous studies (2%) [20].

Preventative or Recuperative System Measures

In practice, the use of a robotic platform interface is a sophisticated machine with surgeons in an area of patient care and safety. From a technological point of view, the use of security practices and controls, substantially improved in its design, operation safety, and validation of robotic surgical systems, could prevent situations of failure and its consequences.

Some Recommendations to Minimize Patient's Risk

- Human-machine interfaces and improved surgical simulators that train surgical teams to handle technical problems [21, 22] and evaluate their actions in real time during surgery.
- Provide real-time information to the surgeon on the anatomical paths and safe decisions that can be taken.
- That the surgeon acquires control and knows the safety barriers that prevent robotic tools to advance more than expected, leading to dangerous situations for the patient by entering certain areas of the workspace during surgery [23], this is achieved based on patient-specific anatomical models which are programmed depending on the surgery to be performed and tracking surgeon's surgical movements at the robotic console while using simulators and live cases performed previously [24].
- Take into account new security engines for monitoring procedures (including the surgeon, patient, and device status), and provide complete information to the surgical team about events and troubleshooting procedure, thus preventing disruptions.
- All health personnel working in the area of robotic surgery should discipline themselves to improve mechanisms for the registration and notification of experienced incidents during the proceedings, to be more precise in security information and efficiency on surgical systems, by learning from situations already experienced by other surgeons.
- The learning curve might be a potential factor in these malfunctions initially and might be related to improper port planning, docking technique, and improper movement of the arms or unfamiliarity with the limited range of motion. Unfamiliarity might result in a total shutdown of the robotic system. Knowledge gives the opportunity to take defensive precaution.
- When the robotic system shuts off repeatedly, the arms, the robot position, and the ports must be adjusted carefully. These malfunctions, in which repeated stops are reported, are common in the first part of the learning curve; once the learning curve is overcome, the reasons for malfunctions are mostly mechanical dysfunction or instrument overuse. Maintenance and regular updates are essential to avoid these problems.
- Discussion with patients and their families regarding risks of mechanical failure and alternative surgeries is important before surgery [25].
- It is recommended that at the time of admission of the patient to the operating room, the robotic system is powered up and has proven its proper functioning. Even the day before any surgery, the machine should be tested. If a malfunction occurs during surgery, the technician should be contacted immediately and expressed of the problem for solutions.
- If a critical error occurs, conversion to open surgery or laparoscopic surgery is an alternative. If the failure occurs before induction of anesthesia, rescheduling is another option. Finally, if finances allow, a second robot da Vinci is another option.

Conclusions

The robotic surgical systems have been successfully adopted in many surgical specialties. It is an extremely safe and reliable system for surgery in multiple specialties. It should be noted that the malfunction is rare and the risk of critical failure is very low. The total number of injuries and death events per procedure has been relatively constant over the years.

Knowledge of adverse situations that can occur is critical since it will allow the necessary measures to prevent and solve those events that occur, even more when it is known that the malfunction of devices and instruments has affected thousands of patients and surgical teams causing complications and prolonged surgery. Managing a malfunction before or during robotic surgery is crucial for the benefit of the patient and to maintain the surgical team's confidence. As surgical systems continue to evolve with new technologies, standard and uniformed disciplined habits in training surgical equipment, more advanced human-machine interfaces, improved accident investigation, reporting mechanisms and design techniques interfaces based on security, incident rates should be reduced in the future.

Robot-assisted surgery has brought new potential technical problems for the surgeon, but most of these problems can be corrected or temporarily overwhelmed to complete the operation. Robotic surgery provides a safe way of minimally invasive treatment.

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Instrument Malfunction

4

Ziho Lee and Daniel D. Eun

Abbreviations

MAUDE	Manufacturer and User Facility Device Experience
TCA	Tip cover accessory
US FDA	United States Food and Drug Administration

General Considerations

Background

Although robotic instrument malfunctions are reportedly rare, they may adversely affect clinical outcomes. The rate of reported instrument malfunctions during robotic urologic surgery ranges between 0.25% and 1.1% [1, 2]. However, many instrument malfunctions are not reported as they may go unnoticed, [3] do not result in clinical complications, [2, 4] and require that the surgical team voluntarily report incidents [3–5]. Nevertheless, depending on the specific type, severity, and timing, instrument malfunctions may increase operative costs, cause operating room delays, and even cause unintended patient injury. Despite this, the literature regarding instrument malfunctions during robotic urologic surgery is limited.

Herein, instrument malfunction refers to any intrinsic defect in a robotic instrument that limits its normal function. System-related defects that inhibit normal function of instruments and malfunctions related to linear staplers are discussed elsewhere and are thus excluded from this discussion. The purpose of this chapter is to describe the major types of instrument malfunctions during robotic urologic surgery and to review their prevention, diagnosis, and treatment.

Robotic Instruments

Currently, robotic urologic surgery generally refers to procedures performed using the da Vinci® (Intuitive Surgical, Inc., Sunnyvale, USA) surgical system. As such, our discussion of instruments and their malfunction focuses on EndoWrist® (Intuitive Surgical, Inc., Sunnyvale, USA) instruments, which are the only instruments designed for use with the da Vinci® surgical system. EndoWrist® instruments are mounted on robotic arms and introduced into the body through ports/cannulas. The instruments may be interchanged during an operation to carry out desired functions. The surgeon relays motions from the master controllers at the robotic console

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to manipulate the instruments within the patient's body. EndoWrist® instruments provide the surgeon with a range of motion greater than the human wrist through 7° of freedom, 180° of articulation, and 540° of rotation. These instruments have a preset number of uses, and most are limited to ten uses.

There are four major components to an EndoWrist® instrument. The instrument housing is the portion of the instrument that engages and disengages with the robotic arm (Figs. 4.1a and 4.2a). An instrument may be disengaged from the robotic arm by pressing on the release levers on the instrument housing. Also, for instruments capable of delivering energy, the connections for monopolar and bipolar energy are located at the instrument housing. The shaft connects the instrument housing to the wrist and acts as the rotating arm (Figs. 4.1a and 4.2a). The wrist mimics the wrist of a human hand and provides the surgeon with additional dexterity (Figs. 4.1b and 4.2b). Lastly, the end effector provides the instrument its specific function and may be used to grasp, retract, and dissect tissue; hold suture needles; apply electrocautery; and deploy clips (Figs. 4.1b and 4.2b). On the instrument housing, there are a series of discs that connect to the wrist and end effector via cables that run through the shaft. These cables allow movements to be translated from the surgeon console to the instrument via an integrated pulley system. On instruments used for the da Vinci® S and Si, the series of discs are on the back side of the instrument housing (Fig. 4.1c); on instruments used for the da Vinci® Xi (Fig. 4.2c), the series of discs are on the bottom side of the instrument housing.

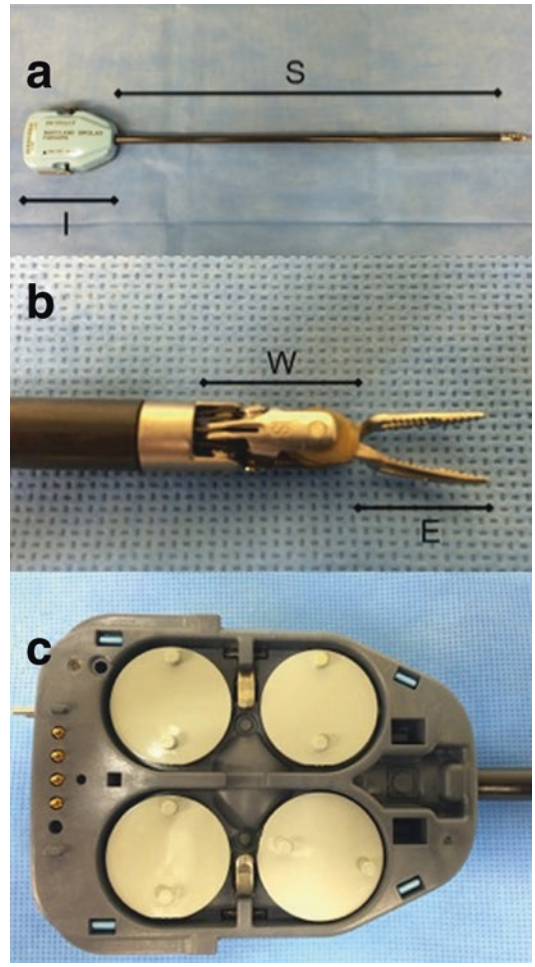

Fig. 4.1 Instrument for use in da Vinci® S and Si. (**a**) *I* instrument housing, *S* shaft. (**b**) *W* wrist, *E* end effector. (**c**) Discs on back of instrument housing that transmit motions to wrist and end effectors via cables that run through the shaft

Types of Instrument Malfunctions

There are two major types of instrument malfunctions: mechanical and electrical. A mechanical malfunction refers to a physical defect in a robotic instrument that compromises normal range of motion and/or function. Although there is a wide range of possible mechanical malfunctions, they all generally inhibit the surgeon's ability to complete an operation. For example, they may lead to an increase in operating room time as the surgical team attempts to evaluate and manage the malfunction, an increase in the cost of surgery as these malfunctions generally require that the robotic instrument be replaced, and an increase in the risk for surgical complications.

The most commonly reported sites of mechanical malfunctions are the instrument wrist and end effector. In a retrospective review of all reported robotic instrument malfunctions in the United States Food and Drug Administration (US FDA) Manufacturer and User Facility Device Experience (MAUDE) database between January 2009 and December 2010, Friedman et al. found that 285/565 (50.4%) of all reports were mechanical

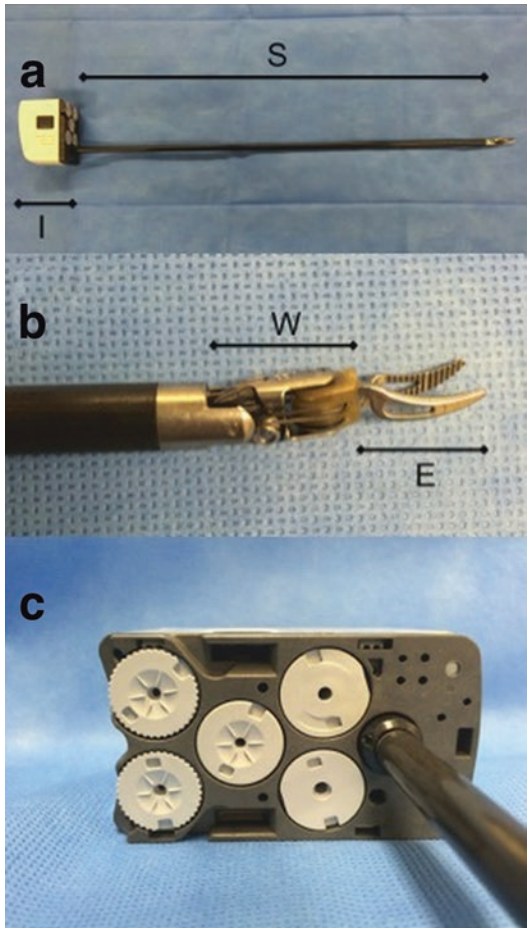

Fig. 4.2 Instrument for use in da Vinci® Xi. (**a**) *I* instrument housing, *S* shaft. (**b**) *W* wrist, *E* end effector. (**c**) Discs on bottom of instrument housing that transmit motions to wrist and end effectors via cables that run through the shaft

malfunctions at the wrist or end effector [3]. Instrument defects at the wrist generally decrease range of motion, while those at the end effector generally decrease the specific functionality of the instrument; instrument defects at both sites inhibit the surgeon's ability to operate.

Instruments with articulating jaws, such as needle drivers, grasping retractors, and scissors, are inherently more prone to end effect malfunctions, and they may present in a variety of different ways. In a case report by Park et al., the joint bolt of a ProGrasp™ (Intuitive Surgical, Inc., Sunnyvale, California, USA) forceps became loose which decreased the ability of the instrument to grasp tissue during robotic radical prostatectomy. As the loosened bolt also prevented the ProGrasp™ forceps from being removed through the robotic trocar, the ProGrasp™ was removed with the robotic trocar en bloc. A second bedside assistant assisted with the remainder of the case in place of the ProGrasp™ forceps, and the surgical team was able to complete the procedure with no complications [6]. Also, bending of the end effectors may result in misalignment of the articulating jaws, decreasing their functionality. This may result from instrument mishandling during sterile processing, improper storage, and aggressive intraoperative use. Although reports regarding bending of the end effectors are limited, we frequently encounter this at our institution. Furthermore, there may be instances when a piece of an end effector breaks off into the operative field (Fig. 4.3a, b). Instrument fragmentation requires that the surgeon look for the broken piece and extract it from the patient's body. In another case report by Park et al., one of the jaws of a needle driver broke off into the surgical field during robotic radical prostatectomy. The surgeons were able to find the broken jaw of the needle driver and extract it from the patient using a laparoscopic grasping forceps [7].

Mechanical malfunctions also occur at the shaft. In the aforementioned study by Friedman et al., the authors found that shaft malfunctions accounted for 76/565 (13.5%) of all reported instrument malfunctions [3]. Instrument shaft defects may be caused by instrument collisions with robotic ports/cannulas and arms. While collisions with robotic ports/cannulas generally cause trauma along the vertical axis of the shaft, collisions with robotic arms generally cause trauma along the perpendicular axis of the shaft. These collisions may cause peeling, bending, cracking, or breaking of the instrument shaft [2, 3].

Furthermore, mechanical malfunctions may occur at the cables that run from the instrument housing to the wrist and end effectors. In the aforementioned study by Friedman et al., the authors found that cable malfunctions accounted for 29/565 (5.1%) of all reported instrument malfunctions. Although the cables most commonly malfunction at the instrument wrist and end effector, the cables may malfunction at any point along their length (Fig. 4.4) [3]. Movement of an

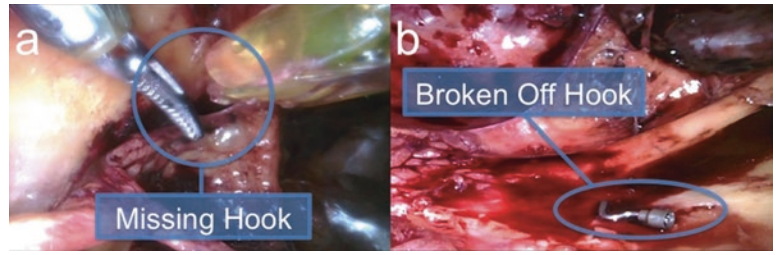

Fig. 4.3 (**a**) *Circle* highlights missing end effector on permanent cautery hook. (**b**) *Oval* highlights missing end effector of permanent cautery hook found on retroperitoneal fat

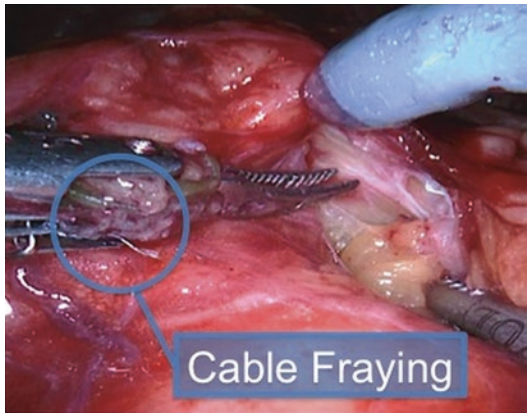

Fig. 4.4 *Circle* highlights cable fraying on Maryland bipolar forceps wrist at two locations

instrument beyond its normal range of motion or applying excessive force on the robotic instrument may cause the cables to fray, break, or become displaced from their pulleys [8]. Cable malfunctions inhibit the transmission of desired movements to the instrument.

An electrical malfunction primarily refers to arcing, when an electrical current deviates from its intended course due to an insulation defect. In the aforementioned study by Friedman et al., the authors found that arcing incidents accounted for 156/565 (27.6%) of all reported instrument malfunctions [3]. Although arching may occur with the use of any instrument that utilizes electrocautery, it primarily occurs with the use of monopolar curved scissors. Arcing is particularly problematic as it may cause unintended tissue damage. Stray electrical currents can reach temperatures between 700 and 1000 °C and cause thermal tissue injury [9]. Hollow organs, such as bowel, ureter, and blood vessels, are particularly susceptible to electrical injury as a single spark can cause an immediate or delayed perforation. Arcing may occur due to an insulation defect at the shaft [9] or at the tip cover accessory (TCA) [10, 11]. A TCA is an insulating sleeve that is applied to cover the metallic joint of monopolar curved scissors to allow electrical energy to be transmitted exclusively from the working tips of the shears to the surgical site of interest.

Mendez-Probst et al. studied instrument insulation defects by performing an in vitro study evaluating 37 robotic instruments that had reached the end of their life cycle. After confirming that all instruments did not have any visible insulation defects, the instruments were tested with monopolar current for the presence of stray electrical currents. All 37/37 (100.0%) instruments leaked electrical energy at the end of their life cycle [9]. These results suggest that microscopic insulation defects may cause electrical malfunctions. This is consistent with reports in the traditional laparoscopic literature that have suggested that visually screening instruments to predict insulation failure is limited [12, 13] and is associated with only 10% sensitivity [13].

In a case report by Lorenzo et al., arcing from TCA failure led to perforations of the right obturator and external iliac veins during robotic radical prostatectomy. Bleeding from the right obturator and external iliac veins was controlled by applying bipolar coagulation and placing a 5-mm metallic clip, respectively. Postoperatively, the authors noted two 1 mm holes on the TCA [10]. In a report by Mues et al., arcing from TCA failure occurred in 12/454 (2.6%) robotic surgeries, and 3/12 (25.0%) of arcing incidents caused significant patient injuries. Iatrogenic arcing injuries included damage to the external iliac vein, small bowel, and ureter. All patients required intraoperative repair [11].

Prevention

Preventing mechanical malfunctions involves the identification of defective instruments prior to the start of an operation and taking measures to minimize the chances of an instrument malfunction. In the preoperative setting, the surgical team should carefully inspect all instruments for broken, cracked, or worn components. Damaged instruments should not be used and should be replaced prior to the start of the procedure. Having a dedicated robotic surgical team that is trained in proper instrument handling and knowledgeable about normal instrument function may assist in the preoperative identification of instrument malfunctions [14].

Intraoperatively, it is important to keep the wrists straight when engaging and disengaging an instrument through a robotic port/cannula to prevent damage. When engaging an instrument, the bedside assistant should straighten the instrument wrists by rotating the discs on the instrument housing, rather than manipulating the wrist directly. When disengaging an instrument, the surgeon should straighten the instrument wrists using the master controls. During robotic port placement, it is important to ensure adequate spacing between ports to minimize instrument collisions. Generally, a distance of at least 8–10 cm for the da Vinci® S and Si and at least 6 cm for the da Vinci® Xi should be maintained between each port. The reason for this is because collisions between instruments, which can occur both intra-corporeally and extracorporeally, may cause physical defects.

With regard to the prevention of electrical malfunctions, the importance of proper intraoperative handling of the TCA cannot be overemphasized. Prior to the use of monopolar curved scissors, TCAs should be carefully applied using the prepackaged tip cover applicator in accordance with manufacturer specifications. The insulating TCA should cover the distal end of the instrument shaft and the entirety of the instrument wrist, leaving only the shears non-insulated. Also, similar to the prevention of mechanical malfunctions, measures should be taken to avoid physical damage to TCAs and instrument shafts. Surgeons and bedside assistants should ensure that the instrument wrists are straight prior to engaging and disengaging robotic instruments and appropriately position robotic ports to minimize intra-corporeal instrument collisions [11]. The reason for this is because defects in the TCAs and instrument shafts will compromise their insulating capacities and cause arcing.

Also, TCA failures may occur when the electrocautery settings are above the insulating capacity of the tip covers. Intuitive Surgical recommends keeping the power settings below 3kV. However, electrical malfunctions may still occur while adhering to these recommended power settings. In the previously mentioned report by Mues et al. that detailed 12 TCA failures, all 12/12 (100.0%) failures occurred while using the manufacturer recommended power settings [11]. As such, when using electrocautery, it is important to use the lowest power setting possible for the shortest amount of time necessary to achieve the desired effect.

Risk Factors

Several risk factors are associated with instrument malfunctions. With regard to mechanical malfunctions, instruments with jaws may be at greater risk for malfunction compared to those without jaws. During surgery, these articulating jaws are used to exert considerable forces. However, given the lack of tactile sensation and force feedback during robotic surgery, the surgeon may inadvertently apply excessive force onto the jaws causing them to break [7]. In a report by Kim et al., in which all robotic instrument malfunctions that occurred during surgeries performed by 6 departments at a single institution from July 2005 to December 2008 were retrospectively reviewed, 16/19 (84.2%) instrument malfunctions occurred in instruments with jaws [2].

Also, reusing instruments increases their cumulative "wear and tear," which may increase the likelihood of mechanical malfunctions. As part of a quality control measure to minimize instrument breakdown with repetitive use, Intuitive Surgical preprograms all instruments to a limited number

of uses. Despite this, there is a paucity of literature evaluating the relationship between instrument reuse and the incidence of mechanical malfunctions. In the previously mentioned case report by Park et al., in which the joint bolt of a ProGrasp™ forceps became loose and decreased the grasping ability of the instrument during a robotic radical prostatectomy, the instrument had been used in three prior robotic radical prostatectomies [6]. Further evaluation is needed to clarify the effect of increasing instrument reuse on mechanical malfunctions.

Additionally, advancements in robotic surgical systems have been suggested to decrease the frequency of instrument pieces breaking off. Lucas et al. reviewed instrument malfunctions in the MAUDE database from 2003 to 2009 to determine whether increased robotic experience or technological improvements improved the frequency of reported instrument fragmentation complications. The year in which surgery was performed was used as a surrogate for robotic experience; and the da Vinci® S compared to the da Vinci was used as a surrogate for technological improvement. Instrument fragmentation decreased by 50% when comparing reported instrument fragmentation incidents from 2003–2006 to 2007–2009. As the frequency of fragmentation observed with the da Vinci® was two times greater than that observed for the da Vinci® S, the difference was mostly accounted for by the specific robotic system utilized [5].

Similar to mechanical malfunctions, instruments that have been reused may be more susceptible to electrical malfunctions. In the aforementioned in vitro study by Mendez-Probst et al., all 37/37 (100.0%) robotic instruments that had reached the end of their life cycle demonstrated leaking of electrical energy at the instrument shaft. However, because the testing only involved instruments that had reached the end of their life cycle, the authors were unable to determine at which specific point the insulation damage occurred. Nevertheless, the findings of this study suggest that insulation damage may occur with repetitive intraoperative uses and that instruments should not be used after they have reached the end of their life cycle [9]. Also, prolonged intraoperative use of monopolar curved scissors may cause physical defects in TCAs, which may cause arcing. In the aforementioned report by Mues et al. in which 12 TCA failures occurred in 454 robotic surgeries, all TCA failures occurred after at least 2 h of intraoperative use. The majority of defects occurred at the junction of the silicone portion and the gray plastic shaft. This finding prompted the authors to begin routinely changing TCAs after every 2 h of surgery [11].

Also, increased robotic experience has been suggested to decrease the frequency of arcing. In the aforementioned report by Lucas et al., the authors used the MAUDE database to determine whether increased robotic experience or technological improvements improved the frequency of reported arcing complications. Arcing was found to have decreased by 67% when comparing reported arcing incidents from 2003–2006 to 2007–2009. Although arcing was three times more frequent with the da Vinci® compared to the da Vinci® S, this difference was mostly accounted for by year of procedure [5].

Additionally, first-generation TCAs have been shown to be more susceptible to electrical malfunctions compared to second-generation TCAs. Intuitive Surgical released the second-generation TCA in July 2012. In a report by Engebretsen et al., 36 first-generation TCAs and 40 second-generation TCAs that had been previously used in a single urologic or gynecologic surgery were inspected for insulation defects. TCAs were examined under light microscopy for visual insulation defects and evaluated for arcing in ex vivo porcine kidney models for functional insulation defects. Visual insulation defects ranging in size from 0.5 to 2.75 mm were noted in 14/36 (39%) first-generation TCAs, while only superficial scratches were noted in 10/40 (25%) of second-generation TCAs. While arcing occurred in 12/36 (25%) first-generation TCAs, arcing did not occur in any 0/40 (0%) of the second-generation TCAs ($p < 0.001$). Furthermore, the authors found that arcing occurred more frequently with increased instrument wrist angulation ($p = 0.014$) and that higher power settings led to shorter time to insulation failure ($p = 0.048$) [15]. Although no arcing was demonstrated in second-generation TCAs in this study, extreme angulation of robotic instrument

wrists and high power settings should still be avoided when using second-generation TCAs.

Diagnosis and Identification

Diagnosis

Instrument malfunctions may occur at any point during an operation, and maintaining vigilance for diagnosing instrument malfunctions is paramount. It is the responsibility of all members of the surgical team—surgeons, bedside assistants, nurses, technicians—to identify instrument malfunctions. Diagnosing instrument malfunctions as soon as they occur is critical in minimizing potential complications that may be harmful to the patient.

As previously mentioned, the most commonly identified instrument malfunctions involve the end effector [3]. However, it is unclear whether this because end effector defects occur more frequently than defects at other locations or because instrument malfunctions at the end effector are most readily noticed. As the end effector is the portion of the instrument that provides its specific function and the surgeon is generally looking at the end effectors for the majority of the procedure, malfunctions at the end effectors may be more easily noticed than those that occur at other portions of the instrument. For example, a fragmented jaw of a needle driver is more likely to be noticed than bending of the needle driver shaft. Despite this, as all instrument malfunctions have the potential to harm patients, the operative team should maintain a high index of suspicion for malfunctions at all portions of the instrument.

There are instances when instrument malfunctions may be difficult to diagnose, especially when they do not cause any major or immediate clinical consequences. For example, in the aforementioned study by Engebretsen et al. that evaluated first- and second-generation TCAs for insulation defects in ex vivo porcine kidney models, 12/36 (33.3%) first-generation TCAs demonstrated arcing on postoperative testing for insulation defects even though there were no intraoperative arcing incidents witnessed in any of the evaluated TCAs. The authors conjectured that this could have been because defects in TCAs may have been out of the field of view during surgery, especially the surface that faces away from the surgeon [15].

Malfunction Reporting

All diagnosed instrument malfunctions, regardless of clinical consequences, should be reported to the MAUDE database, a publically available collection of medical device-related adverse event reports. The US FDA maintains the MAUDE database and uses it as a post-market surveillance system to evaluate device performance and safety. Device-related adverse event reports may be submitted by mandatory reporters such as manufacturers, importers, and device user facilities and voluntary reporters such as healthcare professionals, patients, and consumers [16].

The importance of reporting instrument malfunctions to the MAUDE database is underlined by the fact that manufacturers and the US FDA regularly monitor the MAUDE database to identify and correct device-related safety issues at the user level. Furthermore, as the MAUDE database is large, well organized, and readily accessible, it is well suited for analysis in retrospective studies to investigate reported instrument malfunctions [3, 5]. Despite this, studies that are based on the MAUDE database should be interpreted with caution as the database has several limitations. Foremost, the MAUDE database is a passive surveillance system that inherently facilitates underreporting of robotic instrument malfunctions and requires that users be proactive in reporting [3, 5]. For example, in a report by Chandler et al., only 5/64 (8%) claims made to the Physician Insurers Association of America regarding laparoscopic entry access injuries were identified in the MAUDE database over the same time period [17]. Also, the prevalence of an event cannot be determined using the MAUDE database as the numerator (number of instrument malfunctions) and the denominator (total number of instrument uses) cannot be ascertained. Nevertheless, the MAUDE database provides valuable insight into real device malfunctions. Increasing the diligence

with which instrument malfunctions are reported will not only lead to more accurate and robust research studies, but it will also allow for improved identification and correction of instrument defects.

Treatment and Control

When an instrument malfunction is realized, the surgeon should immediately pause surgery to address and resolve the instrument malfunction prior to progressing with the remainder of the operation. Promptly addressing instrument malfunctions is critical in minimizing potential intraoperative complications and ensuring that the remainder of the procedure may be safely performed. The treatment of instrument malfunctions involves two parts: first, correcting the specific instrument defect, and, second, treating the clinical consequences of the instrument defect.

With regard to mechanical malfunctions, any physical defect that compromises instrument function requires that the instrument be replaced. In the aforementioned retrospective review by Kim et al. in which 19 instrument malfunctions occurred in 1797 robotic cases, all instrument malfunctions were solved intraoperatively by replacing the instruments. After replacing the malfunctioning instruments, all operations were successfully completed [2]. Regardless of how minor the mechanical instrument malfunction may seem, the surgeon should promptly remove all instruments demonstrating mechanical malfunctions from use. The reason for this is because using a defective instrument may cause the instrument to further deteriorate and forces the surgeon to operate under suboptimal conditions. Also, attempts at manually repairing the instrument should not be pursued. As such, it is imperative that the surgeon ensures that a backup set of robotic instruments is available prior to the start of any robotic procedure in case of a mechanical malfunction.

When mechanical malfunctions are promptly diagnosed and managed, they are self-limited and do not cause clinically significant complications in most cases. However, one potentially disastrous complication resulting from a mechanical malfunction is when a piece of the instrument breaks off into the surgical field. In such cases, it is imperative that the surgeon immediately stop surgery to look for the broken piece to remove it from the patient's body as further manipulation may inadvertently push the broken piece deeper into the surgical field [18]. In most cases, a broken piece may be easily identified and retrieved with graspers [7]. If the broken piece is not readily found, fluoroscopy may be used to assist with localization. Taking fluoroscopic images in both the anterior-posterior and lateral planes is useful in pinpointing the broken piece. If the surgeon is unable to find the broken piece despite the use of fluoroscopic imaging or the use of fluoroscopy is unavailable, the surgeon must consider converting to an open procedure.

With regard to electrical malfunctions, it is important to differentiate between insulation defects at the TCA and those at the instrument itself. In cases of TCA insulation failure, the defective TCA should be replaced with a new TCA, while in cases of instrument insulation failure, the instrument should be replaced. At times, it may be unclear where the arc originated from, making localization of the insulation defect difficult to determine. In such cases, the instrument should be disengaged from the robotic arm and the instrument, and the TCA should be carefully inspected for any macroscopic insulation defects. If no visible defects are identified, the instrument and TCA should both be replaced. It is important to note that microscopic defects may be the most hazardous as the energy that is leaked has a high current density [12].

Although prompt diagnosis and management of an electrical malfunction are essential in limiting further complications, all electrical burn injuries caused by the initial arc must be fully evaluated and treated. The nature and severity of an injury caused by an electrical malfunction are variable and dependent on a multitude of factors: location and size of the insulation defect, specific power settings, and proximity to surrounding structures. Discussing the wide range of potential complications resulting from an electrical malfunction and management of each is beyond the scope of this chapter. However, when evaluating and managing arcing complications, it is important to consider

that electrical burn injuries may occur beyond the area of actual contact and the full extent of a thermal injury may take days to weeks to fully manifest [9, 19]. This occurs when thermal energy damages vascular supply beyond the area of contact, which causes delayed necrosis [19].

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Complications Associated with the Use of Clips

5

Matthew Bream and Lee Ponsky

Introduction

With the widespread adoption of minimally invasive surgery that has occurred over the past couple decades, surgical clips have become a valuable tool in the hands of the laparoscopic surgeon. Knowing how they are used properly and having a solid understanding of common pitfalls can be helpful in anticipating and avoiding complications.

General Considerations: Surgical Clips in Urologic Surgery

Surgical clips are frequently used in minimally invasive urologic surgery. They may be used for control of bleeding and prior to ligation of minor and major blood vessels and other anatomic structures. While the cumbersome nature of laparoscopic suturing and knot-tying increased the applications for surgical clips, they are still used frequently in robotic surgery where suturing and knot-tying are less challenging. Other techniques for vessel ligation with overlapping applications include suture ligation, stapling, and instruments that use electrical, ultrasonic, or other energy sources such as the LigaSure®, Harmonic Scalpel®, Gyrus®, and others.

The two general categories of clips are non-locking and locking. Both are nondegradable and the former are made of metal while the latter are made of nonmetallic polymers. The Weck Hem-o-lok® (Teleflex, Research Park Triangle, NC) is a nondegradable locking clip for use on tissue and suture. Another locking clip, the LAPRA-TY® clip (Ethicon, Cincinnati, OH) is absorbable and is used only on suture where it provides a secure anchor for the suture that eliminates the need for tying. Non-locking clips are V-shaped, and when the two arms are compressed, they maintain their closed configuration due to the inherent properties of the metal. Locking clips are also V-shaped prior to application, and when compressed they maintain their closed configuration via a latching mechanism of the two arms. A distinct click can be felt or heard as the arms lock into place properly. Clips used in robotic surgery are most commonly applied using laparoscopic instruments via the assistant port; however a robotic locking clip applier is also available. Non-locking clips may be removed by pulling on the vertex of the closed clip, whereas locking clips must either be cut or a special instrument used to unlock them atraumatically.

Clips, both locking and non-locking, are used on structures of varying size and type. In urologic

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surgery they are commonly used for control of the renal artery and vein, as well as smaller vascular structures or tissue where the use of electrocautery should be minimized such as during nerve-sparing radical prostatectomy. Placements on nonvascular structures such as the ureter or vas deferens are also common applications.

An additional use of surgical clips is for placement on sutures to anchor closures without the need for knot-tying. LAPRA-TY® clips or Hem-o-lok® clips may both be used for this purpose, but if using Hem-o-lok® clips, the suture should be placed in the middle of the clip rather than at either of the edges for a better grip on the suture. A common application of this sliding-clip technique is for the renorrhaphy during a laparoscopic or robotic partial nephrectomy [1]. With this technique one or more clips are placed on the suture after it is passed through the tissue and are then slid down until flush with the tissue to maintain the tension on the closure.

General Considerations: Complications

Complications associated with the use of clips are generally apparent at the time of ligation but also may become known in the postoperative period. Clips may provide inadequate vascular occlusion or become displaced from the ligated vessel leading to hemorrhage. Locking clips in theory may become unlocked and displaced from the compressed structure; however well-documented clinical occurrences of clips becoming unlocked are lacking. Clips may also be placed on an unintended structure such as bowel or the ureter and lead to occlusion or ischemia if not removed in a timely manner.

Clip migration can occur in a delayed fashion and may be of no significance or occasionally become clinically apparent. In the urologic literature, clip migration with apparent clinical manifestations has been reported following laparoscopic and robotic radical prostatectomy. In these reports, clips were found intravesically associated with calculi and at the vesicourethral anastomosis associated with bladder neck contracture [2, 3]. In these instances where the clip is likely contributing to the clinical problem, it is advisable to remove it, either with endoscopic or open surgical techniques.

Special Consideration: Use of Hem-o-lok Clips for Donor Nephrectomy

One important consideration and the topic of much debate with the use of surgical clips is their use during living donor nephrectomy. Unique to donor nephrectomy is the goal of preserving as much arterial length as possible, thus leaving a shorter stump for application of ligating clips and the need to control tributary arteries or veins. Prompted by a published survey by the American College of Transplant Surgeons on complications during donor nephrectomy [4], in 2006 the Hem-o-lok® manufacturer issued a warning stating that use during donor nephrectomy was contraindicated. This survey identified 66 cases of arterial hemorrhage, of which 12 cases used locking clips on the renal artery. In comparison a stapler was used in 13, ties in 16, and non-locking clips in 13 of the hemorrhagic complications. The two deaths from arterial hemorrhage were secondary to failure of multiple non-locking clips. Later that year following the manufacturer contraindication, Meng published an analysis of the US Food and Drug Administration Manufacturer and User Facility Device Experience (MAUDE) database compiling information on the 27 reported cases of adverse events involving Hem-o-lok® clips [5]. Urologic laparoscopic surgery accounted for 13 of the cases, with 9 cases of renal arterial bleeding and 2 of these resulted in death. No clear etiology was identified for these occurrences; however in the cases with detailed information on the re-exploration, it was noted that clips were not present on the renal artery. In one case at autopsy, the question of a ruptured aneurysm proximal to the renal artery clip was raised but not definitively answered.

Several studies have reported safety with clip usage on the renal hilum specifically during donor nephrectomy and are highlighted here. Ponsky et al. reported on over 1600 laparoscopic

nephrectomies at 9 institutions using Hem-o-lok clips, including 486 donor nephrectomies, and reported zero instances of clip-related complications [6]. Ay et al. reported on 883 donor nephrectomies where Hem-o-lok clips were used on the hilum, with about half of patients having an additional Prolene transfixation suture placed between the ligating Hem-o-lok clips [7]. They also encountered no bleeding complications or problems with clip placements. Simforoosh et al. reported on over 1800 nephrectomies using clips on the hilum, with 962 being donor nephrectomies using 1 Hem-o-lok and 1 titanium clip on the renal artery and Hem-o-loks alone on the renal vein [8]. There were no cases of clip dislodgement or slippage during the operations, but there was one case of an aortic root aneurysm requiring reoperation. This was a case early in their institutional experience, and the authors felt that it may have been a result of placing the clip too close on the aorta and causing abrasion to the arterial wall. Baumert et al. included 66 donor nephrectomies in their report on a total 130 nephrectomies using only Hem-o-lok clips on the hilum and experienced no clip-related difficulties or bleeding complications [9]. Regardless of whether Hem-o-lok clips are used alone, or in combination with a titanium clip or suture ligature, these large studies support that they are a safe means for ligation of the renal hilum during donor nephrectomy.

Technique and Prevention of Complications

Several measures should be taken when using surgical clips to ensure their proper function and minimize the risks of complications. The authors agree that the vast majority of clip-related complications may be avoided with adherence to sound surgical techniques described below and summarized in Table 5.1 adapted from Ponsky et al. [6].

Proper surgical dissection of the structure to be ligated is paramount and is particularly important with larger arteries and veins. Entirely isolating the vascular structure from surrounding tissues (Fig. 5.1) ensures ligation only of the intended structure, allows for visualization of the tips of the clip during closure (Fig. 5.2), and allows the clip to maintain an occlusive position without slipping. A vascular stump below the most proximal clip should be maintained (Fig. 5.3) in case additional clips are needed in case of hemorrhage. The vessel should initially be partially cut rather than fully transected (Fig. 5.4) to confirm hemostasis. This allows better control of the vessel in case

Table 5.1 Principles of Hem-o-lok clip placement

1.	Complete circumferential dissection of the vessel (Fig. 5.1)
2.	Visualization of the tips of the clip around and beyond the vessel (Fig. 5.2)
3.	Confirmation of the tactile snap when the clip is engaged
4.	Maintenance of a visual stump below the most proximal clip for control or additional clips if needed (Fig. 5.3)
5.	No cross-clipping
6.	Handles squeezed only hard enough to snap closed (compared to metal clips which require tight squeezing
7.	Careful removal of the applier after placement of the clip (tips are sharp and could cause injury to adjacent structures)
8.	During transection of vessels, only a partial division is performed initially to confirm hemostasis from the closure prior to complete transection (Fig. 5.4)
9.	Minimum of two clips placed on the patient side, with an additional 1–2 mm cuff distal to the last clip (Fig. 5.4)

Modified from Ponsky et al. [6] with permission from Elsevier

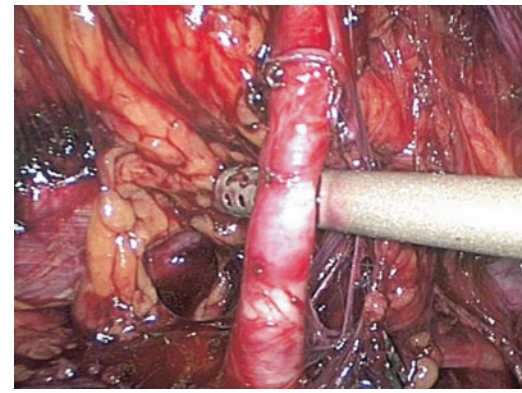

Fig. 5.1 Complete circumferential dissection of the vessel

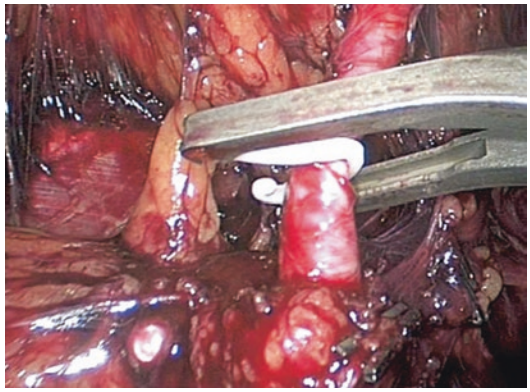

Fig. 5.2 Visualization of the tips of the clip around the vessel, unimpeded by additional tissue

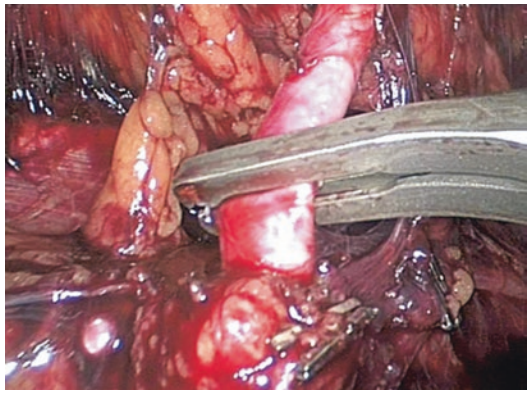

Fig. 5.3 Maintenance of a visual stump proximal to the most proximal clip

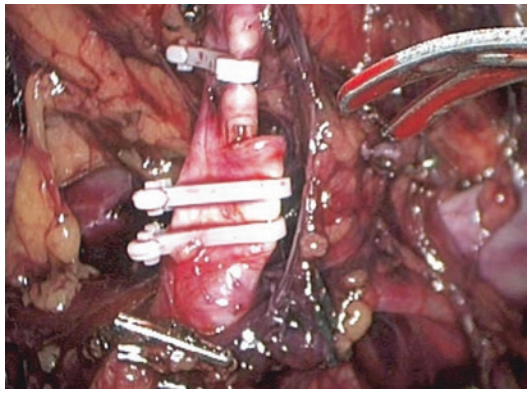

Fig. 5.4 Minimum of two clips on the patient side or stay side of the hilar vessel and with a 1–2 mm cuff of tissue beyond the distal clip in case of slippage. Partial division of the vessel to confirm hemostasis while still maintaining control of the vessel before it is completely transected

additional clips or other hemostatic measures are required. Clips placed over staple lines or other clips are likely to have problems closing and should be avoided. Similarly, calcified, atherosclerotic arteries are also more likely to prohibit proper closure and require a low threshold for the use of additional clips or the addition of a suture ligature.

Both locking and non-locking clips come in a variety of sizes, and an appropriately sized clip should be selected for ligation. If the tips of a locking clip are not completely around a vessel, whether by improper positioning or by using an undersized clip, it should be noted that the vessel will be pierced when the clip is locked into place. For this reason, a larger clip or a non-locking clip that is less likely to pierce the vessel wall should be selected.

For smaller vessels and less-defined structures such as the prostate vascular pedicles, it is helpful to create windows in the adventitial tissue so that the clips can properly lock and the connected tips can be directly visualized. Locking clips will still function if there is some tissue within the latching portion provided that it is not overly thick, and in this situation the tactile feedback from a proper clip closure is key.

Elliott et al. described how closures failed in laboratory studies at supraphysiologic pressures [10]. Non-locking clips tended to fail by leaking through the clip as though the intraluminal pressure was able to pry open the arms. Locking clips maintained a closed configuration; however with proximal ballooning of the vessel, the cut edge would retract behind the clip and result in a bursting failure. Although these failures were well above physiologic blood pressure (>900 mm Hg), this description of the mechanism of failure is helpful in considering prevention. Indeed, in clinical accounts of failures, locking clips were noted to be slipped off of the bleeding vessel but remained locked [11, 12].

In other laboratory studies, Jellison et al. showed that leaving a 1 mm cuff beyond the distal clip resulted in fewer failures than when the vessel was transected adjacent to the clip [13]. We and others advocate leaving at least a 1–2 mm cuff beyond the distal clip to prevent a

slipped clip from catastrophically falling off the vessel [12, 14].

In both Elliott's and Jellison's studies, using more than one clip performed better than a single clip only at supraphysiologic pressures which suggests the effectiveness of using a single clip in clinical use. However, by weighing the very minimal benefits of using a single clip against the potential for catastrophic failure, we and others advocate for leaving at least two clips on the patient side of larger vessels such as the renal artery and vein [4, 6, 8, 13].

Risk Factors

While lapses in the above techniques are the primary risk factor for clip-related complications, there may be anatomic variations that make their use and placement more difficult. Short vascular segments leave little room for clip placement and leaving cuffs and stumps. Large arteries or aneurysmal segments may be oversized for certain clips; however this shouldn't be an issue given the variety of available clip sizes. Hardened, calcified arteries may not be as amenable to using clips, and some authors advocate the use of a stapler in this scenario [15]. Similarly, fibrotic tissue such as with prior surgery or radiation may be more difficult for placing clips.

During minimally invasive surgery, difficult instrumentation angles and visualization may make precise clip placement difficult in some scenarios. Clips that are not placed perpendicular on the vessel or placed over other clips or staple lines may be less secure. While right-angle clip appliers are available for open surgery and can minimize this difficulty, they don't exist for endoscopic clip appliers due to the additional width of the instrument that would be required.

Controlling hypertension in the postoperative period can minimize the forceful arterial pulsations on a freshly ligated artery and reduce the risk of clip malfunction. Adequate pain control is a key component to preventing hypertensive episodes. Although the vast majority of clip failures in laboratory studies were seen well above physiologic pressures, providing adequate pain control and treating hypertensive episodes remain important clinical principles of post-operative care. [10, 13].

Identification and Treatment

As with most complications, a key component to minimizing the impact to the patient is prompt identification and treatment. Being able to anticipate how clip-related complications can occur is helpful in avoiding them altogether but also for their prompt recognition and safe management.

In the rare instance where a clip provides inadequate closure of the artery intraoperatively, there are some techniques to control the situation and avoid the rapid hemorrhage that could ensue. Once the clips are in place, the vessel should first be partially divided and only then completely transected once hemostasis is confirmed. This allows the surgeon to maintain traction on the artery in order to identify and control any source of bleeding. The most proximal clip on the renal artery or vein should not be placed at its initial takeoff due to the tapered nature of this portion. Leaving this small proximal stump allows the surgeon to grasp and temporarily control a hemorrhaging vessel, while also leaving a space to place additional clips or suture ligatures if needed.

Once major vessels have been taken with clips, there is often still a fair amount of maneuvering or surgical dissection in order to free up and extract the specimen. During these steps disturbing the ligated vessels and clips should be minimized. We advocate taking a "second look" at the vascular pedicles and surgical bed with the pneumoperitoneum down to 5 mmHg or less to ensure hemostasis and stable clip positioning prior to completion.

The removal of a clip may be necessary in a few situations such as after placement on an unintended structure or when a clip is in the path of a staple line. For non-locking clips the arms may be pried apart, whereas locking clips require some additional maneuvers. A laparoscopic clip remover is available from the manufacturer; however our experience is that not all operating rooms are equipped with this instrument. The clip remover requires the clip to be completely

situated within the jaws of the instrument before applying firm pressure to open it. When this is not feasible due to angulation, availability, or other difficulty, a harmonic scalpel may be used to safely dissolve one arm of the clip which will allow it to unlock and be removed without thermal damage to the surrounding tissue [16].

In the postoperative period, patients are monitored closely for any changes in vital signs, urine output, abdominal exam, and laboratory results. Delayed hemorrhage, when it occurs, may result in a precipitous decline in the patient's condition in the case of arterial bleeding or may be more gradual in the case of venous bleeding. Diagnostic studies such as conventional or CT angiography may be useful in stable patients where bleeding is equivocal, but in the actively bleeding or unstable patient, these studies will unnecessarily delay management and should be omitted. Prompt recognition and resuscitation, with return to the operating room for exploration, are crucial but unfortunately in some cases may not be sufficient to prevent ischemic complications or death.

Conclusion

Surgical clips are a valuable addition to the toolbox of the laparoscopic and robotic urologic surgeon. They provide an excellent and safe means of controlling large vessels such as the renal hilum as well as smaller vessels and tissue and have an established role as a substitute for more cumbersome suture or staple ligatures. Many of the complications related to clips may be avoided with adherence to sound surgical principles and correct techniques when applying the clips. Nevertheless, no method for ligation is fail-safe, and having an understanding of these complications is important for appropriate management.

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Complications Related to Linear Staplers

6

Gregory A. Joice and Mohammad E. Allaf

Abbreviations

DVC	Dorsal venous complex
FDA	Food and Drug Administration
GIA	Gastrointestinal anastomosis
IVC	Inferior vena cava
MAUDE	Manufacturer and User Facility Device Experience
MIBC	Muscle-invasive bladder cancer
RALRC	Robotic-assisted laparoscopic radical cystectomy
RALRN	Robotic-assisted laparoscopic radical nephrectomy
RALRP	Robotic-assisted laparoscopic radical prostatectomy
RRP	Radical retropubic prostatectomy

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General

The incidence of complications related to linear staplers is difficult to ascertain, as they may not be routinely reported and mechanisms to document them are not standardized. Additionally, minor complications that are easily salvaged are less likely to be reported, and thus the scope of complications from these devices is likely underestimated. Often the exact etiology of a complication related to a linear stapler is difficult to pinpoint and theoretically could be due to a flaw in the device itself, user error, or patient factors. Adding to the complexity in understanding these problems is the fact that stapling devices are manufactured by different companies and their technologies continue to evolve and are released to surgeons without clinical studies to document their relative efficacy, equivalence, or superiority. Among surgical stapler users, urologic robotic surgeons are unique in their common use of these devices to control large blood vessels where a device malfunction could lead to immediate disaster. This is in contrast to malfunction during open surgery or during operations not centered around the control of large blood vessels where salvage of a complication may be easier and the complication presentation may not be as acute or severe.

In terms of reported complications, stapler misfires associated with incomplete staple formation

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or the inability to safely release the tissue from the device jaws appear to be most commonly mentioned. The US Food and Drug Administration (FDA) maintains a Manufacturer and User Facility Device Experience (MAUDE) database that collects hundreds of thousands of reports related to deaths, injuries, and malfunctions associated with medical devices [1]. Several groups have studied malfunctions and injuries attributed to linear staplers.

Brown et al. [2] looked at all surgical stapler-related adverse events in the MAUDE database irrespective of surgery type or approach. In a 10-year period, they identified 112 deaths that were related to surgical staplers. The majority of the cases were in gastrointestinal surgery, and approximately half of the cases resulted from staples not forming or other device failure/malfunction at the time of firing. They also analyzed FDA recalls from 1983 to 2003 and showed that 22 staplers were recalled, several of which were due to manufacturing issues relating to incomplete staple formation. Deng et al. [3] reviewed an institutional database of 460 laparoscopic urologic cases and found the rate of stapler-related complications to be about 1%. All of these complications occurred during radical nephrectomy or nephroureterectomy. Among these cases, 60% required open conversion, and 40% resulted in significant blood loss and transfusion.

Although stapler malfunctions causing injury are a rare event, the majority of laparoscopic surgeons feel that they have experienced at least one malfunction, and one third of surgeons have experienced three or more [4]. It is important to note that not all stapler-related malfunctions are primary device failures and can be the result of improper use and technique. This may be particularly true in cases of multiple failures during the same operation or recurrent failures for specific operators. The following section will address appropriate technique to prevent device failure.

Nephrectomy

Due to the proximity of the renal vessels to the aorta and inferior vena cava (IVC), RALRN represents the highest-risk operation for linear stapling within robotic urologic surgery. Stapler malfunctions can quickly lead to uncontrolled bleeding putting patients at risk for open conversion, blood transfusion, or death if not quickly controlled.

Hsi et al. [5] analyzed the MAUDE database from 1992 to 2006 and identified 111 stapler-related malfunctions during radical nephrectomy. The most common complications were incomplete staple line formation (47%) and difficulty releasing from tissue (30%). Chan et al. [6] analyzed the stapler use in laparoscopic nephrectomy from 1993 to 1999 at two institutions and assessed malfunctions primary to the device (e.g., missing staples, ligation failure) compared to secondary preventable causes (e.g., deployment over surgical clip, poor positioning). This group found a malfunction rate of 1.7% out of 565 cases and showed that 70% of the malfunctions were preventable with proper technique. Proper stapling techniques include ensuring appropriate position of the staple jaws completely across the vessel to be ligated. In addition, it is important that no additional tissue be interposed between the device that could cause incomplete staple formation. Appropriate loading and reloading of the device is required for effective use, and any signs that the device may be loaded incorrectly should prompt investigation and testing prior to its use on tissue. It is important to note that surgical stapler placement across clips is a common cause of device failure in radical nephrectomy. When placing clips for control of non-hilar vessels, care should be taken to avoid placing clips near the hilum where the stapler will be deployed. In patients with heavily calcified vessels, the operator should avoid areas of heavy vascular calcification while stapling which can lead to unpredictable results. Adherence to these basic techniques can significantly decrease the rate of stapler-related complications. In a current review of the MAUDE database for the last 10 years, there were two deaths and six serious injuries reported to the FDA-related to stapler-related complications after laparoscopic nephrectomy. Both deaths and 4/6 injuries were related to stapler misfire where the full staple line did not fire or did not seal a portion of the artery or vein. The additional two injuries were related to the stapler

not releasing from tissue after firing. In these reports there was no way to assess for user error compared to primary device failure [1]. In general, stapling of the renal hilum is safe with a low complication rate, but when complications do occur, they are usually significant requiring quick action. If a stapling misfire is suspected, the jaws should not be released from the vessel and more proximal control should be obtained before removing the device. If this is unable to be performed safely robotically, then open conversion may be necessary to gain vascular control.

En bloc hilar stapling is advocated by some surgeons and institutions as a way to simplify the operation and decrease blood loss. Several studies have reported this technique to be safe and lead to decreased blood loss and operative time without an increase in immediate postoperative complications. Resorlu et al. [7] analyzed 60 patients who underwent laparoscopic radical nephrectomy and compared those who had separate ligation vs en bloc ligation with linear staplers. This group showed that both groups had similar blood loss and length of stay but that the en bloc stapling group had approximately 20 min shorter operative course. They further showed that there were no stapler-related complications in either of the groups and concluded that en bloc stapling is a safe technique. However, it is also important to note that by taking both the renal artery and vein with one staple line, there is a theoretical risk of increased arteriovenous (AV) fistula formation. A prospective randomized trial studied the presence of AV fistula after en bloc stapling vs separate ligation in 60 patients and showed that with 12 months follow-up, no patients had developed an AV fistula in either group [8]. These data suggest that en bloc stapling is a safe technique with comparable complications to individual ligation. However, longer-term follow-up may be needed to definitively rule out an increased risk in AV fistula.

Although staplers are the most standard method for hilar control in RALRN, vascular Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC) are also endorsed by some urologists, and it is important to discuss their related complications. Baumert et al. [9] described a technique where Hem-o-lok clips were used to ligate the renal artery and vein instead of an endovascular GIA stapler. In 130 cases, this group did not experience any complications related to bleeding or faulty clip placement. However, this was met with significant speculation as other groups have seen life-threatening complications. One case described clip dislodgement in the setting of a heavily calcified renal artery suggesting that clip placement was not safe in patients at high risk for significant atherosclerosis [10]. In addition, using large clips on small arteries can result in slippage and delayed bleeding from the renal hilum [10]. Finally, as previously discussed clip placement at or near the hilum may preclude safe stapler firing on the hilar vessels if needed. Ultimately, the FDA in 2006 released a report contraindicating the use of Hem-o-lok clips during laparoscopic donor nephrectomies due to the findings of 12 injuries and three deaths from 2001 to 2005 resulting from Hem-o-lok clips [11]. Due to the FDA's position, the authors do not advocate the use of these clips for renal hilar ligation. Finally, it is important to note that complications related to suture ligation of the renal hilum likely occur but are not well delineated in the modern literature.

Prostate

Traditionally in radical retropubic prostatectomy (RRP), the DVC is controlled using suture to provide hemostasis and is then divided. However, recently some urologists endorse using linear staplers as an alternative nonthermal mean to control the DVC particularly in robotic surgery. This technique was described in open RRP in 1996 and revealed that stapling of the DVC using an endovascular GIA was generally well tolerated with comparable blood loss and complications to suture ligation but with decreased operative time [12]. Since this description, several groups have compared linear stapler control of the DVC to traditional suture ligation. Muto et al. [13] showed that in open RRP, utilization of a linear stapler resulted in significantly decreased overall blood loss and fewer blood transfusions. However, they did show an increased rate of

anastomotic strictures in the stapling group. This finding suggests that the presence of metallic staples in proximity of the vesicourethral anastomosis may result in inflammation leading to increased stricture formation. However, this finding has not been validated in additional studies.

More recently, Nguyen et al. [14] compared suture ligation and stapler DVC control in laparoscopic prostatectomy and showed no difference in terms of EBL, operative time, and positive margin rate. Although they did not look at anastomotic stricture rate specifically, there was no significant difference between PSA recurrence, SHIM score, and continence rate. Wu et al. [15] specifically analyzed patients undergoing RALRP and showed that within a single institution, DVC control using a linear stapler was associated with faster operative times, decreased EBL, and lower apical positive surgical margin rates. Similarly, this group did not assess anastomotic stricture rate but did show similar rates of PSA recurrence, continence, and SHIM status.

Overall, the use of linear staplers for DVC control is a safe and effective method in RALRP. Recent studies suggest that it may be associated with decreased EBL and operative times and potentially a lower positive surgical margin rate. There is some evidence that the presence of staples near the anastomosis may lead to an increased stricture rate; however, this has not been validated in recent studies. Thus, it is critical to end the staple line short of the urethra to avoid staple erosion into the anastomosis or bladder and minimize inflammation. It is important to note that general stapler-related complications including misfires, incomplete staple formation, and inadequate stapler release can occur when controlling the DVC. However, this is less significant than in renal hilar control as additional bleeding is generally mild to moderate and can be controlled safely with additional suture ligation or pressure.

Bladder

In muscle-invasive bladder cancer (MIBC), RALRC has become an increasingly popular option among urologists. Most commonly this is associated with open urinary diversion; however, more institutions are beginning to perform intracorporeal urinary diversions. Linear staplers are utilized both in the extirpative portion of the operation for control of the vascular pedicles and during the reconstructive portion to perform the bowel resection and anastomosis.

Chang et al. [16] in 2003 compared 70 patients who had undergone radical cystectomy with either the use of linear staplers or traditional suture ligation for vascular pedicle control. Within the stapler group, there was decreased blood loss and fewer transfusions compared to suture ligation. Importantly, they did not experience any complications directly related to the use of a linear stapler and determined it safe to use for vascular pedicle control in radical cystectomy. This group later compared the linear stapler to the more modern Impact LigaSure (Covidien Surgical, Boulder, CO) device and showed no difference in blood loss or transfusion rate but did show significantly decreased cost with the LigaSure device without any complications attributable to either device [17]. These studies highlight that the use of a linear stapler for vascular control during radical cystectomy is generally well tolerated and provides excellent hemostasis. However, in these small series, although they do not reveal any stapler-specific complications, larger series would be needed to assess for rare mechanical failures.

In addition to vascular control, in RALRC the linear stapler is also utilized for bowel resection and anastomosis in intracorporeal urinary diversion. Although robotic cystectomy with intracorporeal diversion is still a relatively new technique, there have been several studies analyzing associated outcomes. It is well known that in general surgery, bowel anastomotic leak can occur at the staple line when performing stapled bowel anastomosis and lead to significant morbidity and mortality frequently requiring reoperation [18]. In a prospective study of 70 patients undergoing radical cystectomy with intracorporeal neobladder creation, approximately 6% of patients developed postoperative ileus, but there were no reported cases of bowel leakage from the stapled anastomosis [19]. A similar study analyzing 100 robotic-assisted intracorporeal ileal conduits showed a 22% rate of overall bowel complications

and specifically revealed one bowel fistula requiring reoperation [20]. These studies suggest that overall there is a low rate of bowel anastomotic leak for intracorporeal urinary diversion but that when it occurs it results in significant morbidity. Additionally, as this technique becomes more prevalent, larger studies are needed to clarify the overall rate of staple line leakage in comparison to open surgery.

Unique to urinary diversion, nonabsorbable foreign objects near the bladder or neobladder can predispose to stone formation. Shao et al. [21] studied patients undergoing intracorporeal ileal neobladder formation and compared those with a stapled reconstruction to those with traditional suturing. This study revealed a decreased operative time in the stapling group but with a 9% rate of stone formation from penetrated staples that required removal with cystoscopy.

Overall, the use of linear staplers in robotic radical cystectomy is well tolerated with a low risk of anastomotic leak at the stapled intestinal anastomosis. However, it is important to note the unique complication of stone formation when nonabsorbable staples penetrate into the lumen of the urinary diversion. These stones can be treated readily with cystoscopic removal of the stone and penetrated staple.

Additional Considerations

Robotic surgery is unique in that the main operator is not scrubbed at the bedside. It is important for robotic teams to be thoroughly educated on the use of surgical staplers. Critical to this effort are simulating situations where a stapler complication occurs and reviewing each team member's role. For example, should a stapler malfunction while ligating the renal artery, there is little time for everyone to react. Even when prepared for this scenario, the outcome may be poor, but preparation should hopefully minimize the adverse sequelae.

Depending on the case performed, having a surgical sponge ready to apply pressure in case of a bleeding vein or having a "rescue" vascular suture available are generally advised in case of complications. The robotic surgeon could apply pressure with the robotic arms on a bleeding staple line, but in order to further work safely or for controlled open conversion, the assistant must be able to replicate that pressure—this scenario is unique to robotic surgery, and thus preparation and prevention are both extremely important.

Conclusions

The use of linear staples has become commonplace in robotic urologic surgery for vascular control during major extirpative operations. Generally, linear staplers function well without issues and provide excellent hemostasis. However, there are several specific complications related to stapler malfunction that can lead to significant morbidity. Although the exact rate of stapler malfunctions is not clear due to variable reporting practices, most minimally invasive surgeons have experienced at least one complication attributable to a linear stapler. Across all operations, staplers can misfire leading to incomplete staple formation resulting in bleeding which can vary from mild to severe. In addition, staplers can fire appropriately but not release leading to a challenging situation where the stapler can remain stuck on important vascular structures.

Stapler malfunctions are most significant in radical nephrectomy where misfires or inadequate staple line formation when controlling the hilum can lead to significant blood loss and conversion to open surgery. Techniques to prevent malfunctions include ensuring that the additional tissue is not caught within the stapler and to reduce the number of clips near the hilum that can prevent appropriate staple line formation. If a staple misfire is suspected or the device becomes stuck on an important structure, it is important to leave the device closed if possible and obtain proximal control prior to attempted removal. In radical prostatectomy, staplers have become more common in DVC control but are prone to similar complications related to device malfunction. However, these complications are generally less serious as DVC control can be regained with additional suturing. Finally, robotic cystectomy is increasing in popularity, and linear staplers are utilized for intracorporeal diversion.

Early studies suggest a low rate of bowel anastomotic leakage but do show a low but significant prevalence of stone formation within the urinary diversion. Ultimately good judgment and knowledge on the use of surgical staplers is the key to minimizing complications and managing them with minimal morbidity.

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Complication Grading in Surgery

7

Roxane D. Staiger, Diana Vetter,
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Introduction

In the past postoperative mortality was the central outcome to assess postoperative outcome [1–3]. A continuous decrease of postoperative mortality was recorded over the past 30 years due to progress in indications for surgery, improvements in perioperative medicine, as well as considerable technical advances [4, 5]. Therefore, focus has now shifted toward nonlethal endpoints such as postoperative morbidity or quality of life [6, 7]. In parallel, various non-standardized definitions of morbidity and surgical complications have emerged [8, 9]. Subjective terms like "major," "moderate," or "minor complications" appeared in the medical literature. Their use was inconsistent and difficult to retract [10, 11]. Wide complication incidence ranges were reported, e.g., between 18% and 72% after Whipple's procedure [12–14]. Inconsistent reporting of postoperative morbidity made comparison between studies difficult. In addition, most studies failed to report the severity of the respective complications [15]. In 2002 less than 20% of the published reports on postoperative events provided specifics on the occurred complications [15]. Surgery-related morbidity was the focus of most authors. Minor complications, like a urinary tract infection or a paralytic ileus, may have been missed by many surgeons, potentially leading to an underreporting of complications [16, 17]. In some cultures, the disclosure of the occurrence of complications is considered as a failure of the corresponding surgeon. This "blame culture" may further lead to underreporting of unknown extent [18]. This problem was addressed by *Bruce* et al. in 2001. The authors investigated the quality of definitions, measurement, and reporting of postoperative complications in the surgical literature by selecting four commonly reported surgical adverse events: surgical wound infection, anastomotic leak, deep vein thrombosis, and surgical mortality [19]. The analysis showed significant inconsistencies in the quality of reporting [19]. For example, the definition "wound infection" was missing in most studies or differed greatly between them [19]. The descriptions given ranged from "presence of pus" to specific criteria to distinguish between the levels of surgical wound infections [19]. Similarly, a great variability in description of postoperative events was found in a large study including patients with esophagectomy, pancreatectomy, or hepatectomy [15]. Missing reproducibility by lack of definition of specific complications made conclusive comparison of surgical complications between institutions

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impossible. The inexistence of standardization of methodology to assess, report, and grade postoperative complications has decelerated quality and progress in outcome research [20].

To overcome these shortcomings, several research groups have developed different classification systems to allow a standardized severity grading of postoperative complications [1, 9, 21–25].

Grading of Postoperative Complications

The foundation of today's standard classification system goes back to 1992, with the introduction of a new definition of postoperative negative outcome by *Clavien* and *Strasberg* [21]. Three types of surgical adverse events were distinguished: (1) *complication*, an unexpected event not intrinsic to the procedure; (2) *sequel*, an event inherent to the procedure; and (3) *failure*, an event, where the purpose of the procedure was not fulfilled [21]. In addition, negative events were graded by severity [21] and based on the effect of the corresponding complication on the patient, e.g., prolonged hospital stay, disability or death [21].

The Clavien-Dindo Classification

A revision of this first complication classification system was published 12 years later in 2004 [26]. This new system, known as the "Clavien-Dindo classification", was now based on the treatment of the complication [26]. Five grades were defined analog the increasing danger to the patient's life [26].

A Grade 1 complication can be treated beside or with basic pharmaceuticals.

Grade 2 complications require more complex pharmaceuticals for treatment, such as antibiotics, blood transfusions or parenteral nutrition.

For a Grade III complication surgical or interventional treatment is needed for therapy.

Grade IV complications demand intensive care treatment for the patient or imply the occurrence of organ failure.

Finally, a Grade V complication implicates death of the patient [26] (Table 7.1).

Grades III and IV of this classification are further subdivided [26] (Table 7.1). Subjective criteria, e.g., length of hospital stay, were eliminated from the grading system [26]. Some clinicians criticized the clear underweighting of permanent disabilities [24]. A postoperative motoric paresis due to the positioning of the patient on the operating table, for instance, is classified as Grade I. Yet, unlike a transient wound infection (Grade I), the residual reduction of life quality can be severe. The authors addressed this shortage by adding the suffix "d" for persistent disability to incorporate the patients' perspective [26]. The intended simplicity of the Clavien-Dindo classification was tested and validated on a large cohort [26]; a follow-up study succeeded 5 years after its introduction in 2009 [27]. Additionally, a systematic review of the literature was combined with a survey, performed in seven international centers, where the grading

Table 7.1 The Clavien-Dindo classification

Grade	Definition
Grade I	Any deviation from normal postoperative course Including bedside treatment, urinary catheter, drainage of wound infections, physiotherapy Allowed drugs: antipyretics, analgesics, antiemetics, diuretics, electrolytes
Grade II	Pharmacological treatment required E.g. antibiotics, blood transfusion, parenteral nutrition
Grade III IIIa IIIb	Interventional treatment required Under local anesthesia Under general anesthesia
Grade IV IVa IVb	Life-threatening complications, ICU treatment Single organ failure Multiple organ failure
Grade V	Death
Suffix "d"	Complication still present at discharge

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system was used routinely. The results demonstrated a wide acceptance of the monitoring of surgical complications in different surgical fields [27]. This holds true for today [28–35].

The Accordion Severity Grading System

The Accordion Severity Grading System of surgical complications was introduced in 2009 [24]. Founded on the intent to have an adjustable complication grading system, the Accordion classification provides two versions, using self-explanatory terms rather than grades [24]. The levels range from mild, moderate, and severe complications to the fourth level: death [24]. This grading system, like the Clavien-Dindo classification, is based on the treatment of a complication: thereby, *mild* complications allow bedside treatment, whereas *moderate* events need more sophisticated medication (antibiotics, blood transfusions, parenteral nutrition), and *severe* complications include all interventions as well as organ failure [24]. The third level "severe complications" allows an accordion-like extension for more detailed complication grading. Three categories are offered: "invasive procedures without general anesthesia," "operation under general anesthesia," and "organ system failure" [24]. The practicability of the Accordion classification was tested on an international board of experts, and several modifications of the classification were implemented [36, 37]. In addition, the term "sequel of complications" was introduced to grade an advancement inherent to the complication, e.g., the progression of postoperative transient renal failure to chronic persistence, or the occurrence of pyelonephritis after a urinary tract infection [24]. In the attempt to improve this grading system, specifications were added at cost of its simplicity. Possibly due to this deficiency the Accordion Severity Grading System is not widely accepted to date. It is mainly used in Northern America [38, 39] in connection with The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP), a nationwide program in the United States that collects preoperative through 30 days postoperative data on randomly assigned patients [40, 41].

The Postoperative Morbidity Index

Based on the Accordion Severity Grading System, *Strasberg* et al. developed an index to quantify surgical complications: the Postoperative Morbidity Index (PMI) [42]. Therefore, complications of the ACS data collection of the NSQIP were graded by the Accordion classification. For each of the six expanded Accordion levels, a numerical weight for severity was calculated: Grade 1, 0.11; Grade 2, 0.26; Grade 3, 0.37; Grade 4, 0.60; Grade 5, 0.79; and Grade 6, 1.00 [42]. To calculate the PMI of one procedure (e.g., laparoscopic colectomy), the severity weights of all complications are summarized and divided by the total number of patients who underwent this procedure [42]. For this calculation only the highest rated complication of each patient is taken into account [42]. However, an external validation on urological procedures found the PMI was insufficient for individual risk adjustment [43]. By considering only the most severe complication, the PMI failed to provide accurate information on patients with more than one postoperative event [43]. So far, the PMI is not widely accepted and was only used for outcome measurements in a few studies outside the authors group [40, 44–46].

The Comprehensive Complication Index

To date the Clavien-Dindo classification is the most widely used and accepted postoperative complication assessment classification. Although it allows reporting of all complications, the tabular presentation of multiple complications makes outcome comparison difficult. Therefore, in most studies only the most severe complication is reported. This may lead to

underreproting and therfore underestimation of postoperative morbidity [16, 24, 26, 27]. In order to facilitate assessment of patients' overall postoperative morbidity, the Comprehensive Complication Index (CCI®) was developed [25]. This complication index is based on the Clavien-Dindo classification [25]. Thereby, every complication's severity is represented by a number and can be computed with the help of an online calculator, resulting in a number between 0 (no complication) and 100 (death of a patient) [25]. The formula for CCI® calculation was designed to consider any combination of complications including the ones of lower severity [25]. For its development, methods from operation-risk-index analysis in marketing research were adopted [47–49]. The authors performed an internal and external validation and showed a superiority of the CCI® over traditionally reported morbidity endpoints, e.g. the Clavien-Dindo classification, simply applicable solely for major complications [25, 50]. With its numeric character, this index easily allows inclusion of all complications for the assessment of the overall postoperative burden. In addition, the comparison of morbidity between clinics and studies is simplified. The CCI® is internationally increasingly used [51–54] to assess the overall postoperative morbidity since its introduction in 2013 [25].

Grading of Intraoperative Complications

The most commonly used complication classification systems do not consider intraoperative complications. Of 46 randomized controlled trials published in *JAMA Surgery*, *Annals of Surgery*, and BJS in 2010, 41% of the trials failed to report intraoperative complications [55]. To overcome this shortcoming, new grading systems focusing on intraoperative complications [56–59] were developed. Two of them are presented below.

Oslo Classification of Intraoperative Unfavorable Incidents

The Oslo classification of intraoperative unfavorable incidents is a simple classification with three grades [37]. *Grade 1* is defined as an error without consequences, *Grade II* represents a complication requiring immediate identification and correction, and a *Grade III* event results in significant consequences for the patient. The Oslo classification has been applied in a few studies to grade intraoperative adverse events, but has not been widely adopted so far. [60, 61].

Definition and Classification of Intraoperative Complications (CLASSIC)

The classification of intraoperative complications (CLASSIC) was presented in 2015 [59] (Table 7.2). Every event occurring between skin incision and closure is rated, regardless whether it was surgery or anesthesia related [59]. The CLASSIC grading system is organized in Grades 0–IV [59]. *Grade 0* implies the ideal intraoperative course. *Grade I* declares a deviation from the optimal course, yet without necessity of any treatment. A *Grade II* complication involves an intervention or treatment to correct the incident, but no lethal danger or permanent disability will

Table 7.2 Classification of intraoperative complications (CLASSIC)

Grade	Definition
Grad 0	No deviation from the ideal operative course
Grade I	Deviation without need for treatment or intervention
Grade II	Deviation without permanent disability or threat to life
Grade III	Deviation leading to permanent disability or threat to life
Grade IV	Intraoperative death

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result from it. In contrast *Grade III* events include complications that are potentially lethal or may lead to permanent disability. Ultimately, intraoperative death is classified as *Grade IV* [59]. There are many parallels in the structure of CLASSIC and the Clavien-Dindo classification. This simple classification of intraoperative complications has demonstrated practicability as well as a good inter-rater agreement [59]. CLASSIC was considered "a significant contribution to the surgical literature" [62] but its use is not yet ubiquitous.

Discussion

Uniform assessment and reporting of complications are essential for comparing postoperative complications and morbidity [15, 19]. This highlights the importance of complication classification systems, which should ideally be ubiquitary reproducible and consider every complication.

The Clavien-Dindo classification was the first postoperative complication grading system to be based on the treatment of complications and has experienced a widespread acceptance up to this day. Shortcomings of this classification system are the difficulty to compare patients with multiple complications due to its semi-numeric character. For example, the morbidity of a patient with a Grade IVb and a Grade II complication is difficult to compare to the morbidity of another patient with a IIIb and a IVa complication. The CCI® compensates this shortcoming, by allowing simple calculation of all complications, resulting in a number between 0 and 100. However, it lacks the reflection of what kind of complication a patient endured. For example, in a patient with a Grade IIIb complication, we know he required general anesthesia, whereas, in a patient with a CCI® of 39, it is unclear if this patient had a Grade IIIb or multiple lower-grade complications. Thus, the CCI® seems to be a good addition to the Clavien-Dindo classification, rather than a replacement. Intraoperative complications are not recorded in the Clavien-Dindo classification or the CCI®. Here, novel intraoperative complication classifications such as the CLASSIC seem to be promising.

The CCI® may also serve as a tool for benchmarking interventional outcomes [54]. The benchmarking concept, known from economic research, implies quality improvement by comparing with the best in class. Self-initiated comparison of postoperative outcome with the best – the benchmark – may reduce postoperative morbidity by reevaluation of attuned processes. In the future, public health decisions may be guided by benchmarks set on the basis of standardized outcome measurements. Financial coverage by health insurances, surgical licensure issued by governmental authorities, or a patient's choice of hospital may also be strongly influenced by them [54].

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Ethical and Medicolegal Considerations

8

Lindsay A. Hampson and Maxwell V. Meng

Introduction

Despite the fact that physicians seek to provide excellent clinical care for their patients, issues of medical malpractice may arise for even the most conscientious and well-trained physician. These situations can be challenging, particularly because of the fact that they are often emotionally charged and burdensome for physicians who are diligent in their clinical care and have the best interests of their patients in mind.

Unfortunately, physicians receive little training about the ethical and medicolegal aspects of medical care during their training, and it is often the event of a malpractice claim that will be their first introduction to the legal system. In this way, physicians are forced to learn about this process in the midst a stressful environment. This chapter seeks to inform urologists about the medical malpractice system in the United States, provide some information about the malpractice claim process, and educate urologists about ethical considerations that they should be knowledgeable about in their practice.

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Medical Malpractice

Overview of Medical Malpractice in the United States

The prevalence of medical errors in medicine was recently estimated to be the 3rd leading cause of death in the United States at 251,454 deaths per year, behind heart disease (614,348) and cancer (591,699) [1]. Given this high prevalence, it is not surprising that 7.4% of physicians will face a malpractice claim each year, with an estimated 1.6% of all physicians having a claim that leads to a payment [2]. In terms of physician specialty, neurosurgery faces the highest rates of annual claims at 19.1%, followed by thoracic-cardiovascular surgery (18.9%), and general surgery (15.3%), with urologists at about 11% annual risk of a claim (about 3% of urologists per year face a claim that results in a payment to a plaintiff). The cumulative malpractice risk over a physician's career is significant—80% of surgeons are estimated to face a malpractice claim by age 45, and this rises to 98% by age 65 (26% of surgeons are estimated to face a claim by age 45 with a rise to 63% by age 65).

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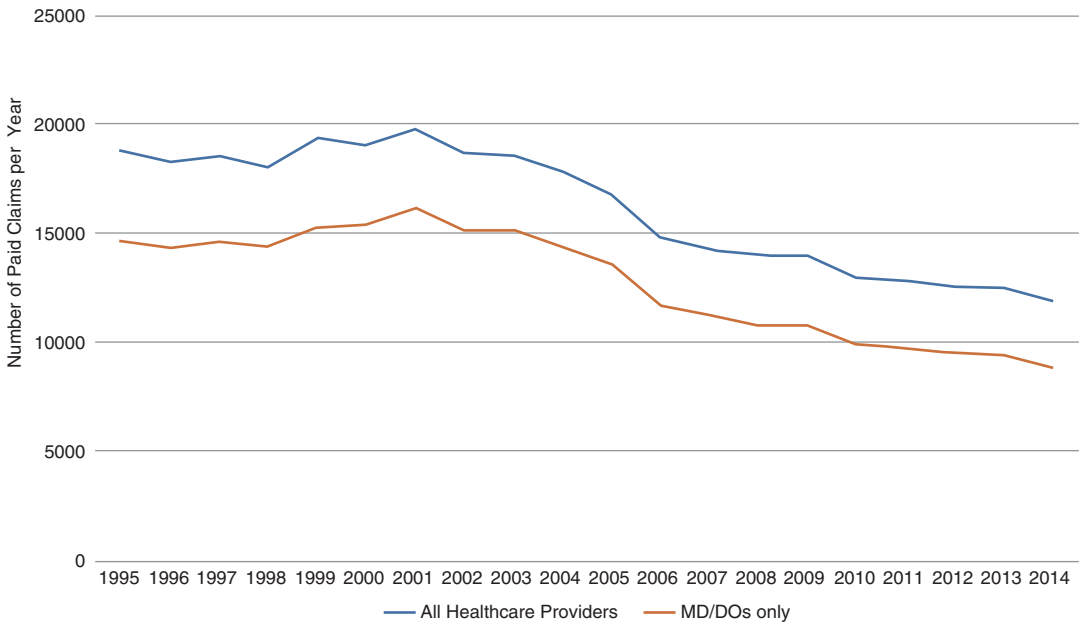

Fig. 8.1 Number of claims represents those paid and reported to the National Practitioner Data bank (Generated using the Data Analysis Tool at https://www.npdb.hrsa.gov/analysistool. Aug 23, 2016. Data source: National Practitioner Data Bank (2014): Adverse Action and Medical Malpractice Reports (1990–2014))

Using the most recent data from the National Provider Data Bank, there were 8875 reported paid malpractice claims for MD/DO's in the United States in 2014 [3]. This represents a decreasing trend in the number of paid claims over time since a peak in the early 2000s (Fig. 8.1). In terms of a breakdown by state, there were six states that represented about 50% of paid claims for physicians: New York (14.9%), California (9.7%), Florida (8.5%), Pennsylvania (7.2%), New Jersey (4.7%), and Texas (4.6%).

The vast majority of payments from these claims are less than $500,000, although it is notable that the proportion of small payments (less than $100,000) has decreased while the proportion of large payments (over $1,000,000) has remained relatively stable [3]. (Figure 8.2) Payments to plaintiffs do vary by physician specialty; the mean payment was $247,887 (median $111,749) across specialties and for urologists was estimated at just under $300,000 (median payment about $75,000) [2].

In 2014, total payout amount for malpractice suits in the United States was estimated at nearly $3.9 billion, which represented a rise for the second straight year since a nadir in 2012 [4]. Malpractice payments were fairly evenly distributed between inpatient (46%) and outpatient (40%) settings. The leading cause of payouts was diagnosis (33%), followed by surgery (24%), treatment (19%), and obstetrics (11%). Thirty percent of payouts were a result of patient death, whereas 18% represented a significant permanent injury, 17% a major permanent injury, and 13% represented an outcome of quadriplegia, brain damage, or requirement of lifelong care.

Frequency and Types of Malpractice Claims in Urology and Indemnity Payments

In a survey of urologists in the United States, the frequency of malpractice claims was found to be 0.09 claims per physician per year (one claim every 11 years), and this rate was not found to be affected by professional reputation [5]. In effect, the chances of a malpractice suit increase the

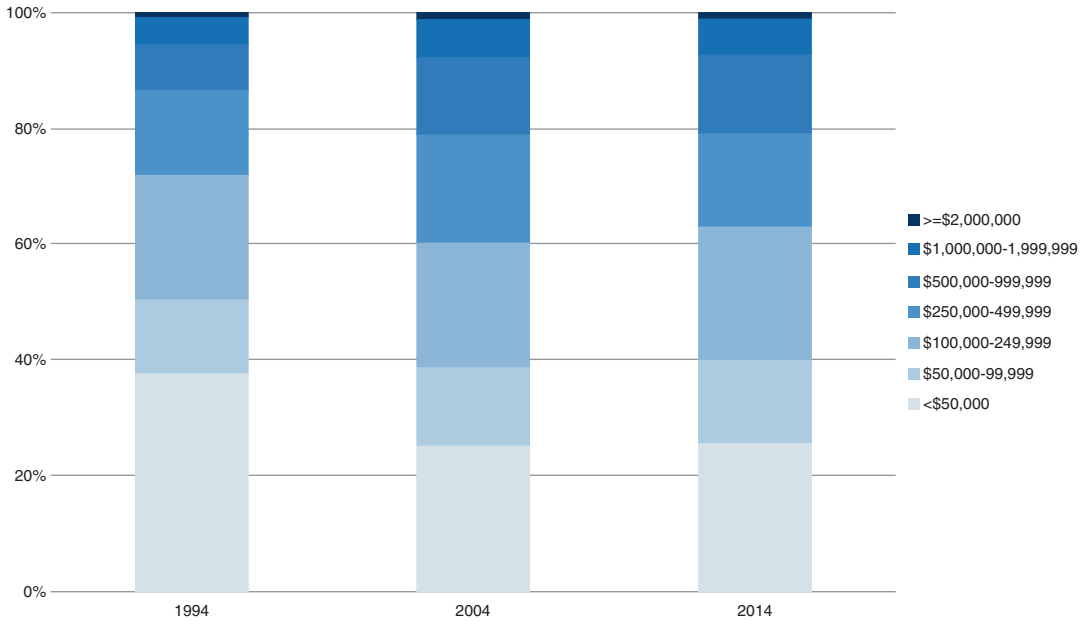

Fig. 8.2 Number of claims represents those paid and reported to the National Practitioner Data bank. Payment amount is inflation-adjusted (Generated using the Data Analysis Tool at https://www.npdb.hrsa.gov/analysistool. Aug 23, 2016. Data source: National Practitioner Data Bank (2014): Adverse Action and Medical Malpractice Reports (1990–2014))

longer one is in practice, and according to published data, most urologists can expect to be sued twice in their careers [5, 6].

Although older data showed that vasectomy and endourology generated the highest rate of malpractice claims, in multiple recent evaluations of urological claims, oncology (28%) and endourology (12%) have accounted for the majority of malpractice suits, with female urology (10%) following close behind [6, 7]. By 2012, the conditions most likely to result in a closed claim were prostate cancer and kidney cancer [8].

In an analysis of urology malpractice claims associated with indemnity payment, the majority of claims were related to postoperative (31%) and intraoperative events (29%), followed by failure to diagnosis a condition (18%), errors in medication administration (6%), and foreign bodies left at the time of surgery (6%) [9]. Another study of urological claims found that about half of the claims were due to improper performance and diagnostic errors [10]. In terms of severity of injury in closed claims, major and minor temporary injury made up the most amount of claims at 21% each (mean indemnity $244,597 and $205,403, respectively), patient death constituted 17% (mean indemnity $372,071), whereas emotional injury (mean indemnity $15,143) and grave injury (mean indemnity $514,844) made up only 2% each [11].

In an updated analysis of PIAA closed claims data, Sherer et al. found that urology ranks 13th of 26 in the total number of closed claims amongst other medical specialties, with 27% of claims leading to an indemnity payment to the patient [11]. High payouts of greater than $1 million represent less than 8% of payouts since 2008, and although the authors found that these large payouts are occurring more frequently in urology, the overall percentage of high dollar payouts is overall less than for other specialties. Despite the increase in large payouts, it is thought that the driver of overall increased payments recently has been an increase in the average payment amount rather than the increase in large

payouts [8]. One survey of urologists found that the mean pretrial settlement for urologists was just under $200,000 (median $70,000), and the mean award to the patient at trial was $214,000 (median $100,000). If the patient was awarded compensation for pain and suffering, this amounted to a mean award of $270,000 (median $85,000) [6].

Medical Malpractice Claims: Parties and Components

Tort law, which deals with professional negligence, is the legal process by which medical malpractice claims are handled in the United States. Medical malpractice constitutes any improper, illegal, or negligent act by a healthcare provider that occurs during patient care that causes patient harm and diverges from the accepted standards of medical practice (known as the "reasonable person" standard). In the United States, malpractice law is governed by state, rather than federal, law. The plaintiff, who is typically the patient or a legally designated party acting on behalf of the patient, brings a suit against the defendant, who is the healthcare provider. The allegation must be filed in a timely manner that is determined by the state ("statute of limitation"). Unless malpractice occurs at a government facility or federally funded clinic, the suit is filed in a state court.

Malpractice lawyers involve the plaintiff's lawyer who is hired by the patient or patient's representative, and the defense lawyer who is usually appointed by the physician's insurance company. The plaintiff lawyers are typically hired on a contingency-fee basis, which means that the lawyer only receives payment if a monetary damage is awarded, whether in a settlement or as damages determined by a court. The amount of money taken by the lawyer varies as a percentage (typically 5–50%). The defense attorneys, on the other hand, are paid in legal fees. Physicians can hire their own personal lawyer to additionally provide representation for themselves at their own expense [12].

There are four main elements that constitute medical malpractice, the key of which is determining negligence. (1) A duty was owed: a legal duty is determined to exist when a professional relationship has been established between a patient and a healthcare provider. (2) A duty was breached: the alleged misconduct by the healthcare provider must diverge from the standard of care which a reasonable, similarly situated professional would have administered. Often, expert witness testimony is used to establish this reasonable person standard. (3) The breach caused an injury: there must be a causal relationship established between the alleged misconduct and the resulting injury to the patient. (4) Damages occurred from the injury: damages must be shown to establish medical negligence, and these are typically monetary damages that take into account both actual costs (such as loss of income) and costs of future medical care, and can include noneconomic costs (such as pain and suffering). Damages are rarely punitive and are typically reserved for cases involving egregious and/or deliberate conduct.

Logistics of a Malpractice Claim

After a claim is filed, the defendant will receive a summons, which is a notice that a lawsuit has been filed. At that point, the physician should notify his/her institution and/or insurance company, and the pretrial litigation process of discovery begins. This is typically the most involved and lengthiest portion of the process, and is designed to facilitate cases being settled outside of the courtroom. Discovery involves establishing the facts of the case through sharing information, and will typically comprise a request for medical/billing records, interrogatories (which involves finding out information about the litigants, or those individuals who are involved in the claim), and depositions.

In a deposition, litigants are questioned by lawyers from both sides under oath, and these transcripts are then made available as evidence during a subsequent trial. Typically before litigation, a litigant will engage in extensive preparation with their lawyer, and this may involve study of the medical records and/or other individuals'

depositions, as well as mock deposition with trained specialists. The time and place for the deposition are set by both parties' lawyers, and a court reporter is present to administer an oath of honesty and take a verbatim transcript which is later made available to both sides. The plaintiff may choose to attend deposition sessions involving the defendant, and a malpractice insurance representative may also be present.

During a deposition, direct examination will occur, with questions from the plaintiff's attorney directed toward the physician defendant. A cross-examination is allowed by the physician's attorney, and this can be followed by a redirect and re-cross until all questions have been asked. There are two types of objections that are allowed, and these relate to assertion of privilege and to the form of the question asked.

If a claim does not get settled or dropped, it then moves on to a trial. It is estimated that less than 10% of medical malpractice claims move on to trial, and of those that do go on to trial, about 80% of them are decided in favor of the physician defendant [13]. One survey of AUA members found that nearly 50% of suits were dropped or dismissed without financial settlement, and 36% involved a pretrial financial settlement. Of all claims, only 3.5% of the time did the case go on to trial with the verdict in favor of the patient, compared with 13.2% of all claims that went to trial and were found in favor of the physician [6]. In an analysis of PIAA urology claims, data between 1985 and 2013, 64% of cases were dropped/withdrawn/dismissed, 24% were settled out of court, 7% were found in favor of the physician defendant in court, and 1% were found in favor of the patient plaintiff [11].

At a trial, the information gained during pretrial litigation can be presented, but no new information may be introduced at that time. The burden of proof rests with the plaintiff's attorney to establish what is known as a "preponderance of evidence." This is a less rigorous standard of evidence than the "beyond a reasonable doubt" standard used in criminal cases, and means that the jury believes there is a greater than 50% chance that the negligence did occur. After a decision is reached and damages are awarded by a court, either side can appeal the judgment or for a new trial. If the court finds that malpractice has occurred, this is typically reported to state medical licensing boards and/or medical societies, as well as the national practitioner database.

Based on a survey of AUA members, the mean amount of time that a urologist spent defending their first lawsuit was close to 22 days [6]. Costs to defend claims have been rising; from 2007 to 2012, one study found that the average expense to defend a claim increased by 70% (from $29,000 to $50,000); and the average cost to defend a paid claim increased by 77% (from $42,000 to $74,000) [8]. In the last decade, the average cost of defending a claim that went to trial was $104,155 [11].

Preventing Malpractice Claims

The best way to survive medical malpractice is to prevent a malpractice claim in the first place. The goal of risk management is to help identify and address cases where a patient care issue may lead to a lawsuit to prevent it in the first place. Risk management may be available to a physician through his/her clinic, hospital, or insurer. Physicians should be in contact with risk management if they have any concerns about the provision of care to a patient or a patient's outcome that may be perceived as negligence. This means involving risk management in the case of a complication if necessary, even if the physician him/herself does not believe it has resulted from negligence.

In addition, Feld and Moses give some pointers for preventing malpractice claims [14]. These include being knowledgeable about society guidelines and standards of care and careful preoperative assessment of patients including obtaining adequate informed consent. Liability does extend to a physicians' responsibility to any subordinates; thus, it is important to ensure that office staff and subordinates are well trained and knowledgeable about clinic or hospital policies including how emergency calls are handled. They also caution that emails are discoverable as evidence and one should be knowledgeable about

electronic medical record policies regarding timing and completeness of responding to results and communications.

One other strategy for preventing malpractice claims that has garnered recent attention is disclosing medical errors with patients and providing patients with an apology. Studies have shown that one of the biggest factors that leads patients to file a malpractice claim is ineffective communication between physicians and patients which leads to distrust or a perception of a lack of honesty [15–17]. One study that surveyed patients who had filed malpractice claims found that 60% of patients or their family members filed a claim not because of the incident itself but because of how it was handled and poor communication [18].

Thus, the goal of disclosing errors is to restore trust, improve communication, decrease patient anger, and demonstrate accountability and honesty [14]. Ultimately, the end result is to prevent malpractice claims that may have otherwise stemmed from these events. Studies show that when physicians apologize and provide an explanation of a medical error when it occurs and maintain open communication with the patient and family members, they are less likely to be faced with a malpractice suit [8, 19, 20]. The Joint Commission has issued a nationwide disclosure standard that requires patients to be informed about all aspects of care, including unanticipated outcomes; however, no guidance was provided in terms of how to implement this standard [21].

There are several hospital systems that have implemented medical error disclosure programs and have successfully shown their ability to reduce costs while restoring trust and improving patient satisfaction, in addition to decreasing the number of malpractice suits, decreasing litigation costs, and increasing the number of patients who are compensated and the timeline by which they are provided this compensation [22–24]. In one example, the University of Michigan Health System implemented a three-pronged medical error disclosure program, which involved acknowledging cases where patients had an adverse outcome due to an error and compensating those patients expeditiously and equitably, aggressively defending cases that were not believed to constitute neglect, and studying adverse events to improve processes or policies which could prevent future adverse events or improve patient outcomes [22]. They were able to decrease their annual litigation costs by a third (from $3 to $1 million), decrease their average time to resolution of claims from 20.7 to 9.5 months, and more than halve the number of claims (from 262 to 114) after implementation of a three-pronged medical error disclosure program.

Physicians should work with their hospital's risk management system to understand their own hospital's policies (as these policies vary widely across institutions) and determine the best method to disclose medical errors. Disclosing a medical error can be a very difficult conversation, and one that physicians have not necessarily been trained how to do. Thus, physicians may require training before a disclosure to learn how to carry out the conversation and what information should be communicated [15, 23]. Gallagher et al. provide some guidelines on the key elements to think about when disclosing unanticipated outcomes to patients, including factual evidence about the event, expressing regret, and providing a formal apology if it was caused by an error or failure of the system [23]. In addition, they advocate for the institution to integrate this into the institutional knowledge through risk-management and patient-safety activities and to establish a "disclosure support system" to ensure that physicians are knowledgeable and all parties receive appropriate emotional support.

Malpractice Insurance, Tort Reform, and Defensive Medicine

Malpractice insurance premiums have been increasing nationwide (8–20% per year in some states), at times outpacing inflation, and the American Medical Association has identified 19 states in "crisis states" [6, 8]. In a survey of urologists, the mean medical malpractice premium in 2003 was $30,665 (median 22,500) [6]. An AUA

survey found that 28% of urologists noted having difficulty obtaining coverage, particularly in the Southwestern region [25].

In general, the cost to the healthcare system of medical malpractice is astounding. Costs have been estimated at 2.4% of total healthcare spending in the United States, estimated at $55.6 billion in 2008 dollars [26]. In their 2010 Health Affairs publication, Mello et al. estimated annual indemnity payments to represent $5.72 billion, whereas other costs included administrative expenses (estimated at $4.13 billion) and defensive medicine costs (estimated at $45.59 billion).

The practice of defensive medicine has unfortunately risen because of the malpractice environment. One survey of AUA members found that in light of the current malpractice environment, 58% of urologists considered referring difficult cases to another urologist, 60% considered limiting the scope of their practice, 26% are considering changing the state in which they practice, and 41% are considering leaving the practice of medicine [6]. Another study found that many urologists refer out some types of procedures, with 60% referring laparoscopic surgery, 54% referring urinary diversion, and 20% referring for radical cystectomy [25].

Tort reform has been a hot-button issue in the United States, with advocates seeking to minimize frivolous claims, reducing the costs of malpractice litigation, making malpractice insurance affordable, and ultimately ensuring that patients are protected during this process. There are a variety of the proposed options for tort reform, starting with what has been deemed "conventional" tort reform (including shortened statues of limitations, establishing screening panels, imposing higher standards, damages reform, modification of liability rules, and placing limitations on access to Courts) [27].

One conventional method to try to prevent frivolous claims and decrease the rising premiums of medical malpractice insurance has been to implement caps on noneconomic damages. One study of jury verdicts involving malpractice claims against urologists found that although states with caps had a lower overall median verdict settlement compared with states without caps, this did not seem to influence the number of filed suits and was not thought to be necessarily related to the decreased settlement amounts. Moreover, states with caps on noneconomic damages continued to experience an increase in insurance premiums for urologists [7]. Another study to evaluate caps found that bladder cancer patients with stage III and IV disease were more likely to undergo cystectomy in regions that had malpractice caps, and that the presence of malpractice caps was actually a predictor of disease-specific survival, suggesting that despite whether caps have an effect on insurance premiums or claims, caps may actually influence urologists' practice patterns when it comes to surgical procedures or patients that they might identify as a potential source of malpractice claims [28].

Some advocate that beyond the costs to the healthcare system, the tort system does not actually serve the patients that it is in place to protect [15]. As a result, alternatives to the tort system have been proposed, including mediation-based models such as mediation or arbitration, and institution of apology and disclosure laws which would foster communication by protecting clinicians who engage in an open and honest discussion of adverse events [29]. Other alternatives include encouraging early settlements, use of "medical courts," enacting alternatives to the negligence standard, shifting liability to organizations, and predetermining compensable events [27].

Medicolegal Considerations in New Surgical Technology and Techniques

Of note, there is no consensus on development and implementation of new technology and techniques in surgery. Randomized controlled trials have long been considered the gold standard for guiding decisions about new treatments, but this technique does not always apply or may not always be feasible when it comes to surgical interventions [30]. For one, there are very few randomized controlled trials in urology, and this is often due to difficulty with feasibility in conducting a

randomized controlled trial in a surgical setting—whether because of cost, long timelines, lack of generalizability, or patient accrual [31]. As a result, comparisons of surgical treatments often rely on case–control studies or in incremental changes in surgical techniques. It can be difficult in the surgical setting to determine when a procedure has evolved to become a new or different procedure, and this also raises questions about necessity of informed consent for evolving procedures or regarding requirements for validation of new procedures. Some have advocated that new surgeries require validation before they should be routinely adopted, but as a field, we have neither determined what procedures meet this requirement nor what the concept of "validation" means in the surgical setting [30].

Robotic Urological Surgery

One specific topic to mention with regard to robotic surgery is malpractice and the development of surgical standards specifically in regard to robotic surgery for prostatectomy. The utilization of minimally invasive technology for performing prostatectomy is increasing [32, 33]. However, studies have shown that patients who undergo robotic prostatectomy are less likely to be satisfied and more likely to have regret about their treatment choice compared with patients undergoing open prostatectomy [34]. The authors postulate that this is a result of patients having higher expectations with the more advanced technology offered through robotic prostatectomy.

This transition to minimally invasive surgery occurring in the setting of the finding that, in recent years, prostate cancer operations have become the highest source of closed claims as a result of surgical error and account for the highest average indemnity payments [8]. One study found by evaluating malpractice claims that about 75% of claims related to radical prostatectomy went to trial and of those, patients were awarded damages in one in five cases; the biggest reason that led to these suits being filed was patients claiming that they had not received proper informed consent [33]. Some have argued that the reason for this increase in claims for prostatectomy is the introduction of robotic surgery as a new technology, leading to assertions that there should be centralized authority to monitor and credential urologists utilizing robotic technology [8]. In fact, one recent study of closed malpractice claims in which patients alleged that a surgical error had occurred found that 75% of claims arose from errors that occurred intraoperatively, with systems factors contributing to more than 80% of cases—the most common type of systems error identified was inexperience or lack of technical experience [35].

Various groups have advocated for a formalized process for robotic surgery training, such as preclinical training, clinical training, simulation, and proctoring [36, 37]. It should be noted that the responsibility and liability for the patient rest with the primary surgeon rather than with the supervisor in the case of proctoring; legally, the courts have ruled that the proctor is not responsible given that there has not been an establishment of a duty because there is no physician–patient relationship between the proctor and the patient [35]. It is recommended, however, that consent should be obtained from the patient and that the proctor's role should be predefined with the patient, although this is not necessarily commonly done [38].

In terms of case volume to demonstrate competence, one group used operative time as a marker for competence, finding that the learning curve for robotic prostatectomy for residents was 20 cases [39]. Other studies have echoed these results in both laparoscopically trained and laparoscopic-naïve urologists, finding the learning curve to be anywhere from 12 to 25 cases [40–42]. Some have noted, however, that it is not necessarily the number of cases that are required to achieve proficiency, but a better marker may be proficiency in certain tasks or skills that should be demonstrated [37]. It should be noted that there are some training programs, such as the 5-day "mini-fellowship" at the University of California—Irvine, which have been developed to provide both didactic and hands-on training to facilitate training and certification in robotic surgery [43].

The AUA has set out some basic parameters for delineating privileges for laparoscopic and

robotic procedures, requiring that urologists who utilize these minimally invasive technologies have proficiency in the equivalent open procedures and understand how to manage complications of the operation, have experience in laparoscopy through experience and/or instruction, and have completed supervised performance of these procedures [44].

The Society of Urologic Robotic Surgeons (SURS) has proposed recommendations for ensuring the safe implementation and credentialing of robotic prostatectomy at an institution, including the development of a centralized certification authority that would be responsible for instituting and upholding standards for the safe introduction of robotic technology in an institution [45]. In addition, the AUA has developed a Urologic Robotic Surgery Online Course [46] that provides a defined curriculum covering nine modules and requires participants to complete intuitive surgical's online training system and has developed a set of standard operating practices for robotic surgery which have been adapted from the SURS recommendations [47].

Ethical Considerations

Principles of Medical Ethics

The American Medical Association has developed standards of professional conduct which have been adopted by the American Urological Association to guide physicians' behavior (Table 8.1) [48]. These standards put forward a policy of responsibility to patients, society, other health professionals, and self. In practice, these standards of medical ethics apply in a variety of contexts.

Table 8.1 American Medical Association Principles of Medical Ethics

A physician shall be dedicated to providing competent medical care, with compassion and respect for human dignity and rights.
A physician shall uphold the standards of professionalism, be honest in all professional interactions, and strive to report physicians deficient in character or competence, or engaging in fraud or deception, to appropriate entities.
A physician shall respect the law and also recognize a responsibility to seek changes in those requirements which are contrary to the best interests of the patient.
A physician shall respect the rights of patients, colleagues, and other health professionals, and shall safeguard patient confidence and privacy within the constraints of the law.
A physician shall continue to study, apply, and advance scientific knowledge, maintain a commitment to medical education, make relevant information available to patients, colleagues, and the public, obtain consultation, and use the talents of other health professionals when indicated.
A physician shall, in the provision of appropriate patient care, except in emergencies, be free to choose whom to serve, with whom to associate, and the environment in which to provide medical care.
A physician shall recognize a responsibility to participate in activities contributing to the improvement of the community and the betterment of public health.
A physician shall, while caring for a patient, regard responsibility to the patient as paramount.
A physician shall support access to medical care for all people.

[a]Standards from the American Medical Association, June 1957, revised June 2001 [48]

Informed Consent

Informed consent is a basic tenet of medical practice, but this concept has evolved over time. In modern medicine, most accept the principle of consent espoused by Judge Cardozo in Schloendorff v. Society of New York Hospitals (1914), that "every human being of adult years and sound mind has a right to determine what shall be done with his own body; when a Surgeon performs an operation without his patient's consent, he commits an assault for which he is liable in damages" [49]. This concept has been expanded in legal rulings over time, requiring physicians to disclose the potential dangers of treatment and the potential results if the patient remains untreated [50, 51].

There are three key critical aspects of informed consent, requiring that the patient is competent, informed, and that the consent is voluntary [52]. It is important to note that a written consent form is not required, nor does it in itself represent legal informed consent; consent is a *process* and an

understanding between the physician and the patient, and the consent form is simply a written documentation of this process. The American College of Surgeons has developed principles that are integral to the consent process, such as a discussion of the diagnosis and the risks/benefits of not receiving treatment, the nature/purpose/risks/benefits of the treatment or procedure including a discussion of expectations during the hospital course and recovery, any treatment alternatives (including their risks/benefits), and the various medical professionals who will be involved in the patient's care and their roles [53].

Conflict of Interest

Conflicts of interest are pervasive and often unavoidable in the medical profession and have been described in urological practice as well [54]. A conflict of interest exists when a professional's judgment related to their primary interest (i.e., patient care or research integrity) is influenced, potentially influenced or perceived to be influenced by a secondary interest (i.e., financial gain or academic advancement). Importantly, undue influence does not have to occur for a conflict to exist; merely the perception that an individual's judgment is affected constitutes a conflict of interest. Just as vital, the presence of a conflict of interest does not imply misconduct or wrongdoing.

The American Urological Association has developed policies and procedures for dealing with conflicts of interest, including universal disclosure and in some cases other means of managing a conflict such as divestiture or recusal [55]. The goal of these policies is to facilitate informed decision-making by allowing individuals to take into account the existence and impact of conflicts. These guidelines in particular govern the officers, guidelines panel and committee members, and consultants of the AUA, in addition to abstracts and publications at the AUA Annual Meeting and in the Journal of Urology, and are enforced by the AUA Judicial & Ethical Committee.

The American Urological Association has also released principles for guiding its members' interactions with industry (Table 8.2) [56]. Although it is accepted that physician interaction with industry is a critical aspect of advancing patient care and research, the AUA maintains that it is important to establish appropriate interactions to protect the public and improve transparency to prevent improper influence from conflicts of interest.

Table 8.2 AUA Guiding Principles for Membership Interactions with Industry

Compensation:
Should not receive personal gifts or payment for entertainment
Any compensation for services rendered should be provided at fair market value
Educational content should be free from outside modification
Educational content should identify the company sponsoring the event
Pharmaceutical samples:
Should not be sold
Should not be gifted to individuals other than patients
Patient consent and confidentiality:
Industry presence in an operating room should be limited to circumstances where industry presence is of benefit to patient care
Industry presence should be disclosed to the patient prior to their presence
Patient confidentiality should be maintained in the midst of industry presence
Non-FDA approved treatments:
Use of drugs or devices outside of the FDA-approved purpose is allowable in accordance with the physician's medical knowledge and professional judgment
Physicians must provide accurate informed consent and disclosure about any competing agreements when counseling patients about use of non-FDA approved treatments
Fee-splitting is illegal and unethical
Research studies:
IRB approval should be obtained prior to participation in industry-sponsored studies
Funding from industry-sponsored studies should be paid to an institution or practice
Informed consent is required

[a]Adapted from http://www.auanet.org/education/policy-statements/membership-interactions-with-industry.cfm

Expert Witness Testimony

Expert witnesses are required to provide background on standard of care and evaluation of malpractice suits, and this has been posited as an ethical obligation for urologists by the American

Urological Association [57]. In one study of urology expert witnesses in malpractice claims, both expert witnesses for the plaintiffs and defendants had on average more than 30 years of clinical experience, although experts testifying for the defendant were found to have a higher scholarly impact and be more likely to practice in an academic setting [58].

The AUA policy statement on expert witness testimony has a set of recommendations to guide selection of expert witnesses, including that the witness should be active in the field of urology, have at least 5 years of experience after completing residency/fellowship training, have knowledge of relevant literature and guidelines, and have clinical experience in the subject of the case, and be able to provide an impartial review and opinion for the court [57].

In-office Ancillary Procedures

Particularly germane to urologists, the provision of in-office ancillary procedures is designed to streamline medical care for patients to provide coordinated care and is allowed through the so-called Stark Law, which allows physicians to provide ancillary services when they are a part of their practice. As a result of this exception, there have been concerns about the prevalence of self-referral and over-utilization of ancillary services for those who provide these services [59–63].

The AUA has set forth some ethical guiding principles in this setting, advocating that patients should be informed about their condition and all possible treatment options, patients should be advised that they can seek a second opinion, all treatment advice and referrals should be based on standard-of-care and supported recommendations, and that there should be transparency in providing ancillary services, ensuring that they are in the best interests of the patient [64].

Conclusions

Despite urologists' best efforts at diligent and compassionate clinical care, most urologists will face a malpractice claim in their careers, and as such, it is important to understand the malpractice environment as well as the ethical principles underlying the fields of surgery and urology. Urologists should utilize these principles in concert with continuing education to ensure that they are knowledgeable about the standards of care in urology in an effort to provide excellent care and avoid potential complications.

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Part II

Complications in General Robotic Urologic Procedures

Complications of Patient Positioning

9

Raed A. Azhar and Mohamed A. Elkoushy

Introduction

Different patient positions are required during robotic surgery, depending on the type of procedure, to provide appropriate access to the target organ. However, each surgical position has its own implications for circulation, ventilation, and hemodynamics. They may possibly expose patients to adverse events such as neuromuscular injuries and pressure sores secondary to compression, excessive stretch, or ischemia with subsequent necrosis, due to a reduction in perfusion. Specifically, the Trendelenburg position may result in increases in intracranial and intraocular pressure and can lead to facial and laryngeal edema. The lithotomy position, with or without Trendelenburg, may impact the cardiovascular and respiratory systems and lead to peripheral neuropathies, especially affecting the sciatic, common peroneal, and saphenous nerves. The same complications can arise during supine positioning together with pressure injuries that typically involve the occiput, sacrum, and heels.

The overall complication rates after robot-assisted radical prostatectomy (RARP) in a recent systematic review remained low and were found to decrease following learning curve improvement of the surgeons [1]. In a single center series, the incidence of pressure skin redness dropped from 27% to 5% following a technical modification in patient positioning, which was attributed to the improvement of the learning curve [2]. Moreover, positioning-related wounds have been variably reported, with a rate of severe pressure ulcers as high as 3% [2]. A 5% incidence of severe pressure wounds was reported in another study and mostly involved the gluteal region [3]. These pressure-related injuries were associated with longer operative times, increased patient comorbidity and body mass index, and Trendelenburg positioning [2, 3].

Therefore, patient positioning during robotic surgery necessitates the collaboration of the entire surgical team to maintain patient safety. It is crucial to consider the complications unique to different positions to avoid or minimize these possible risks. These neuromuscular and pressure injuries can be avoided by careful attention to appropriate patient positioning while considering the different risk factors which may predispose and aggravate these adverse events. In the present

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chapter, positioning considerations during robotic urologic surgery will be reviewed together with the possible injuries, which may be incurred. Management and preventions of these complications will also be discussed.

Positioning Considerations

Appropriate positioning should provide adequate exposure of the surgical field, accommodate the robotic camera system and working arms, and maintain vital patient functions, including circulation and airways. Moreover, it should protect the patient against neuromuscular pressure injuries, give the anesthesia satisfactory access to intravenous lines, and allow for adequate equipment checks [4].

The different patient positions required during robotic surgery include supine, Trendelenburg, lithotomy, and lateral flank positions. In robotic surgery, extreme positioning, such as the steepest degree of Trendelenburg position (roughly defined as 30–40°), is often used to gain maximum exposure to the surgical field and is utilized in conjunction with the lithotomy position (Fig. 9.1) for prostate surgery or pelvic lymph node dissection. These extreme positions help to avoid readjustment of the table, which is not always feasible without undocking the robot, but can result in significant injury to the patient. Transperitoneal or retroperitoneal procedures of the kidney, ureter, and adrenal gland are commonly performed using modified or full flank positions. The patient should be positioned as close to the edge of the table as possible to employ a wide range of movement for the instruments and camera. The more severe the degree of flexion, the greater is the possibility of expected neuromuscular complications.

For radical prostatectomy, a modified lithotomy position is used where the head is placed in extreme Trendelenburg to keep the intra-abdominal contents out of the pelvis. The legs are placed in the low lithotomy position with the ankle, knee, hip, and contralateral shoulder in alignment. The weight of the leg should rest on the heel rather than the back of the knee to avoid popliteal artery occlusion, or, secondarily, weight should rest on the lateral surface of the lower leg to avoid peroneal nerve injury [5].

The arms are tucked into the patient's sides with foam pads, and the palms should be supported and pronated. Arm board use is avoided, except in obese patients.

Positioning Complications

Patient positioning during robotic surgery may be associated with rare but serious perioperative complications. The surgical team must have in-depth understanding of the potential complications that may arise from different positioning [6].

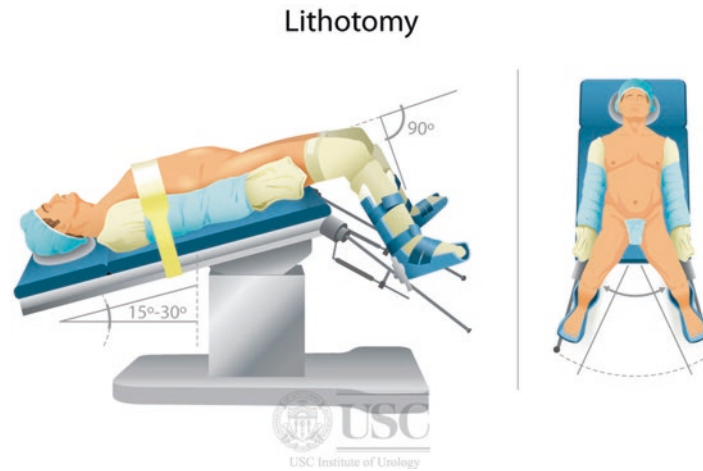

Fig. 9.1 Steep Trendelenburg with lithotomy position

Postoperative positioning complications were identified in 13.3% of patients undergoing RARP. Postoperative pain and neuromuscular injuries were observed in more than 10.1% and 5% of patients, respectively. The majority of nerve injuries during robotic procedures were caused by stretching (neuropraxia), electrofulguration injury, and dissection injury rather than direct nerve transaction. In a large multicenter review of 2775 procedures, patient positioning represented the most common type of injury resulting from robotic surgery. The most common injuries identified were abdominal wall neuralgia, sensory and motor nerve deficit, rhabdomyolysis, and shoulder and back pain [7].

The modified or full flank position may be associated with various neuromuscular complications, including upper and lower extremity neural stretch injuries such as sciatic nerve injury, paresthesia, numbness, rhabdomyolysis of the thigh, and paraspinous muscle pain. These complications are exacerbated by prolonged operative time, especially when the patient is in direct contact with an unpadded table. In addition, the pressure generated at the skin-to-table surface interface was increased in patients with a body mass index (BMI) greater than 25 kg/m^2, independent of gender [8]. Higher skin pressure was also observed with the use of full flank position and elevation of the kidney rest. The peroneal nerve may be injured due to compression of the lower leg against the table, while the obturator nerve may be injured during pelvic lymph node dissection (Fig. 9.2). Overstretching of the brachial plexus typically resulted from extended arm abduction, external rotation, and/or posterior shoulder displacement, either in the supine or flank positions [9]. It has been observed that application of shoulder braces in combination with a steep Trendelenburg position may be associated with brachial plexus injuries [4, 10, 11]. The exaggerated lithotomy position for radical prostatectomy may be associated with a high risk of neuromuscular complications due to prolonged flexion and abduction of the patient's legs, with increased risk of sciatic nerve stretching.

Rhabdomyolysis, defined as muscle injury with consequent myonecrosis and myoglobinuria, results from prolonged muscle compression, prolonged operative time, and increased patient BMI. It develops in the areas of direct pressure between bony structures and the surgical table when local blood pressure is approximately 10–30 mmHg below the diastolic blood pressure, resulting in tissue ischemia. The patient usually presents with muscular pain and a dark brown discoloration of the urine due to myoglobinuria; this can lead to renal impairment in up to one-third of patients with rhabdomyolysis [12]. A high serum level of creatinine kinase (CK) (>5000 U/L) may be detected immediately postoperatively [13]. *Shaikh* et al. found a direct relation between the degree of injury and the length of tissue exposure, where necrosis of the muscle cells occurred mainly after prolonged ischemia of 4 h (Fig. 9.2) [12].

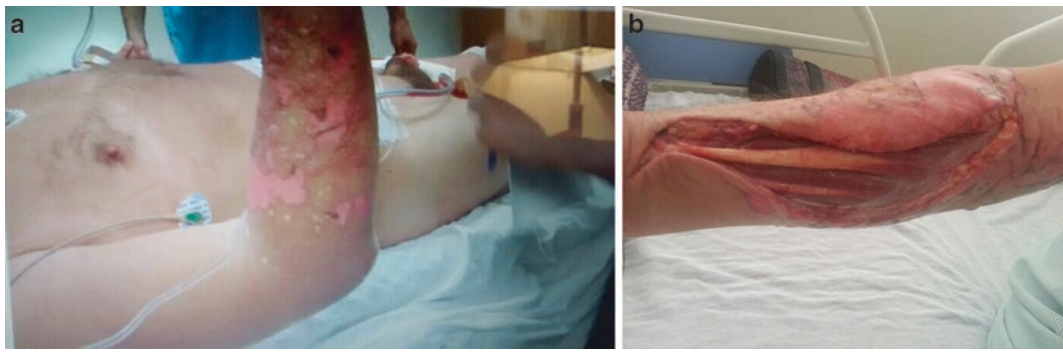

Fig. 9.2 (**a**) Upper limb compartment syndrome caused by incorrect intravenous line placement during robotic radical prostatectomy. (**b**) The patient underwent an emergency fasciotomy (Images courtesy of Juan Arriaga MD, MHA)

Abnormal positioning of the lower limb during the lithotomy position may result in lower limb compartment syndrome, which is different from that caused by trauma or direct injury, and presents with extreme postoperative and unusual leg pain. Prolonged compression and edema of the lower limbs increase the pressure inside the muscle fascial boundaries with consequent ischemia. Increases in normal intracapillary pressure or decreases in capillary perfusion pressure can compromise blood flow, leading to ischemia and edema. Additional ischemic damage, neuropathy, and rhabdomyolysis may result from reperfusion injury, which induces a cascade of signaling pathways. Symptoms of compartment syndrome can worsen dramatically within a short period and can include severe localized pain on passive stretch of the involved muscles. Neuralgia and/or paresthesia along the dermatomes of the nerves crossing through the affected muscles may also be detected. As a permanent result, muscle paralysis may occur with the loss of peripheral pulses and atrophic changes of the skin.

Elevation and abduction of the lower limbs may injure the superficial and deep branches of the peroneal nerve and the tibial and sural nerves. Clinically, calf swelling and pain may be observed with plantar hypoesthesia and weakness of toe flexion. The use of shorter leg supports may facilitate da Vinci robot docking in the split-leg position, eliminate or reduce the need for hip hyperextension, and prevent or reduce the development of lower extremity neuropathy.

Molloy has recently observed an increase in the intraocular pressure when a patient is in steep Trendelenburg (head down) position [14]. Postoperative corneal abrasions were also observed in 0.1–0.6% of patients, together with postoperative ischemic optic neuropathy [15]. Blindness was detected in less than <0.1% of patients as a devastating complication that has recently been reported after prolonged steep Trendelenburg position [16]. Intraocular pressure is increased in a time-dependent fashion in patients undergoing RARP in a steep Trendelenburg position. Therefore, time-limited procedures appear to have little to no risk from increased intraocular pressure in patients without preexisting ocular disease, and visual function is not significantly changed postoperatively.

Risk Factors for Positioning Complications

Apart from abdominal wall cutaneous neuralgia, which is likely caused by direct surgical trauma at the trocar site, an operative time of greater than 5 h is a risk factor for all neuromuscular injuries [5]. Other well-documented risk factors for positioning injuries include: increased patient BMI (especially with large muscle mass), use of the kidney rest, and male gender [13]. The most important risk factors for rhabdomyolysis include: exaggerated intraoperative lateral position, patients with high muscle mass or morbid obesity, hypovolemia, prolonged operative time, preexisting diabetes, hypertension, or renal insufficiency [13].

Patient positioning in both lithotomy and Trendelenburg positions (with the ankles elevated) represents the main risk factor for development of compartment syndrome, especially with direct calf compression. In addition, prolonged operative time, high BMI, hypovolemia, lower blood pressure, and concomitant peripheral vascular disease may predispose patients to compartmental leg syndrome [17].

The prolonged lithotomy position has been associated with an increased risk of postoperative lower extremity neuropathies [18]. Lower extremity neuropathy was detected in 1.7% of 179 consecutive patients operated on by an experienced robotic surgeon following patient placement in the low lithotomy position [19]. Duration in the dorsal lithotomy position was a potential contributing factor to this injury. The authors expected a higher risk for postoperative lower extremity neuropathies at lower-volume and less experienced centers due to suspected longer durations of the dorsal lithotomy position.

Clinically relevant positioning injuries and rhabdomyolysis can occur in patients who are subjected to prolonged extreme Trendelenburg position during RARP and extended pelvic lymph node dissection; these positions may be

prolonged due to the learning curves of early surgeons [3]. Serum CK level immediately increases significantly, peaking at 18 h postoperatively. In patients with a high BMI who are subjected to a very long operation in a Trendelenburg position and have visible position injuries, the authors recommended serum CK measurement at 6 and 18 h postoperatively. Hypervolemic therapy should be started promptly to prevent possible renal injury from rhabdomyolysis if serum CK is >5000 IU/L [3].

Koc et al. reviewed the records of 377 patients who underwent RALP using a split-leg table [20]. Despite the comparable complication rates between split-leg positioning and those previously reported for lithotomy positioning, the length of time in the former position was the only detected potential risk factor for development of lower extremity neuropathy. In addition, split-leg positioning seems to threaten the femoral nerve from hip hyperextension, a condition which is more severe than common peroneal neuropathies secondary to extended lithotomy positioning [20]. Surgeon's experience can decrease the incidence of most of these complications. *Mills et al*. reported an incidence of 6.6% positioning injuries from 334 operations; including hand and foot numbness, radial and median nerve palsy, and hip adduction and flexion weakness [21]. This incidence rate is likely higher than anticipated due to the author's increased awareness of injury, as they claimed. Most of these injuries (59.1%) are resolved within 1 month, while 18.2% resolved between 1 and 6 months, and 22.7% persisted beyond 6 months. Prolonged operative time, in-room time, and American Society of Anesthesiologists class were significantly associated with these positioning injuries [21].

Prevention of Positioning Complications

Positioning problems can be prevented by careful planning and thorough perioperative assessment of all patients undergoing robotic surgery. The surgical team should assess patient positioning at regular intervals throughout the surgical procedure as well as postoperatively, especially in prolonged procedures and/or when extreme positioning is used. As the length of robotic procedures may extend up to 6 h, frequent and careful attention to patient positioning is necessary. The longer the operative time, the higher are the risk factors for all neuromuscular injuries. Careful and appropriate patient positioning before robotic surgery is the cornerstone to avoid or minimize neuromuscular injuries. The surgical team should be aware of the potential dangers of different surgical positions. Moreover, adequate padding for extremity pressure points and appropriate table cushioning can help reduce the risk of pressure-induced complications.

Notably, the surgeon should avoid extreme limb flexion, extension, and abduction in order to minimize postoperative neuromuscular injuries. Furthermore, other precautions should be considered, such as using partial rather than full flank positioning, decreasing the degree of table flexion, and limiting the duration and/or the elevation of the kidney rest. During the flank or semi-lateral position, the patient's shoulders and hips should be turned simultaneously to prevent torsion of the spine. Placing a pillow under the head will ensure cervical alignment with the thoracic spine. Nerve damage may be avoided by appropriate padding of all bony prominences under the feet, ankles, elbows, hips, and arms. A pillow may be placed under the knees and between the legs to prevent back strain and protect bony prominences. Securing the patient with safety straps at the shoulders, hips, and knees helps prevent the patient from shifting or sliding. A mild flank position (30° body rotation) during kidney surgery has been suggested to avoid neurological lesions, especially of the brachial plexus. Minimizing table flexion and placing the upper arm in an ergonomic position resting on the mid chest can also help reduce the incidence of neurological lesions [22]. Over-flexion of the bed (to open the space between the iliac crest and the lower ribs) should be avoided [5].

During robotic procedures, there is a risk that robotic arm contact with the patient may cause injury. Safety checks by the surgical team will ensure proper positioning of the robotic arms and

their position to the patient [4]. The goal is to avoid direct contact of bony prominences or body surfaces with the hard table and consequently reduce pressure-related injury. The circulating nurse should make sure that the patient is positioned appropriately, protected from injury, and checked for any positional shifts throughout the procedures. Moreover, the nurse should monitor other systems that may impact the risk for positional injury, such as the cardiovascular, musculoskeletal, and neurological systems [23].

In an obese population representing 12% of all patients in a urologic laparoscopic database, *Mendoza et al.* found that 2% of those patients had peripheral nerve injury secondary to surgical positioning [24]. Therefore, careful positioning of obese patients with adequate padding is crucial because they have a higher rate of perioperative neuromuscular complications. This higher rate is due to the patient's own body weight compression and might be aggravated by extended operative times.

Placement of an axillary roll during renal surgery might help prevent brachial plexus injuries. Shoulder braces should be entirely omitted; the upper arm should not be abducted more than 90° and/or should not be externally rotated to prevent the head of the humerus from impinging upon the brachial plexus [25]. Appropriate padding of the lateral surface of the leg will avoid peroneal nerve injuries, especially when the weight of the lower leg rests upon the heel rather than the lateral surface of the leg.

Prevention of rhabdomyolysis includes the recognition of high-risk patients, including men with increased body weight, especially those with large musculature [13]. These patients should be meticulously evaluated clinically and have an immediate assessment of serum creatinine and CK levels in order to prevent or reduce renal damage. Acute renal failure occurs in the majority of these patients with myoglobinuria, and dialysis may be necessary. Similarly, risk factors for lower limb compartment syndrome should be identified in all patients undergoing robotic pelvic surgery in the lithotomy position. It should be mentioned that any degree of Trendelenburg positioning may also increase compartment pressures [26]. Efforts should be made to confirm or exclude this diagnosis even if there is a low degree of suspicion. Careful lithotomy positioning is recommended in order to avoid this complication. This can be achieved by avoiding the head down position, minimizing dorsiflexion of the ankles, and minimizing ankle elevation above the heart. For prolonged operations, the recommendation is to lower and remove the leg supports every 2 h to prevent reperfusion injury. Hypotension and hypovolemia should be avoided, especially in high-risk patients with cardiovascular disease.

The patient should not be positioned in steep Trendelenburg for a prolonged time. Repositioning at regular intervals is recommended in these situations to avoid increased intraocular pressure and the possibility of subsequent blindness [11]. Intervals of 5-min supine rests may be indicated for high-risk patients and during prolonged surgical intervention [14]. Transparent occlusive eye dressings should be used rather than taping the eyes shut to avoid or minimize corneal abrasions. Finally, the surgeon's documentation of patient positioning in the operative record may help diagnose and manage positioning complications: comprehensive documentation would describe the specific positions used, the use of padding and safety straps, intraoperative position changes, and postoperative skin assessment [10].

Management of Positioning Injuries

To prevent or reduce renal damage, patients with rhabdomyolysis should have an immediate assessment of serum creatinine and CK levels. Management includes aggressive fluid resuscitation and correction of metabolic acidosis. Acute renal failure occurs in the majority of these patients with myoglobinuria and dialysis may be necessary.

If a postoperative neurologic deficit is suspected, a neurology consultation is indicated, and electromyography may be required. Focal compression or stretch nerve injury can increase intraneural venous pressure and result in impaired

transmission. The severity depends on the degree of the insult and can lead to Schwann cell damage and demyelination; this can take hours or weeks to reverse. Recovery depends on the regeneration of peripheral axons and occurs at a rate of approximately 1 mm/day [27]. Nonsteroidal anti-inflammatory medications or neuropathic agents can typically relieve pain, while physiotherapy should be instituted for muscle weakness. Nerve grafting may be considered for repair in injuries which do not improve or show progress [27].

Brachial plexus injury is a self-limiting condition which can lead to sensory or motor deficit of the arm or hand. It should be treated with nonsteroidal anti-inflammatory and neuropathic medications and may require physical therapy; rarely, surgery may be indicated to regain function [10]. Compartment syndrome leads to lifelong disability in 41.5% of cases and can be fatal in 6% of cases [26]. If left untreated, it can result in permanent injury, renal failure, or death. Therefore, if there is evidence of compartment syndrome, orthopedic or vascular surgical consultation for fasciotomy is warranted immediately. In addition, administration of mannitol, with its diuretic effect, may protect against reperfusion injury and decrease compartment pressures. Urine should be alkalinized to prevent urate and myoglobin precipitation [15].

Conclusion

Patient positioning is a critical part of any robotic surgical procedure and may be associated with significant morbidity. Peripheral nerve and pressure-related injuries, including sciatic nerve injury, paresthesia, numbness, rhabdomyolysis of the thigh, and compartment syndrome, can all occur. Patients, particularly those at high risk, should be counseled about the risks of positioning injuries, especially with lengthy surgical procedures. Despite the fact that positioning injuries are rare in robotic urologic procedures, collaboration of the entire surgical team is recommended to maintain patient safety. It is crucial for urologists and anesthesiologists to consider complications unique to each position in order to avoid or minimize the potential for complications. The longer the operative time, the higher the risk factors are for all neuromuscular injuries. The surgical team should assess patient positioning at regular intervals throughout the surgical procedure as well as postoperatively, especially in prolonged procedures and/or when extreme positioning is used.

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Complications of Port Placement

10

Alexis Sánchez and Jose Rosciano

General Considerations

Port placement is the first step in every minimally invasive surgery. Besides the general recommendations related to port placement in laparoscopic surgery, in the particular case of robotic surgery, certain guidelines for proper docking and operation of the system should be met during surgery. Certainly, a key component for achieving a safe and effective robotic surgery is the optimal port placement. Proper entry and avoiding external clash of the robot arms are fundamental for surgery success.

The first step in laparoscopic surgery is the creation of the pneumoperitoneum and initial trocar placement. These steps are very significant as most of the complications occur during this initial approach. It is well established that over 50% of the trocar-related injuries to the bowel and vasculature are during the initial entry [1]. In robotic surgery, 8-mm cannulas are used. It is important to point out that the inherent risk of inserting these ports does not differ from standard laparoscopy.

Although complications associated with port-site placement are uncommon, in experienced hands, the potential for associated morbidity is high. Surgeons performing robotic surgery must have the knowledge and necessary skill to prevent, recognize, and manage complications related to port-site placement.

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Risk Factors

Multiple factors are involved in complications related to port placement. There are factors related to the patient and the surgeon.

Patient-Related Risk Factors

Obesity

Obesity is a growing problem worldwide; in some cases, it constitutes a real public health problem. Due to the association of obesity with diseases such as renal cancer and prostate cancer, there is no doubt that in practice the need to treat a significant proportion of patients with high body mass index is observed [2].

A thick layer of adipose subcutaneous tissue limits the access, especially to the insertion of needle and primary trocar. Due to the thickness of the abdominal wall and the preperitoneal fat,

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accurate assessment of the location of the needle tip is difficult.

The open technique is an alternative as regards these patients; however, some researchers believe that a larger skin incision is necessary for Hasson trocar insertion in obese patients, leading to leakage of gas and disadvantages during surgery [3], this is particularly important when the Xi system is used, in which case all ports, including optics, are of 8 mm. Other studies suggest that the use of optical trocar is an excellent choice regarding these patients, with a low rate of intestinal or vascular injuries [4].

The difficulty in mobility of conventional laparoscopic instruments when surgery is performed on obese patients is one of the limitations that have been overcome with the use of robotic surgery because the surgeon does not need to overcome the resistance of a large abdominal wall before carrying out the necessary movements, instead s/he would find him/herself in an optimal ergonomic position on the console. The use of long cannula is highly recommended for these groups of patients to keep the remote center in proper position and to prevent the cannula from accidentally slipping out; in this case, there is the risk of losing the pneumoperitoneum and the robot docking.

Not only obesity is a disadvantage, very thin patients are also susceptible to injury due to the proximity between the skin and the intra-abdominal and retroperitoneal structures. In the case of robotic surgery, sometimes patients with very low body mass index are a challenge for a proper port placement as it is difficult to obtain the recommended distances between the ports and the space for the assistant.

Prior Abdominal Surgery

Prior abdominal surgery is associated with an increased risk of access-site complications [5]. According to some studies, the rates of adhesions are 0–15% in patients with previous laparoscopic surgery, 20–28% in those with previous laparotomy through a low transverse incision, and 50–60% in patients with previous midline laparotomy [6]. Adhesions may be right under the scar or may be further away.

Therefore, in patients with a history of abdominal surgery, the following options should be taken into account: the use of Palmer's point or the open approach preferably far from the site of previous incisions. Care should be taken that the selection of the entry site may not lead to a port misplacement that may cause difficulties in the docking and operation of the system during the surgery.

Once the abdomen is insufflated and the primary port is placed, the abdominal cavity should be inspected to determine whether adhesiolysis is needed prior to the placement of additional ports. The handling of these adhesions by using the robot will depend on the possibility to dock the robot prior to the adhesiolysis. If this is not possible, the adhesiolysis will be performed by conventional laparoscopy and subsequently the docking will be performed.

Other Abdominal Conditions

Pregnancy or large abdominal masses may cause problems when approaching the abdominal cavity as they may displace the abdominal viscera and reduce the space within the abdominal cavity [7].

In patients with portal hypertension or inferior vena cava obstruction, the presence of a collateral venous network on the abdominal wall increases the risk of bleeding during the placement of ports, and the increase of pressure within the portal system makes the patient more susceptible to bleeding at the level of the mesentery and the omentum [8].

Surgeons-Related Risk Factors

The experience of the surgeon is intimately related to the occurrence of complications in minimally invasive surgery, and robotic surgery is not an exception. The surgeon must know the guidelines, master the relevant aspects of the abdominal anatomy, select and use the instruments properly, identify high-risk patients, select the suitable technique according to each patient and procedure, and be familiar with the alternative strategies. In any case, the surgeon must have the ability to identify and manage the complications that may occur.

Previous studies in nonrobotic laparoscopic surgery have shown that the incidence of com-

plications in the first 100 cases was considerably superior to the subsequent cases (13.3% vs. 3.6%) [9].

Training in robotic surgery is gradual, and it is divided into four phases – introduction to da Vinci surgery, da Vinci technology training, initial case series plan, and continuing development. For the first proctored surgical procedures, the surgeon has already fulfilled case observations, in service training with a clinical representative, virtual simulation, and animal simulation lab. Therefore, s/he is completely acquainted with the system. This outstanding training model has become an example in the introduction of new technologies into surgical practice and contributes to reduce the incidence of complications.

Prevention

Obviously, the best method to manage port-site complications is prevention. So, the following considerations must be taken into account when performing the procedure.

Choosing the Initial Approach

There are three main options for the creation of the pneumoperitoneum – closed technique, open technique, and optical trocar.

The Veress needle is used in the closed technique. It is a blunt-tipped, spring-loaded inner stylet with sharp outer needle. The stylet retracts during passage through the abdominal layers to allow penetration. Once the peritoneum is entered, the lack of resistance allows the blunt stylet to protrude; theoretically, this should prevent perforation of intra-abdominal structures. As the blunt tip does not lock once in the peritoneal cavity, it can again retract exposing the needle if it comes into contact with an intra-abdominal structure.

It has been shown that the most effective way to confirm intraperitoneal placement of the Veress needle is initial gas pressure <10 mmHg. Other techniques such as the double-click test, aspiration test, and the saline drop test are not useful in confirming placement [10] (Fig. 10.1).

In the open technique, the abdominal cavity is approached passing through each of the layers until the peritoneal cavity is reached. No step is

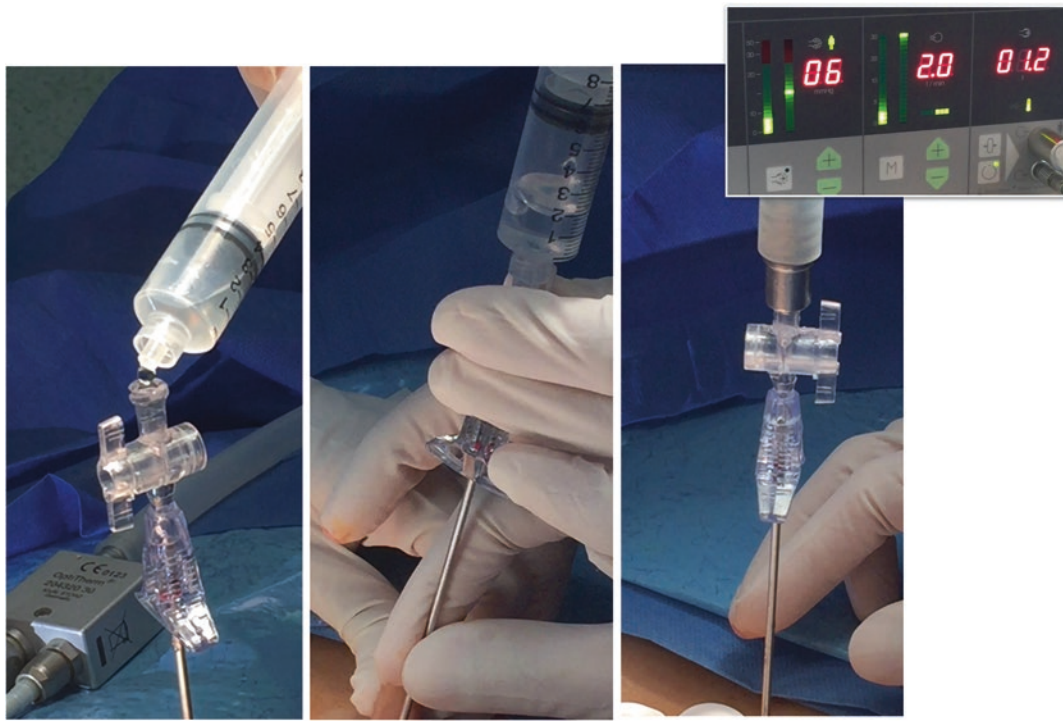

Fig. 10.1 Intraperitoneal Veress needle confirmation

completed blindly; therefore, theoretically it offers advantages such as certainty of establishing peritoneum, anatomic repair of the facial incision, elimination of the risk of gas embolus, and reduction in vascular and bowel injuries related to the initial access [11].

According to some studies, the open technique eliminates the risk of major vascular injury and reduces the rate of major visceral injuries. However, the study of a higher level evidence of Cochrane database concluded that no significant differences in the incidence of injury between both techniques were found [12].

The visual entry technique accesses the abdominal cavity with a specialized optical port that has a conical nonbladed transparent tip, allowing each layer of the abdominal wall to be seen with a 5 mm 0-degree laparoscope as it is being traversed (Fig. 10.2). A firm, constant alternating clockwise–anticlockwise motion is used. According to Thomas et al., despite each layer of the abdominal wall is displayed, the use of this device does not remove intra-abdominal injuries [13]. The combination of pneumoperitoneum with closed method followed by the optical trocar placement is an excellent choice.

Each surgeon should choose the method that s/he feels more comfortable with and s/he has more experience with, but should be familiar with alternative techniques.

Nasogastric Tube and Foley Catheter

The placement of a nasogastric tube to decompress the stomach reduces the likelihood of gastrointestinal injuries, in operations involving port placement in the lower abdomen is also recommended to empty the bladder using a Foley catheter; this also allows an early detection of injuries. The presence of air or hematuria in the urine collecting bag should be considered a suspected bladder injury [14].

Palmer's Point

Palmer's point is located in midclavicular line 3 cm below the rib in left upper quadrant. This is a point where in theory the probability of abdominal adhesions is considerably lower than the rest of the abdomen, which is the best option in the case of patients with a history of abdominal surgery [15] (Fig. 10.3).

If Palmer's point is used, it is especially necessary to empty the stomach using a nasogastric tube. This point should not be used in patients

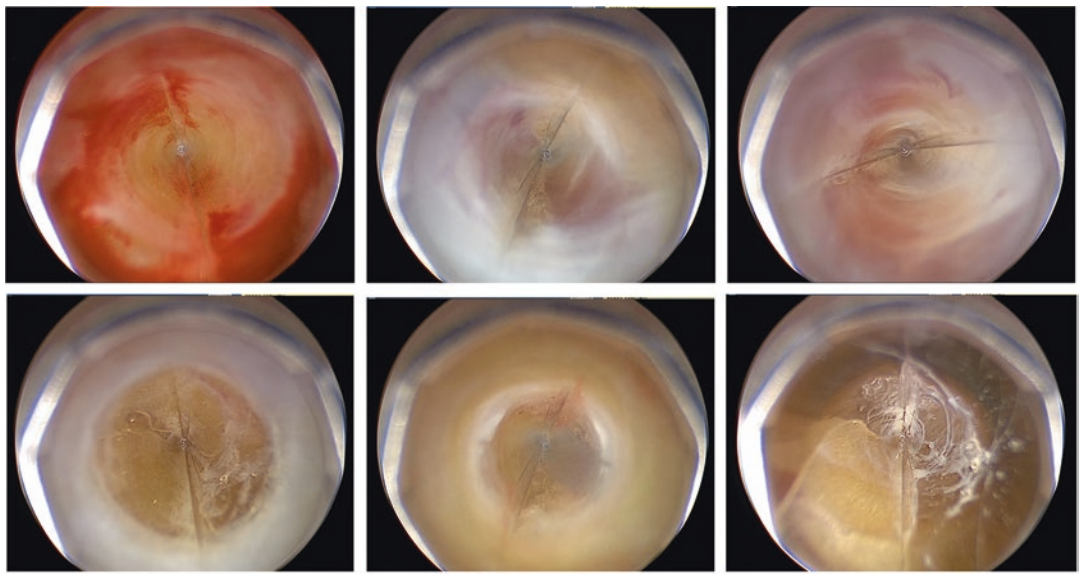

Fig. 10.2 Abdominal wall layers identified during optic trocar introduction

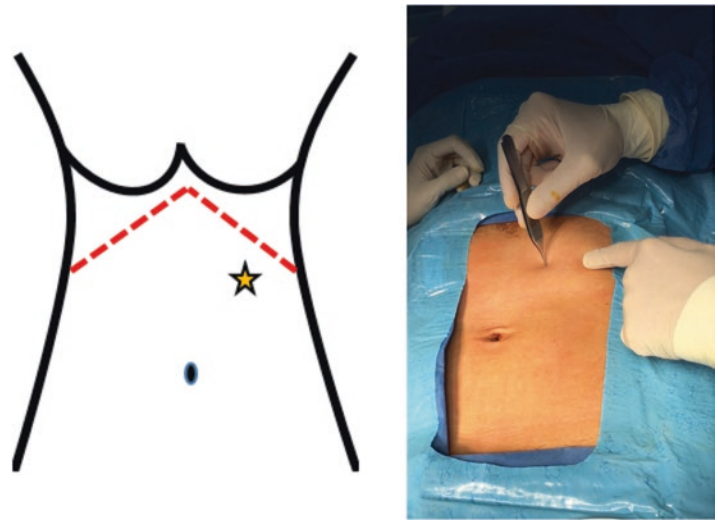

Fig. 10.3 Palmer's point ubication

with a history of splenectomy, gastric surgery, or in the presence of hepatosplenomegaly.

Primary Trocar Placement

If the open technique has been used, the trocar is already on the site, which is an advantage because a blind step was avoided.

If the pneumoperitoneum was created using the Veress needle, the entry of the primary trocar is carried out following these recommendations: Oblique direction, introduce with the valve open, as the escape of pneumoperitoneum through this, is a sign of intraperitoneal location. The pressure of the pneumoperitoneum can be temporarily increased for this first port placement; such temporary increase proves no hemodynamic impact on the patient [6]. Once the port is placed, the camera is introduced to confirm a proper location and to examine the abdominal cavity.

This first port placement by using an optical trocar is an option that requires experience, has shown to decrease the time required for the initial approach and the creation of pneumoperitoneum, yet this technique is not free of complications [16].

Secondary Trocar Placement

Injuries can occur during secondary trocar insertion. The number, size, and portion of these trocars are dictated by the procedure being done.

Fig. 10.4 Robotic trocar obturators

Transillumination technique helps avoid bleeding produced by vessel injury on the abdominal wall. In any case, ports should be introduced under direct vision with special care to identify and avoid epigastric arteries.

There are different robotic trocars obturators: sharp, bladeless, and blunt (Fig. 10.4). The use of noncutting trocars has shown advantages over the incidence of bleeding in the abdominal wall, postoperative pain, and patient satisfaction. However, trocars require much more application of force for insertion, which can potentially increase the rate of injury [17].

Other Considerations in Robotic Surgery

Remote center: Trocar location with the remote center in proper position is particularly important

to reduce postoperative pain and increase patient satisfaction. However, trocar location at the appropriate point should not become a limiting factor when carrying out the procedure or in specific situations that require going further or retract the trocar.

Tension in the abdominal wall: Once the robot arms are connected, it is important to release the tension on the abdominal wall to prevent injuries and reduce postoperative pain.

Avoid external conflict and clash with limbs: The movement of robot arms must be verified during the procedure, so that arms do not clash each other. Also, it is important to be certain that they will not clash with patient's limbs or with costal arches to avoid injuries.

Diagnosis and Treatment

The incidence of bowel and vascular injuries is quite low. However, a major vascular injury or an unrecognized bowel injury may carry a significant increase in morbidity and mortality. Complications and its prevention are summarized in Table 10.1.

Table 10.1 Prevention of complications in portals placing and management

Complication	Prevention	Management
Vascular lesion	–	–
Abdominal wall	Transillumination	Direct pressure rotating the tip of the trocar
	Visualization of the epigastric vessels	Insert Foley catheter
	Secondary trocar introduction under direct vision	Place U stitches with the suture passer
	Removal of trocars under direct vision to verify hemostasis	Extend the skin incision
		Use of monopolar, bipolar, or ultrasonic energy for hemostasis control
Intra-abdominal	Trocar introduction under direct vision	If serious vascular injury is suspected, conversion to an open procedure must be considered
	Proper technique	Direct compression of the bleeding site
	Open access	Increase insufflation pressure
		Repair with precise intima to intima apposition without tension
		If ligation of a vessel does not lead to ischemia, definitive repair may be postponed until the patient is stable
Visceral injuries	*Open access*	–
	Palmers point	
	Secondary trocar introduction under direct vision	
Solid organ	–	Apply pressure on the injury using an instrument or with sterile gauze
		Increase the pressure of the pneumoperitoneum
		Use of monopolar, bipolar, or ultrasonic energy
		Application of dry hemostatic agents
Small bowel	–	Primary closure
		Resection and anastomosis
Colon	–	Consider colostomy depending on the patient condition and procedure
Bladder	Use Foley catheter in lower abdominal surgery	Less than 5 mm – Foley catheter
		Major injuries – Primary closure and Foley catheter placement

Vascular Injuries

Vascular injuries during laparoscopic surgical procedures are probably underreported, and their incidence rate is estimated to be 0.05–0.26% [18].

Vascular injuries may involve retroperitoneal, intra-abdominal, or abdominal wall vessels. The most common vascular injury site is the abdominal wall, especially considering the epigastric vessel injuries.

The options for controlling bleeding from the abdominal wall include using the trocar that the bleeding is coming through for direct pressure rotating the tip against the bleeding site. Alternative strategies are as follows: a Foley catheter can also be inserted, inflated, and gentle traction applied to tamponade the site; also, U stitches can be placed under direct visualization using a suture passer (Fig. 10.5). In rare cases, it is necessary to enlarge the incision in the skin for adequately controlling the vessel and to achieve hemostasis.

Major vascular injury is a preventable, unacceptable, and potentially lethal complication; its incidence should be reduced as much as possible.

The most common sites of intra-abdominal vascular injury include iliac vein, greater omental vessels, inferior vena cava, aorta, pelvic and superior mesenteric veins, and lumbar veins [2].

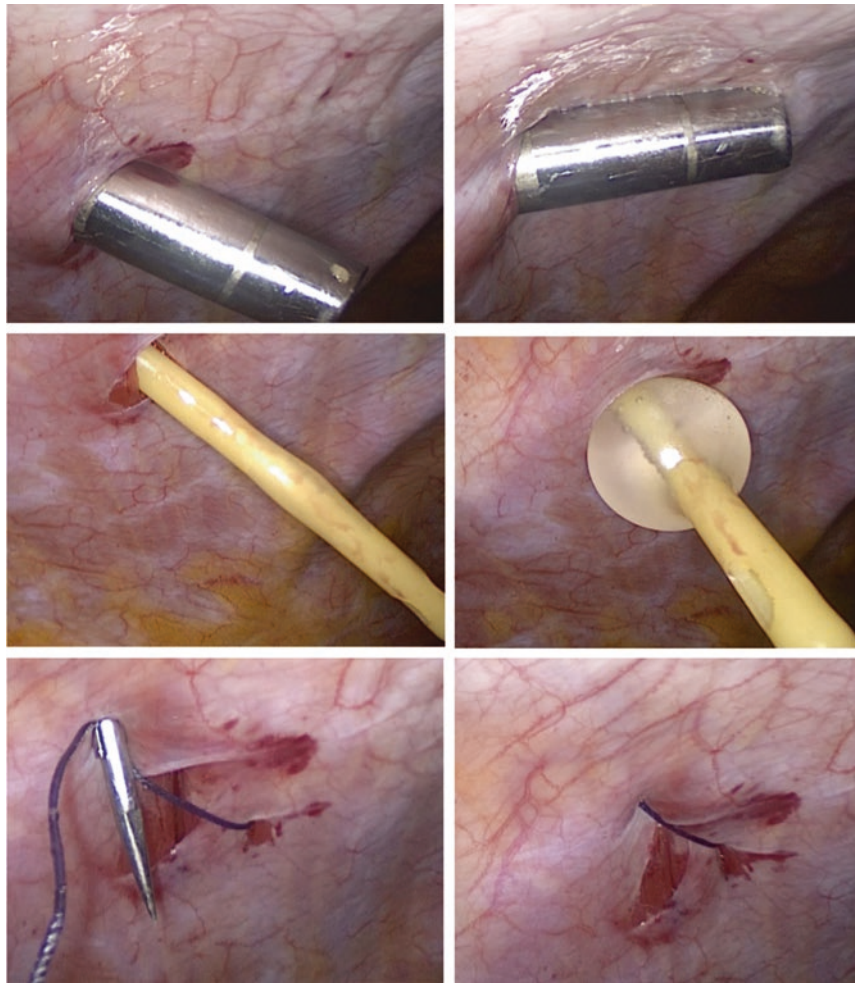

Fig. 10.5 Hemostatic maneuvers for abdominal wall bleeding control

Concerning intra-abdominal injuries, Suarez [19] has described basic principles of repair, as follows:

- Once a potentially serious vascular injury is suspected, immediate conversion to an open procedure must be considered.
- Direct compression of the bleeding site is the quickest and safest way to gain initial control of blood loss, especially with a venous injury.
- If the patient exhibits unstable vital signs, adequate volume replacement, while controlling the blood loss, must take place prior to attempting repair of the injury.
- If the bleeding site is difficult to see, early and wide exposure of the site and the surrounding structures must be obtained.
- The vessel wall must be repaired with precise intima to intima apposition without tension; venous injuries may be best handled by ligation rather than suture repair if the patient is unstable.
- If ligation of a vessel does not lead to ischemia, definitive repair may be postponed until the patient is stable.

If a retroperitoneal hematoma is found at the time of the examination of the abdominal cavity with the optical trocar, it may indicate that it should be explored and the injury should be repaired immediately according to the findings.

At the conclusion of the procedure, after trocar removal, all ports should be visualized to ensure that there is no bleeding that was tamponaded by the trocar itself. If this bleeding is present, it can be stopped by cautery, pressure, or any of the measures mentioned above.

Visceral Injuries

The incidence of bowel injury is between 0.04% and 0.5% [20], and 30–50% of the bowel injuries are not diagnosed intraoperatively, this leads to a mortality rate of up to 30% [6]. Adequate exploration of the abdominal cavity with the camera is essential to discard the presence of injuries following the initial approach.

Solid Organ Injuries

The management of liver or spleen injuries includes initially to apply pressure on the injury using an instrument or by introducing sterile gauze into the abdominal cavity. Increasing the pressure of the pneumoperitoneum may help control hemostasis. It is ideal to use bipolar forceps once the bleeding site is identified. The use of dry hemostatic agents (Surgicel and Gelfoam) or thrombin sealants should be considered if the bleeding does not stop. The use of suture to achieve hemostasis should be carefully assessed as it could lead to larger tears.

Gastrointestinal Tract Injuries

This injury must be repaired at the time of its detection. It should not be delayed until the end of the procedure because detecting it again could be very difficult. Once identified, the extent of the injury must be determined. Small bowel injuries may be controlled by primary closure using intracorporeal suturing and knot-tying techniques, which are hugely facilitated by the da Vinci system. Major injuries requiring bowel resection can be managed by stapling or manually using the robot.

Colon injuries pose a bigger problem. Depending on their severity, they can be treated by primary repair, in which case, drainage is always recommended. Major injuries will require a segmental resection. The decision to perform primary anastomosis or colostomy should be individualized taking into account the patient's condition and the primary procedure to be performed.

The great majority of the delayed diagnoses require laparotomy, bowel resection, washout, and drainage of the cavity.

Other Visceral Injuries

Bladder injuries may occur during procedures in lower abdomen. As discussed above, the use of a Foley catheter may reduce the risk of injury and allows early diagnosis by noting that the collection bag fills with air or the presence of hematuria.

Instilling dye into the bladder allows an accurate diagnosis of bladder injury. If the injury was caused by a Veress needle and is less than 5 mm, it can be managed with bladder decompression using a Foley catheter for 7–10 days. Major injuries will require closure with absorbable suture, for which the robot's excellent vision and handling are of great help. Likewise, the Foley catheter must remain during the postoperative period.

Final Consideration

Abdominal access and properly port placement without complications are key to the success of robotic surgery. When complications do occur, excellent training will allow them to be properly managed.

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Complications in the Abdominal Wall in Robotic Urology Surgery

11

Eduardo Parra Davila, Carlos Hartmann, Flavio Malcher, and Carlos Ortiz Ortiz

Introduction

Minimally invasive approaches to urological surgical pathology, have become common place. Numerous studies show the decreased blood loss, shorter hospital stay, convalescence, and lower patient morbidity of minimally invasive surgery (MIS) when compared with open surgery [1–6].

MIS has its advantages, but, like all surgical therapeutic interventions, carries a risk of complications. In fact, with increasing MIS surgical experience, the incidence and magnitude of complications increase because more complex procedures are increasingly tackled laparoscopically [7].

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Intraoperative Complications

Access-Related Vascular Complications

These are considered a rare entity; analysis of all trocar-related injuries reported to the USA Food and Drug Administration (FDA) from 1993 to 1996 identified 629 reports. Nearly 70% of access-related injuries were vascular. Additionally, 81% of access-related deaths had a vascular cause, with aortic and inferior vena cava (IVC) injuries being the most common [8]. An additional study of 103,852 laparoscopic procedures identified a trocar-related vascular injury rate of 0.05%, with a 17% mortality rate [9].

Injury to the inferior epigastric vessels (Fig. 11.1) is the most common vascular complication, often recognized intraoperatively, and is usually caused during insertion of the pararectal trocars [10].

Bipolar coagulation and clipping are often effective in controlling any bleeding. If the bleeding is persistent, suturing through the abdominal wall with the aid of a straight needle, encaging the bleeding vessel, is very useful. The suture should be released 2 days after the initial operative procedure [11]. Remember to inspect all trocar sites after removal because bleeding may not be apparent until trocar removal and lowering the pneumoperitoneal pressure [11].

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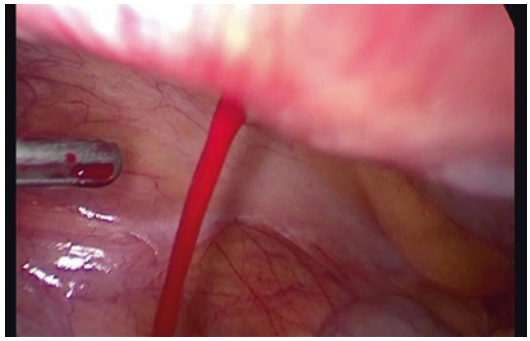

Fig. 11.1 Right epigastric vessels bleeding after a trocar insertion

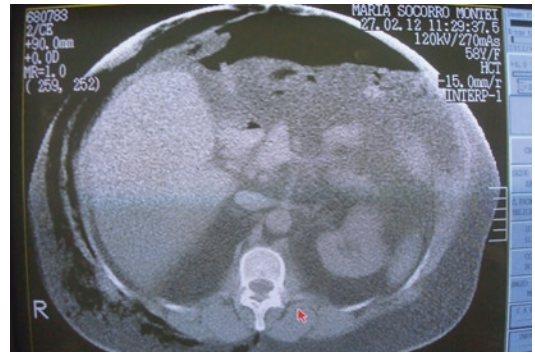

Fig. 11.2 Large SE over the right costal margin seen on a CT scan

Careful inspection of the abdominal wall via the laparoscope before trocar insertion is useful. It is also useful to prepuncture and visualize the site of planned trocar insertion [11]. The first robotic instrument has to be inserted under direct vision because it has no memory and can go further than desired. Inserting the instrument under direct vision is also required because touching the clutch of the robotic arm causes it to lose its memory.

During the course of a laparoscopic procedure, bleeding at any trocar site should not be overlooked. Bleeding might be a harbinger of vascular injury. In this situation, open suture ligation via the "cut-down" technique, or fascial closure with the Carter–Thomason device, can be used to achieve vascular control [12].

Large abdominal or scrotal hematomas have been described due to small amounts of bleeding that were not seen during surgery. Care must be taken with the position and movement of the robotic arms during surgery, especially when one of the arms is placed outside the field of view, because the pressure of the instrument on vascular structures could cause delayed injuries due to intramural hematomas or thrombosis due to blood stasis [13].

Subcutaneous Emphysema

Although insufflation with carbon dioxide (CO_2) for laparoscopic procedures is considered to be relatively safe, there exists a small but important risk of developing complications, including massive subcutaneous emphysema (SE), hypercarbia, pneumothorax, pneuomomediastinum, and even CO_2 embolism [14].

The incidence of SE varies from isolated and confined in a small space to extravasation outside of the abdominal cavity extending into the labia, scrotum, legs, chest, head, and neck. The literature range is 0.43–2.3% for grossly detectable SE. It has been shown in postoperative computed tomography scans (Fig. 11.2) from laparoscopic cholecystectomy patients that there was a 56% rate of grossly undetectable or clinical subcutaneous emphysema 24 h after the procedure [15].

SE, in its mild form, is not uncommon after laparoscopic MIS. It generally resolves within 1–2 days, but its true incidence is underreported [16, 17].

The clinical significance of SE is development of hypercarbia and acidosis. The increased risk of hypercarbia is caused by the large peritoneal surface tissue area exposed to CO_2 [18, 19]. A combination of factors contribute to increased arterial partial pressure of CO_2 in arterial blood: rapid absorption of CO_2, reduced diaphragmatic movement, a decrease in residual functional capacity, and decreased pulmonary CO_2 excretion, leading to ventilation-perfusion mismatch [20, 21]. Cardiovascular compromise can be caused by mechanical factors from increased intraabdominal pressure, affecting ventilation and venous return and with

accumulation of CO_2 in the circulation, leading to acidosis and cardiopulmonary system compromise [22]. Hypercarbia increases heart rate, systemic blood pressure, central venous pressure, cardiac output, and stroke volume, and it decreases peripheral vascular resistance because of the release of epinephrine and norepinephrine [23–28].

The CO_2 may also track along the pre-fascial planes and cause life-threatening conditions such as pneumothorax, pneumomediastium, pneumopericardium, and the most devastating complication: gas embolism [14].

Factors associated with SE during MIS pneumoperitoneum are methods of laparoscopy MIS (video assisted or robotic) [29], insufflator settings for pressure and flow, actual IAP, actual flow rate, number of abdominal entry sites, size and geometry of fascial incision to trocar size of entry site, snugness of fit between trocar and fascia, number of times the entry site is entered, amount of torquing and pressure on entry sites, vectoring of the laparoscope, fulcrum effect between laparoscope and fascia, length of procedure, volume of gas used, patient age, patient BMI, coexisting metabolic diseases, tissue integrity, type of trocar used, and purposeful extraperitoneal dissection. The total amount of gas used may or may not be related to the length of time of the procedure and may be more important than the length of time of the procedure. Insufflator settings for pressure and flow rate influence insufflation dynamics, the amount of gas absorption or extraperitoneal extravasation with higher pressures, and flow rates contributing to the increased incidence of gas extravasation.

Peritoneal separation can occur because of multiple repetitive movements of the laparoscope acting through a cannula. The cannula acts as a fulcrum for the laparoscope (lever arm) to act as a class-one lever and force multiplier. The pivot point is the fascial entry site. The resulting mechanical advantage can extend the original peritoneal penetration site, allowing gas extravasation into planes outside of the abdomen. During robotic surgery, instrument manipulation occurs without the surgeon's ability to sense or appreciate these forces because of lack of haptic feedback and the inability to see the relationship of the length of the laparoscope to the abdominal entry point. Separation of the surgeon at a console from the patient removes the ability to see the results of their hand movements and how this affects trocar angle and amount of stress and torquing of the peritoneal entry site, because there is little to no haptic feedback (tactile) to alert the surgeon of overstressing the port entry sites. Attention of the assistant at the operating table is important for monitoring not only the robotic instruments but also the entry sites and robotic movements that may compromise the port sites.

Torque is the force causing an object to rotate about an axis, fulcrum, or pivot. The laparoscope rotates about an axis or pivot point as it passes through the cannula, penetrating the abdominal wall. The distance from the pivot point to the point where the force acts is the moment arm, creating a vector that can increase the size of the peritoneal entry defect. Torque pressure sensation can be appreciated during traditional straight laparoscopic procedures but is not felt during robotic procedures, because there is a loss of force feedback and haptic awareness. During robotic procedures, force feedback related to angulation of instruments and trocars and lack of direct visualization of the cannula by the operating surgeon increases the potential for overstressing tissues and loss of tissue layer integrity, which leads to gas extravasation tissue dissection and SE [30].

To reduce the likelihood of subcutaneous emphysema, the following are recommended: awareness of its potential; physician vigilance; attention to detail regarding abdominal entry; monitoring insufflator settings for pressure, flow rate, and volume of gas with alarm settings; quickness, but not rushing, to complete the procedure (length of procedure and gas consumption relate to the condition); reduce the number of attempts to enter the abdomen; have a snug trocar skin condition; test for correct placement by initial IAP assessment; and monitor end tidal CO_2 [30].

Postoperative Complications

Pain

There are several types of pain associated with robotic surgery: incisional port site pain, pain from the peritoneum being distended with carbon dioxide, visceral pain, and shoulder tip pain. The most severe pain occurs immediately after operation and decreases with time [31, 32]. If the pain is not treated effectively, readmission for pain makes the previous benefit of laparoscopic surgery for a shorter hospital stay redundant.

The initial concept of preemptive analgesia was formulated by Crile [33] in 1913 when he described the use of regional techniques to prevent postoperative pain; it is thought to prevent central sensitization and hyper-excitability, which decreases postoperative pain by preventing wind-up and is thought to decrease the incidence of chronic pain [34]. Pre-emptive analgesia is defined as any treatment that prevents establishment of central sensitization caused by incisional and inflammatory injuries and should start before incision, covering the surgical period and the initial postoperative period [34–36]. There remains controversy over the effectiveness and timing of preemptive analgesia, there is only one study that looks at preemptive analgesia in a urological laparoscopic procedures and one systematic review and meta-analysis from nonurological studies that looks at the impact of local analgesia timing and postoperative pain. Coughlin et al. [37] analyzed 26 studies and showed that surgeons should use local analgesia in laparoscopic surgery to decrease postoperative pain (infiltration at port sites or intraperitoneally), but the timing of administration is significant only for intraperitoneal infiltration but not for port infiltration with local anesthetic. Preincisional use of bupivacaine has been recommended (Grade A evidence) in another systematic review of interventions in laparoscopic cholecystectomy [38].

Surgical Site Infection (SSI)

SSIs are infections consequent to the surgery, which are present within a month of the operative procedure. According to the definitions developed by the United States Centre for Disease Control (CDC), SSIs were categorized into [39]: (1) superficial SSIs which involve skin and subcutaneous tissue; (2) deep SSIs, which involve fascia and muscle layers; and (3) organ/space SSIs. Wounds are classified as (as per CDC criteria for SSI 2015) [39]: (1) clean: A surgical wound that is neither exposed to any inflamed tissue nor has breached the gastrointestinal, respiratory, genital, or uninfected urinary tract; (2) clean-contaminated: Surgical wounds where there is controlled entry into the gastrointestinal, respiratory, genital, or uninfected urinary tract with minimal contamination; (3) contaminated: Fresh wounds related to trauma, surgical wounds with major breach in sterile technique or gross contamination from the gastrointestinal tract, and incisions through nonpurulent inflammatory tissues; and (4) dirty or infected: Old wounds following trauma having devitalized tissue and surgical procedure performed in the presence of active infection or visceral perforation.

Most of the surgical procedures done by MIS belong to classes 1 and 2 wounds. The human body hosts a variety of microbes that can cause infections. When the host systemic immunity is suppressed due to any disease, medications, or disruptions of the integrity of the skin or mucous membranes secondary to surgical insult, patients' own commensal microbial flora may cause infection. The SSI in MIS manifest in the form of seropurulent discharge from the port sites with surrounding skin inflammation or symptoms related to the organ/space infection (Fig. 11.3).

Several authors have found that SSI rate is much higher in conventional surgical procedures than in MIS [40–42]. Besides the smaller incisions, the immune functions are less affected in LS as compared with open surgery [43].

SSI soon erodes the advantages of MIS, with the patient becoming worried with the indolent and nagging infection and losing confidence on the operating surgeon. There occurs a significant

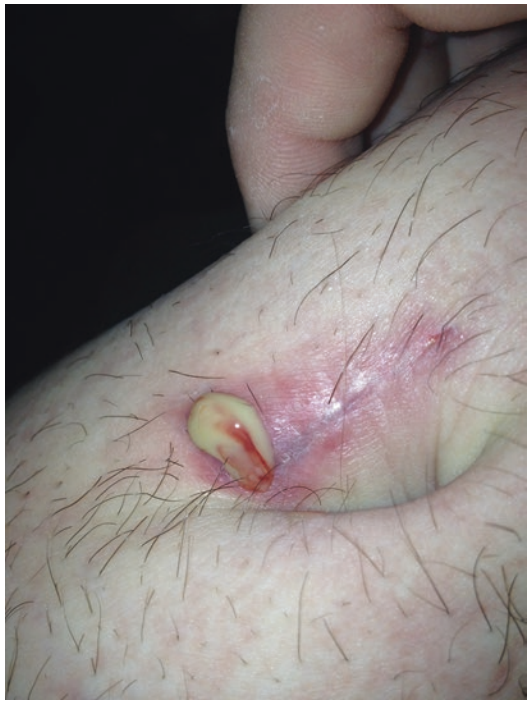

Fig. 11.3 Purulent discharge from umbilical incision

increase in the morbidity, hospital stay, and financial loss to the patient. The whole purpose of MIS to achieve utmost cosmesis is turned into an unsightly wound, and the quality of life of patients is seriously affected [44].

The active surveillance for SSIs in MIS remains a challenge, due to the early discharge and day care setting [40, 42]. In the absence of postdischarge surveillance, it is estimated that a third of all SSIs will be missed [45].

A number of contributing factors are somewhat responsible for the emergence of postoperative PSIs. Antibiotics always may not be the answer to this problem. Thus, using them irrationally, as is often done will only result in the emergence of multidrug resistant microbes. The majority of the reports of postoperative wound infection are of superficial SSIs [42]. The risk factors for SSIs are preoperative stay longer than 2 days [40], duration of operation longer than 2 h [40], emergency/multiprocedure surgery and surgery in acutely inflamed organs [46, 47], history of nicotine or steroid usage, diabetes, malnutrition, long preoperative hospital stay, preoperative colonization of nares with *Staphylococcus aureus*, or perioperative blood transfusion [48, 49]. Obesity, prophylactic antibiotics, and drains have no effect on the rate of SSIs following laparoscopic cholecystectomy [50]. SSIs are also more common in the umbilical port [42]; the infection rate may depend upon the port through which the specimen is extracted. The infected specimen should be removed in an endobag to prevent wound infection and accidental spillage of contents or occult malignant cells.

Specifically about after radical prostatectomy, there was reported a higher incidence of SSI when comparing patients submitted to open radical prostatectomy (ORP) and robotic-assisted radical prostatectomy (24.5% vs 0.6%). Furthermore, SSIs in patients undergoing RARP resolved more quickly (median, 7 vs 16 days) and were less likely to require wound incision and/or drainage (1 vs 84 patients), hospital readmission (0 vs 11 patients), or return to the operating room for debridement (0 vs 6 patients) [51].

SSIs are of two broad varieties based on the timing when they are present. The more common type manifests early, within a week of the surgical procedure. Gram-positive or Gram-negative bacteria are the usual offending organisms which are contracted from the native skin or infected surgical site. They usually respond well to the commonly used antimicrobial agents. The other variety is caused by rapid growing atypical mycobacterium species, which has an incubation period of 3–4 weeks. They show a poor response to the usual antimicrobial agents [52].

Wound discharge and erythema around the port site are the most common presentation of nonmycobacterial infection usually occurring within a week of the surgery. They are usually limited to the skin and subcutaneous tissue [42, 53]. There may be surrounding tissue inflammation with pain or tenderness and low-grade fever [54]. Gram stains and culture sensitivity of the pus from port site wounds are to be taken. The swabs obtained are processed aerobically and anaerobically by standard methods to find the nonmycobacterial isolates. *Staphylococcus aureus* strains are usually isolated from clean wounds. Daily dressing, cleaning of the wound,

and a course of empirical antibiotic are started. Specific antibiotics as per the culture and sensitivity report are to be given subsequently. Drainage and debridement may sometimes be required for assisting in wound healing.

The delayed type of presentation commonly caused by mycobacteria manifests nearly a month after surgery, in the form of persistent multiple discharging sinuses or lumps/nodules, not responding to antibiotics. There may be pigmentation and induration at the port site starting in a single port and spreading to others [44].

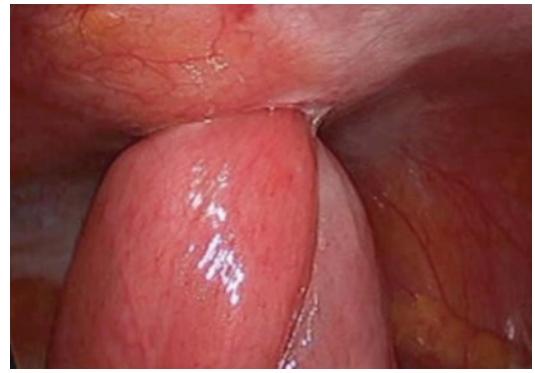

Fig. 11.4 Small bowel obstruction after early-onset trocar site hernia

Trocar Site Herniation

Since the introduction of MIS, trocar port site herniation has become a well-recognized complication. Available estimates of the incidence of laparoscopic trocar site herniation across all surgical subspecialties, based on the largest available studies, range from 0.2% to 1.3% [55–59].

Three types of trocar site herniations have been described: (1) fascial and peritoneal separation (associated with early presentation), (2) fascial separation with intact peritoneum (associated with a later presentation), and (3) herniation of the entire abdominal wall (seen at the time of trocar removal or shortly after surgery) [60]. Early-onset hernias are the most commonly described and typically become apparent within 2–12 days after surgery. Patients with early-onset hernias most often present with small bowel obstruction (Fig. 11.4), which can be a surgical emergency, often necessitating reoperation [57]. It has been reported that approximately 16% of trocar site herniations must be emergently repaired [55].

Patients with late-onset hernias generally present with a bulge several months after surgery, ranging from 0.7 to 27 months [57]. The rate of reoperation in these patients is low, as late-onset hernias can often be managed conservatively, as incisional hernias.

Incisional hernia represents a potentially serious complication to minimally invasive surgery because most require further surgical intervention [57]. In general, incisional hernias represent a technical issue.

Multiple risk factors for trocar site herniation have previously been identified. The most commonly cited risk factor is trocar size, with trocars larger than 12 mm being associated with significantly increased risk [56, 58], but there is a report of a single-case report of herniation at an 8-mm trocar site following robotic prostate surgery [60] and another previously published study on trocar site herniation after robotic surgery is a report in the urologic literature, in which two herniations were seen at 10-mm and larger trocar sites and no herniations were seen at robotic trocar sites [61].

Other previously identified risk factors for trocar site herniation include pyramidal trocars, a long duration of surgery, manipulation of the trocar for specimen retrieval, larger prostate weight, history of prior laparoscopic cholecystectomy, closure of the fascia at the time of surgery, umbilical location (Fig. 11.5), older age, and a higher body mass index [56, 58, 62].

Special attention has been taken to the extraction site of the specimen during RARP. Studies have shown that the extraction site at midline of the abdomen in longitudinal incisions have a higher chance of becoming hernias and suggestions of preferential extraction sites to minimize incisional hernia rates should be incisions off the midline [63, 64]. Most of the extractions site used for robotic urology is the camera port located usually at the midline of the abdomen.

In one single-surgeon MIRP series, incisional hernias occurred more often after a vertical than after a transverse incision [65], corroborating a

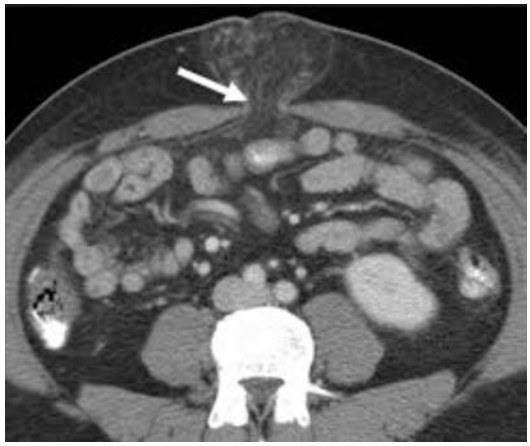

Fig. 11.5 CT scan of an incisional periumbilical hernia (*white arrow*)

Cochrane review of seven trials of abdominal surgery, in which a significant difference was seen in favor of the transverse incision over the midline [66].

A large Danish review of more than 7,000 laparoscopic procedures showed that emergent reoperation was needed in 16% (15/95) of patients with trocar site herniation [55]. No patients in this large study or our study required bowel resection. The need for bowel resection due to incarcerated hernia has been reported [60, 67]. A review of 30 case reports of trocar site herniation reported a 17% (5/30) incidence of need for bowel resection when emergent reoperation was performed [57].

Inguinal Hernia

Inguinal hernia (IH) after ORP using the retropubic approach is well described [68]. Recent reports suggest that the frequency of inguinal hernia within 4 years after surgery is 12–21% after ORP [69, 70] and 6% after MIRP [71].

It has been reported a lower incidence of postoperative IH after robotic-assisted radical prostatectomy (RAPL) than ORP. The two procedures differ concerning the incision through the abdominal wall [71]. When ORP is performed through a 10–15 cm long incision in the midline between the symphysis pubis and the umbilicus, the RALP is performed through five or six shorter incisions spread out on the lower part of the abdomen, suggesting that the length of the incision is of great importance for the development of IH. They reported a postoperative IH incidence as high as 38.7% after RRP, but only 2.9% in a group of 272 patients in whom the procedure was performed through a so called "mini-laparotomy" incision of only 6 cm [72].

It has been also reported an IH incidence of 1.8% after radical perineal prostatectomy, in which the whole procedure is performed through a perineal incision, and consequently, there is no abdominal incision at all [73].

Reinforcing the idea that the length, and possibly the placing, of the abdominal incision seems to affect the development of postoperative IH, it was published a study with 5478 men treated by RRP for the outcome of IH repair rates, with an incidence of IH of 17.1% at 10-years follow-up [74]. The corresponding rate after transurethral resection of the prostate was 9.2%.

Although it is not known who is destined to develop IH after RARP, the risk factors of increased age, lower BMI, and previous inguinal hernia repair for post-RP inguinal hernia might define a subset of patients that should undergo careful preoperative and intraoperative evaluation for subclinical inguinal hernia so that concurrent inguinal hernia repair can be undertaken at RARP [75]. Defining the role of prophylactic inguinal hernia repair in those without a subclinical inguinal hernia would require evaluation.

Our experience and observation is that after the dissection is performed for the robotic prostatectomy and the internal ring of the inguinal canal is altered and the fatty tissue removed there is a change of the patients that had a nonclinical inguinal hernia become symptomatic after the surgery.

Port-Site Metastasis

Postlaparoscopic occurrence of port-site metastasis (Fig. 11.6) refers to tumor foci either localized at single or multiple locations under the skin or in the scar tissue of the abdominal wall adjacent to

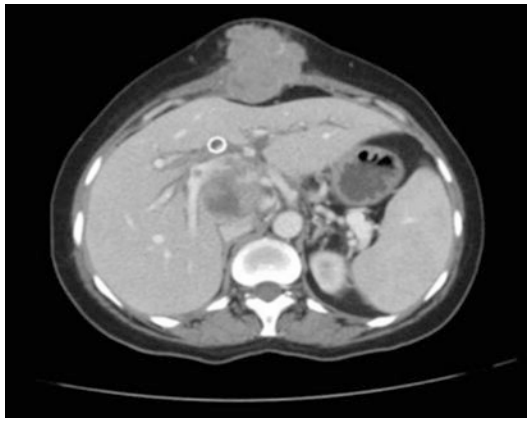

Fig. 11.6 Large port-site metastasis seen on CT scan

the port [76]. Port-site metastasis is a rare complication that may occur following laparoscopic surgery for malignant tumors of the urinary system, with an incidence of 0.09–0.73% of all patients who undergo laparoscopic surgery for urological malignancies [77, 78]. Previous studies have reported ~50 cases of abdominal wall implantation metastasis following surgical resection of malignant tumors of the urinary system [79], of which, 9 cases occurred following surgical resection of renal carcinoma [80–93]. Thus, this indicates that the occurrence of port-site metastasis subsequent to laparoscopic radical resection of renal carcinoma and nephron-sparing surgery is relatively rare.

The performance of a laparoscopy is associated with a number of additional factors that may provoke metastasis, including the presence of pneumoperitoneum, contamination around the port site, incomplete tumor resection, and the particular method used to remove the specimen [94].

A review of the current literature indicates that the occurrence of port-site metastasis subsequent to laparoscopic radical resection of renal pelvis carcinoma and nephron-sparing surgery is relatively rare, and its cause is multifactorial. Although the exact cause remains unclear, the occurrence of port-site metastasis may be considered attributable to the combination of holistic and local factors. Measures to reduce the occurrence of port-site metastasis include strict abidance to the surgical guidelines for tumor resection, avoidance of air leakage at the port site, use of impermeable specimen bags to remove the specimen under direct vision, irrigation of the laparoscopic surgery instruments and incisional wound with povidone-iodine when necessary, and enhancement of the body's immunity [95].

Summary

The complications of the abdominal wall during urologic procedures have been described during the laparoscopic era, and now, we are facing an increase in the incidence due to the larger adoption of MIS facilitated by robotic technology. Recommendations to avoid them and how to resolve them if they are encountered are given.

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Vascular Complications

12

David Michael Hatcher and René Sotelo

General Considerations

Vascular complications are one of the most common and urgent complications encountered during robotic urologic surgery. Although complication rates for robotic surgery compare favorably with their open and laparoscopic counterparts [1], complications can occur during any stage of surgery, including during initial access and port placement, intraoperatively, and postoperatively. Timely recognition and a calm, thoughtful response are critical to ensure minimal harm to the patient. Management may require blood transfusions, open conversation, angioembolization, or reexploration.

Avoidance of vascular complications requires appropriate patient selection, knowledge of the surgical anatomy, and proper surgical technique. Thorough preoperative planning and preparation can go a long way toward reducing the risk of vascular complications. All imaging studies should be reviewed prior to surgery to identify anatomic variations. Preoperative coagulation tests should be obtained on high-risk patients. When appropriate, anticoagulation/antiplatelet agents should be held prior to surgery.

At the time of a suspected vascular injury, the surgeon must quickly decide if it can be managed with a minimally invasive approach or if open conversion is necessary. In fact, vascular injuries are the most common cause of open conversion. Patient safety should be the only concern in this situation, not maintenance of a minimally invasive approach, as this is a life-threatening situation. Eighty-one percent of deaths during laparoscopic surgery were attributed to major vascular injuries [2]. An open tray should always be available in the room and ready to be opened without advanced notice. If open conversion is necessary, a large incision should be used. A midline location typically works well, depending on patient positioning and the procedure being performed. Obtain proximal and distal vascular control, and repair the injury.

In the event of a major intraoperative vascular injury, anesthesia should be notified immediately so that they may request blood products and begin hemodynamic resuscitation of the patient. Additional surgical, nursing, and anesthesia staff may be required. Vascular or trauma surgeons may be called into the room if needed.

This chapter discusses common intraoperative and postoperative vascular complications including thromboembolic complications. Procedure-specific vascular injuries are discussed in their respective chapters.

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Access-Related Complications

Seventy-five percent of major vascular injuries occur during initial access for laparoscopic cases [3, 4]. Initial access can be obtained with either a closed or open technique (Veress needle technique or Hasson technique, respectively). Veress needle access entails blind puncture of a hollow needle with a retractable blunt tip. Insufflation is through the needle. Hasson (open entry) technique entails obtaining access via sharp dissection through all layers [5, 6]. When choosing the location to obtain initial access and deciding between an open versus closed technique, keep in mind if the patient has had previous surgeries and the location of previous incisions. Choose a site a safe distance away from scars. Prior to attempting initial access, always ensure a working camera, insufflation, cautery, and laparoscopic suction. Precious time may be wasted setting up equipment after a suspected injury has occurred.

The AUA Handbook of Laparoscopic & Robotic Fundamentals concluded there was insufficient evidence to recommend one technique over another for obtaining access [7]. Although there is likely a greater incidence of vascular injury with the closed technique, the open Hasson technique does not eliminate the risk of vascular injury [8–10]. The most commonly injured vessels are the aorta, the inferior vena cava, the iliac vessels, and the epigastric vessels [11]. When the great vessels are likely to be near the site of access, the Hasson technique may be preferable [12]. The open approach may also be preferable for children, very thin patients, and patients with extensive adhesions. In some instances, access may be preferable through a retroperitoneal or extraperitoneal approach.

Ultimately, comfort and familiarity with different access approaches are critical when encountering difficulty in gaining access.

Veress Needle Injury

The reported incidence of vascular injury during Veress needle access is low [8, 13–16]. A meta-analysis reported a 0.23% risk of vascular injury with the Veress technique [15]. During needle passage, there is a risk of injury to superficial abdominal wall vessels or deeper abdominal, retroperitoneal, or pelvic vessels. Very thin and obese patients are at an increased risk for injury as the angle and distances of common surgical landmarks and vascular structures are different. During Veress needle insertion, the needle should be advanced without exerting too much force. Two distinct "pops" or "clicks" should be felt/heard as the needle is advanced through the fascia and the peritoneum. The angle of the needle during insertion should be adjusted based on patient body mass index (BMI) from 45° in nonobese patients to 90° in obese patients (Fig. 12.1) [17]. Decide in advance the number of attempts of Veress needle passage before switching to open access. The bifurcation of the great vessels is approximately at the level of the umbilicus, placing the right common iliac artery at risk when obtaining access from a periumbilical location.

After placement of a Veress needle, the needle should always be aspirated to assess for blood. This is done to recognize vascular injuries and prevent insufflation into vascular structures. Possible causes of injury include incorrect angle of insertion and/or too much axial force on the needle during insertion. If blood is withdrawn during aspiration, access should be obtained in a different location. Some surgeons prefer to leave the needle in place with the stopcock closed, without further manipulation of the needle, to help identify the location of the injury. Others prefer to remove the Veress needle if a vascular injury is suspected, before attempting access in a different location. Either approach is normally acceptable as most Veress needle vascular injuries are small and do not require repair. If a major vascular injury is suspected, however, the Veress needle should always be left in place to facilitate quick identification of the location of the injury.

Insufflation should not be performed through a Veress needle into a suspected vascular structure as this may cause a CO_2 embolism. CO_2 embolism presents as acute circulatory collapse with elevated central venous pressure (CVP), elevated right heart pressure, hypoxia, hypercarbia, and a stereotypical "mill wheel" heart

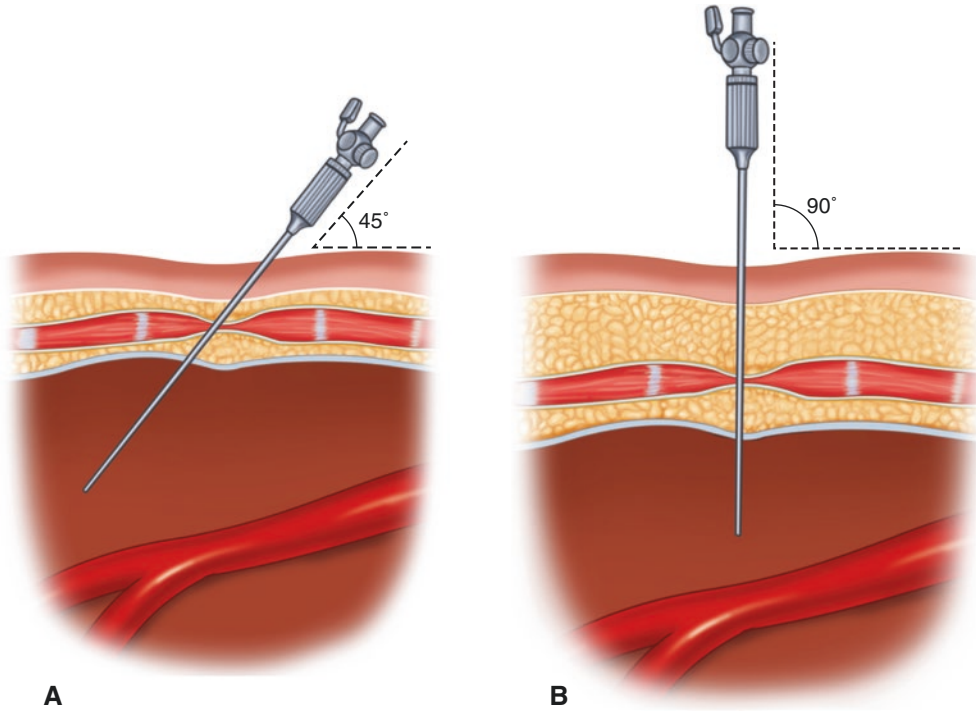

Fig. 12.1 Angle of Veress needle during placement in nonobese (**a**) and obese (**b**) patients

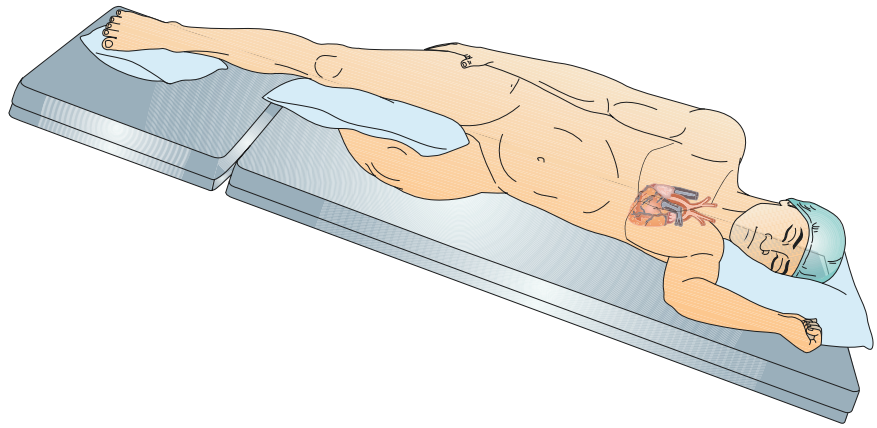

Fig. 12.2 Left lateral decubitus position with the head down

murmur. To treat, immediately stop insufflation, desufflate the abdomen, and place the patient in the left lateral decubitus position (right side up) with the head down (Trendelenburg position) (Fig. 12.2) [18]. This maneuver, the Durant maneuver, prevents an "air lock" in the pulmonary circulation. An attempt may then be made to aspirate the gas bubble with a central venous catheter from the right ventricle. The patient may ultimately require cardiopulmonary bypass.

Trocar Injury

Vascular injury during initial trocar placement has the potential to be much more devastating (Fig. 12.3). A meta-analysis showed a 0.03% incidence of vascular injury with the Hasson technique [19]. Although the likelihood of this injury is low, the mortality rate is higher than with a Veress needle injury. Unlike with smaller diameter Veress needle injuries, trocar injuries almost always require open conversion. Trocar injuries may occur during initial trocar placement, but they should never occur during secondary trocar placement as these are performed under direct vision. Ensure the skin incision is long enough to accommodate the trocar, and do not apply too much axial force during trocar insertion. For additional control, both hands may be used while advancing the trocar, to prevent sudden, deep progression of the tip of the trocar.

Optical trocars, in which the camera sits within the trocar's transparent obturator, allow for direct visualization of all layers as the trocar is inserted and are associated with few complications [20]. This can be used in either a desufflated abdomen, which has a higher complication rate [21, 22], or after initial insufflation with a Veress needle. Cutting trocars, which use a blade to penetrate the fascia, are associated with a higher risk of injury to abdominal wall vessels compared to blunt/dilating trocars.

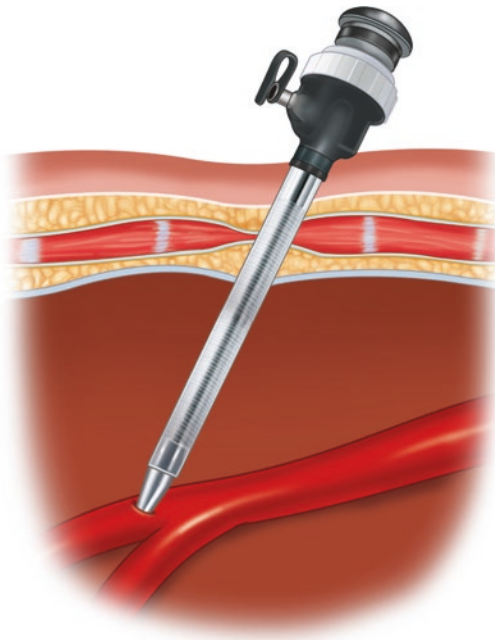

Fig. 12.3 Vascular injury during initial trocar placement

Injury is initially suspected by blood filling the trocar. If this is encountered, the trocar should be left in place to help tamponade the injury and facilitate rapid identification of its location, similar to suspected major Veress needle injuries. The trocar port should be closed and not connected to insufflation. If secondary trocars can be safely inserted, pressure may be held on the bleeding site with a gauze sponge or laparoscopic instrument, allowing for a more controlled assessment of the situation. Alternatively, if there is concern for a major injury, immediate laparotomy should be performed. If open conversion is necessary, the laparoscope may be directed toward the body wall, and the incision may be made directly over the laparoscope to facilitate a rapid, safe entry [23].

Of note, sometimes a major bleed may be more subtle, and a retroperitoneal or mesenteric hematoma may be the only sign of an injury. A small, non-expanding hematoma may be monitored intraoperatively. If it is expanding, the hematoma should be opened and repaired. Opening a hematoma is likely to cause bleeding, so this should be anticipated.

Bleeding alongside a trocar or along the inner anterior abdominal wall is suggestive of an injury to the epigastric vessels. These are the most commonly injured small vessels during Veress needle or trocar placement [11]. Injury most often occurs during insertion of secondary trocars through the rectus muscle [24]. To avoid this injury, trocars should be placed either in the midline or at least 6 cm lateral to midline. There may also be a delayed presentation with development of an abdominal wall hematoma or port site ecchymosis. Different techniques have been described for the management of epigastric bleeding encountered intraoperatively including direct cauterization, temporary tamponade with the trocar or a foley balloon placed through the trocar, or suture ligation either under direct vision or with a fascial closure device (Carter-Thomason CloseSure®

System, Inlet, Trumbull, CT); however, suture ligation is the preferred method. Cauterization may lead to re-bleeding. Foley placement through the port site will stretch the opening, disrupt muscle, and may further disrupt the vessel in the abdominal wall.

Intraoperative Vascular Injuries

Vascular injuries occurring after initial access may be a result of blunt, sharp, or thermal dissection or by suture ligation, clipping, or stapling. Vascular injuries during tissue dissection account for 25% of major vascular injuries [3, 4]. Proper surgical technique helps to prevent most vascular injuries. This includes meticulous dissection, working from superficial to deeper layers, to prevent "working in a hole." Injuries may be caused by unintentional instrument motions or may even occur outside the camera's field of view by the surgeon or the bedside assistant. The most feared injuries with the highest risk of mortality are to the great vessels and their major branches. Intuitively, vascular injuries are more common during those procedures that require dissection around major vascular structures.

Initial management often involves raising the pneumoperitoneum to 20–25 mmHg, ensuring adequate suction, and holding direct pressure, sometimes with the use of a mini-laparotomy pad. Bleeding from a venous source is often reduced solely by raising the pneumoperitoneum. The bleeding site should be compressed either with a robotic grasper, laparoscopic instrument, suction, or fourth arm [23, 25]. The surgeon must assess the magnitude of the injury and whether it is arterial or venous; low-volume oozing typically suggests venous bleeding, while large volume, pulsatile bleeding suggests arterial bleeding.

Management options include direct pressure, monopolar cautery, bipolar thermal sealing, clipping (e.g., titanium or locking clips), stapling, suture repair, and hemostatic agents. Simply applying direct pressure will often stop the bleeding from small venous tears. When needed, the surgeon should insert additional trocars, use a gel hand port, or convert to open surgery. If the patient is hemodynamically stable, then repair may be attempted robotically. Suction should be used judiciously in the event of a venous injury, as it decreases pneumoperitoneum and promotes bleeding.

In addition to an open tray, additional equipment should be available in the room in the event of a vascular injury. This includes laparoscopic and robotic needle drivers, Lapra-Ty and Weck clip appliers, Bulldog clamps, Satinsky clamps, hemostatic agents, gauze sponges, and a "rescue stitch." The rescue stitch typically consists of a large needle suture with a clip tied at the end for the rapid repair of a vascular injury [26]. Multifilament sutures are easier to handle and tie, although vascular surgeons typically recommend monofilament sutures. A large needle is easier to see in a blood-filled surgical field (e.g., 2-0 Vicryl, CT-1 needle, 10 cm, with a Hem-o-lok clip tied at the end).

If the patient is unstable or the bleeding is massive, then immediate open conversion should be performed [27]. The bleeding will be worse after opening the abdomen and losing pneumoperitoneum, so the bleeding site should be immediately compressed. To counteract this, a mini-laparotomy pad may be inserted and pressure applied against the source of bleeding with a laparoscopic instrument while obtaining open access. Alternatively, a laparoscope can be used to directly compress the source of bleeding.

Vascular load staplers and clips, such as titanium and locking clips (e.g., Hem-o-lok, Teleflex Medical, Research Triangle Park, NC), have been shown to safely control large vessels as securely as traditional suture ligature [28–30]. Vascular stapler malfunction has been reported in up to 1.7% of cases and can result in major blood loss. To avoid this, ensure there are no clips within the stapler jaws when firing. Conversely, clips can be placed over staple lines. As a general rule, clips should be used sparingly in areas where staplers may be fired (e.g., renal hilum). Align the vessel or intended tissue within the markings on the stapler cartridges prior to firing. The stapler should be applied several millimeters distal to the origin of the blood vessel to provide an adequate stump

in case of malfunction. The same rule also applies to clip application. When controlling large vessels with clips, it is advisable to place three clips on the "stay" side of the vessel and one or two clips on the "specimen" side.

Hemostatic agents are often used to minimize blood loss by promoting local coagulation, as adjuncts to traditional hemostatic techniques. There are numerous agents on the market including "glues" or "sealants," gels, and sheets. These should not be relied upon to stop significant surgical bleeding alone. A detailed discussion of individual agents is beyond the scope of this chapter. Comparative trials are lacking, so the utility of many of these agents remains mostly speculative.

Unintentional injuries to the spleen and liver may be caused by overzealous retraction. This may be prevented by a careful division of attachments and gentle retraction or packing to keep these organs out of the operative field. Splenic injuries have been reported in up to 2.6% of retroperitoneal surgery [31]. Small lacerations and capsular tears to the liver or spleen may be treated by releasing traction and applying gentle pressure with or without hemostatic agents. Splenectomy may be necessary if other measures to obtain hemostasis fail. These patients should receive meningococcal, pneumococcal, and Haemophilus influenzae type b immunizations [32].

At the end of an operation, the operative field should be inspected at low insufflation pressure. If a significant volume of blood accumulates during this period of low pressure, an exhaustive search should be conducted to find and control the site of bleeding. Irrigation of the surgical site may demonstrate pooling of blood, which aids in identification. Because trocars may tamponade bleeding, all port sites should be inspected under direct vision at low pressure and while being removed to assess for bleeding [24]. Minor bleeding can be managed with cautery. More significant bleeding may require suture ligation either directly or with a fascial closure device (Carter-Thomason CloseSure® System, Inlet, Trumbull, CT).

Postoperative Bleeding

Patients can present with signs and symptoms of bleeding at any time after surgery. These include hypotension, tachycardia, anemia, dyspnea, altered mental status, lightheadedness, syncope, low urine output, high drain output, ecchymosis, abdominal pain, and abdominal distension. The quality and volume of surgical drain output can be indicators of hemorrhage, but the absence of blood in the drain does not exclude bleeding. Postoperative labs should be performed. It may take several studies before hemoglobin levels indicate anemia.

The diagnosis is often made based on clinical suspicion and characteristic signs and symptoms; however, additional imaging including CT can be utilized. Small hematomas may be managed conservatively [33]. Large hematomas pose the risk of severe pain and infection, with drainage of the hematoma an option [34]. Hemodynamically stable patients with suspected delayed bleeding can be managed with selective angioembolization. Hemodynamically unstable patients should be managed with surgical exploration. Reexploration by a robotic or laparoscopic approach may be attempted. If a surgical drain was placed, it can be used for insufflation. A large 10 mm suction cannula should be used to aspirate all blood clots [35].

Delayed bleeding presenting for several weeks after surgery may be due to an arteriovenous fistula or pseudoaneurysm [36]. These most commonly occur after partial nephrectomy with a reported incidence of 0.4% for pseudoaneurysm and 12% for arteriovenous fistula [37]. A venous fistula may also present as postoperative hematuria. These can be managed with angioembolization.

Thromboembolic Complications

Thromboembolic diseases include both deep vein thrombosis and pulmonary embolism. These are the most common preventable causes of hospital death [38]. Although the advent of minimally

invasive surgery has decreased the incidence of thromboembolic events, many patients undergoing robotic urologic surgery are at an increased risk for these complications. Risk factors include hypercoagulability from cancer, pelvic surgery, prolonged immobilization, lithotomy position, pneumoperitoneum, and vascular injury [39].

There are several different modalities available to prevent these life-threatening complications, including early ambulation postoperatively. Mechanical devices, which act by reducing lower extremity venous stasis and releasing antithrombotic factors, include graduated compression stockings and intermittent pneumatic compression devices. Of note, in the event of an iliac vein injury, intermittent pneumatic compression devices should be deactivated as they increase bleeding and counteract the tamponade effect of pneumoperitoneum. Pharmacologic prophylaxis includes low-dose unfractionated heparin, subcutaneous low molecular weight heparin, oral warfarin, and newer anticoagulants.

The perioperative management of anticoagulation/antiplatelet agents must weigh the increased risks of significant bleeding against those of thromboembolic events. For certain elective procedures, the risk of thromboembolic complications is considerably higher than that of significant bleeding. In general, anticoagulants/antiplatelets should be resumed as early as possible after surgery [40]; however, there is limited evidence of the shortest interval after which the risk of significant bleeding is minimal. Mechanical prophylaxis should be used in all patients during the entire postoperative period, with an emphasis on early mobilization. The decision to give pharmacological prophylaxis must be taken on a case-by-case basis [41].

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13 Visceral and Gastrointestinal Complications in Robotic Urologic Surgery

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Introduction

With the widespread use of minimally invasive techniques, robot-assisted urologic surgery has become widely adopted worldwide. Despite the great advantages of this technique, associated complications also must be considered. Along with vascular injuries, visceral and gastrointestinal lesions are among the most dangerous complications, and it is crucial to recognize them. Despite their infrequency, these complications could be life-threatening, and early diagnosis and management is crucial [1].

Overall Incidence

Reports from large multi-institutional studies of laparoscopic and robotic urologic procedures show overall complication rates from 4.4% to 16% [2]. Focusing on gastrointestinal injuries, the reported incidence of bowel injury is approximately 1.3 per 1000 cases [3].

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Access-related gastrointestinal injury has an incidence rate of 0.13%. The most frequent such injury is to the small intestine, with incidence of 41.8%. Incidence of nonaccess-related bowel injury is 0.8% [3].

Regarding general bowel complications (including ileus, small bowel obstruction, and port-site or incisional hernia), the overall incidence with robot-assisted laparoscopic surgery is 0.85–8.2%.

Impact on Outcomes and Management: Clavien–Dindo and Martin–Donat Classifications

Several publications have assessed complications after robot-assisted urologic procedures, but many studies are limited by their small simple size, short follow-up, and lack of risk factor analysis. In addition, a lack of uniformity exists in documenting and reporting these complications. This lack results in incomplete data, precluding accurate analysis and comparisons [4].

Standardized systems for reporting and classification of surgical complications provide better information and can support correct identification and management. The Clavien–Dindo classification (Table 13.1), reported for the first time in 1992, is based on the main criterion of the needed intervention to resolve the complication [5, 6]. The urologic literature shows a substantial increase recently

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Table 13.1 The Clavien–Dindo classification of surgical complications

Grade	Definition
I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions Allowed therapeutic regimens are drugs as antiemetics, antipyretics, analgesics, and diuretics, electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside
II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications Blood transfusions and total parenteral nutrition are also included
III Requiring surgical, endoscopic, or radiological intervention III a Intervention not under general anesthesia III b Intervention under general anesthesia	
IV Life-threatening complication (including CNS complications)[a] requiring IC/ICU[b] management IV a Single organ dysfunction (including dialysis) IV b Multiorgan dysfunction	
V	Death of a patient
suffix « d »	If the patient suffers from a complication at the time of discharge, the suffix "d" (for "disability") is added to the respective grade of complication. This label indicates the need for a follow-up to fully evaluate the complication

From: Mitropoulos et al. [5] with permission from Elsevier

[a]CNS = central nervous system complications: brain hemorrhage, ischemic stroke, subarachnoid bleeding, but excluding transient ischemic attacks

[b]*IC* intermediate care; *ICU* intensive care unit

in the use of this classification. Growing evidence suggests that the classification is valid and applicable worldwide in many fields of urologic surgery, including robot-assisted procedures [7].

Given the lack of standards in reporting surgical complications, Martin et al. identified ten critical elements of accurate and comprehensive reports: data accrual, outpatient information, follow-up duration, mortality and morbidity rates, definition of complications, procedure-specific complications, severity grade, length of stay, and risk stratification analysis [8]. In 2007, Donat modified the criteria to include procedure-specific complications for urology, such as urine leak, lymphocele formation, ileus, or inadvertent visceral injury [9] (Table 13.2).

The use of both standardized classifications helps to objectively rate the cumulative data and to make well-established comparisons of the published literature. Agarwal et al. [4], for example, carried out an analysis of >3300 robot-assisted radical prostatectomy (RARP) cases by reporting the complications according to the Martin–Donat criteria and stratifying them using the Clavien–Dindo classification. The authors provided a safety profile for this procedure. Verification of these observations will require well-designed, collaborative, quality initiatives.

Rabbani et al. [10] retrospectively reviewed 4592 retropubic and laparoscopic (including robot-assisted) radical prostatectomy cases performed at a single institution. They captured and graded all medical and surgical complications according to the Clavien–Dindo classification and comprehensively reported the complications using the standards determined by the Martin classification. They found higher complication rates than those described in the literature, possibly because of more accurate reporting. In multivariate analysis, the laparoscopic approach was associated with higher incidence of complications except for the major surgical complications that were more frequent with the retropubic approach. The authors claimed that this finding could be related to the presence of more frequent and severe comorbidities in the laparoscopic group. Consequently, they concluded that accurate reports of complications based on standardized classification systems could result in higher complication rates but are crucial for identifying risk factors and making well-established comparisons with the literature.

The importance of correct classification lies in the ability to identify complications correctly and to determine their subsequent management.

First Trocar Placement

Laparoscopy and robot-assisted laparoscopy are minimally invasive techniques for access to the peritoneal cavity or to the retro- or extraperitoneal space. Insufflation of CO_2 is necessary for the correct creation of a working space in the abdomen.

Table 13.2 The Martin–Donat complication reporting criteria

Reporting criteria	Definition of criteria
Method of accruing data defined	Prospective or retrospective accrual of data indicated
Duration of follow-up indicated	Report clarifies period of prospective accrual of complications such as 30 days or same hospitalization
Outpatient information included	Study indicates complications first identified after discharge are included in analysis
Definitions of complications provided	Report identifies at least one complication with specific inclusion criteria
Mortality rate and causes of death listed	A number of patients who died in postoperative period of study are recorded, together with the cause of death
Morbidity rate and total complications indicated	Number of patients with any complication and total number of complications are recorded
Procedure-specific complications included	Radical nephrectomy: bleeding/transfusion rate, vascular injury, inadvertent visceral injury (pleural, colon, pancreas, spleen), ileus Partial nephrectomy: same as for radical nephrectomy plus urine leak Radical cystectomy: bleeding/transfusion rate, ileus, urine/bowel leak, thromboembolic events, anastomotic stricture, fistula, rectal injury, vascular injury Radical prostatectomy: bleeding/transfusion rate, inadvertent visceral injury (nerve, rectal, ureteral), urine leak, lymphocele Retroperitoneal node dissection: bleeding/transfusion rate, vascular injury, lymphatic leak/ascites, pulmonary (atelectasis, ARDS[a], pneumonia), inadvertent visceral injury (pleural, colon, kidney, spleen, pancreas, ureteral), ileus
Severity grade used	Any grading system designed to clarify severity of complications, including "major versus minor," is reported
Length of stay data	Median or mean length of stay indicated
Risk factors included in analysis	Evidence of risk stratification and method used indicated

From: Donat [9], with permission from Elsevier
[a]*ARDS* acute respiratory distress syndrome

There are three options for initial port placement: (1) closed access with a Veress needle, (2) open Hasson technique, or (3) direct access with or without an optical port [11, 12].

Blind Veress Needle Access

Blind Veress needle access is the oldest and most common method of peritoneal insufflation [12]. The Veress needle design uses two cylinders: The inner one has a retractable blunt tip; the outer one, with a sharp edge, allows tactile feedback as it passes through the layers of the abdominal wall [13].

Once Veress needle is placed, before starting insufflation, several maneuvers can be used to confirm proper positioning (e.g., aspiration to exclude blood or bowel content, the "drop test," the "advancement test"). The abdomen is then insufflated with CO_2. At that moment, the abdominal pressure should be <9 mm Hg. This low intra-abdominal pressure indicates the correct placement of the needle [13, 14].

To avoid failures such as placement into an adherence or the bowel, the Veress needle should be placed away from previous surgical scars [11, 13]. For Bianchi et al., the intestinal perforation rate with the blind access technique was 0.33% [12].

Open Hasson Access

The Hasson technique was developed in 1971 [15] as a safe way to enter into the peritoneal cavity. Since then, many laparoscopic and robotic urologists have used open Hasson access as a primary technique [16].

To begin, a 12- to 15-mm skin incision must be made and deepened to the fascia of the rectus. Next, the fascia is incised, and muscle layers are split. After that, the peritoneum is opened sharply. Using a finger, the surgeon checks the correct opening of the peritoneum and the absence of near adhesions. Finally, a blunt-tipped Hasson cannula is inserted directly into the peritoneum. Sutures are placed on both sides of the incised fascia to hold the trocar and to help with closure at the end of the surgery.

This technique is recommended when the patient has had previous abdominal operations, and the risk of abdominal adhesions is high. Retroperitoneal renal access also typically uses this technique [11]. The intestinal perforation rate with this technique has been described as 0.05% [12].

Direct Optical Access

Optical ports have a conical nonbladed trocar tip beside an inner sleeve-handle system for 10-mm lens insertion. This technique requires elevation of the anterior abdominal wall with hands or preplaced clamps. After skin incision, the bladeless optical trocar is placed at the entry site and allows visualization of the different tissue layers. With a twisting motion, the trocar advances in the desufflated abdomen until the peritoneal cavity is identified and entered. Despite visualization of tissue layers, these ports cannot prevent serious injuries because the lack of pneumoperitoneum can easily result in bowel or vascular injury [13]. Nevertheless, Bianchi et al. present this access technique to be one of the safest [12].

Intestinal Preparation

In 1977, Freiha applied the mechanical bowel preparation that was first developed for colorectal surgery to urologic surgery [17]. Preoperative bowel preparation attempts to reduce bacterial loading in the intestinal lumen to prevent complications after intestinal surgery and, historically, has been considered the standard of care for patients undergoing colorectal and urologic surgeries involving the bowel [18].

Surgeons performing bowel anastomosis strive to achieve quick recovery of bowel function, to reduce hospitalization days, and to avoid infectious complications, bowel leak, and anastomosis dehiscence.

In recent years, routine preoperative bowel preparation has been questioned. A number of nonrandomized and randomized clinical trials have shown that this kind of preparation may not be effective in reducing postoperative complications [19–21]. In fact, bowel preparation has some disadvantages such as potential nutritional imbalance, long hospitalization, patient exhaustion, and patient inconvenience [22, 23].

The literature suggests that mechanical bowel preparation can be safely omitted in robot-assisted laparoscopic prostatectomy [23], as well as in cystectomy with ileal urinary diversion, given the absence of demonstration that bowel preparation could prevent the development of postoperative complications [21–24].

The benefits of use of oral antibiotic bowel preparation in urologic surgeries have yet to be demonstrated but have been shown in colorectal literature to decrease infectious complications [23].

Preoperative Imaging to Prevent Injuries

Preoperative imaging based on computed tomography (CT) scan or magnetic resonance imaging (MRI) is mandatory for assessing the complexity of the cases and planning the appropriate operative intervention and approach. Consequently, the potential difficulties are predicted and anticipated, allowing better intra- and postoperative outcomes and low complication rates. These advantages create a safer surgical environment [25].

Initial trocar insertion, outside of the surgeon's field of vision, could cause visceral damage (e.g., liver or spleen injuries). To avoid it, preoperative imaging studies based on CT scan are important to detect organomegaly; in such cases, the sur-

geon could perform lower abdominal or umbilical trocar placement [3].

In renal surgery, identifying the presence of intra-abdominal adhesions should change the surgical trocar access; therefore, initial retroperitoneal access should be considered in patients with multiple prior abdominal surgeries. It is important to note that both the retroperitoneal and transperitoneal approaches have equivalent overall complication rates [26]. Furthermore, in nephron-sparing surgery, it is important to correctly characterize renal masses to identify complexity groups and to estimate the potential perioperative complications. Several standardized anatomical classification-scoring systems have been described for this purpose [27, 28] and have proven to be important tools for preoperative planning and effectively correlating postoperative results and complication rates [29].

Regarding prostate surgery, comprehensive preoperative planning, including MRI, is important to ensure safe and successful surgery, even among challenging operative cases [30]. MRI provides anatomical information about the prostate and pelvis cavity, and this prior knowledge allows the surgeon to perform precise prostate dissection, with preservation of neurovascular bundles if indicated, and to avoid complications like rectal perforation [31].

In robotic bladder surgery, specifically radical cystectomy, the complications include those relating to radical prostatectomy as well as those inherent to bowel-based urinary diversions. Imaging techniques used for assessment of local extension are CT and MRI, but both are able to distinguish only the macroscopic invasion of perivesical fat and adjacent organs, as well as upper urinary tract involvement, if present [24]. Consequently, prior knowledge of the extent of the disease is essential when planning surgery and preventing potential complications. In addition to gastrointestinal complications after robotic bladder surgery, such as rectal or bowel injury or anastomosis dehiscence, other potential visceral complications include ureteral injury. This may occur in patients in which ureteral identification is challenging, such as those with fibrosis, prior radiation, or chemotherapy. To avoid this problem, intraoperative retrograde instillation of indocyanine green (ICG) into the ureter could aid ureteral identification. ICG is instilled using a ureteral catheter and causes fluorescence, appearing bright green when viewed under infrared imaging using the Firefly system on the da Vinci robot system (Intuitive Surgical, Sunnyvale, CA) [1]. This tool might also be useful in renal and ureteral surgery.

In summary, preoperative imaging in robotic urology surgery may help decrease the likelihood of bowel or visceral injury and increase the chance of recognition when injury occurs.

Intra-Abdominal and Pelvic Visceral Lesions

Small Intestine

As in laparoscopic surgery, a bowel injury can occur anytime during robotic urologic surgery, from access to closure, and may be life-threatening if not recognized and repaired during the procedure. Van der Voort et al. showed that the incidence of gastrointestinal tract injury during laparoscopy was 0.13% [32]. Others described intestinal injury rates of 0.23% [12] and even 0.6% [2]. With an injury rate of 41.8%, the small intestine is the most commonly injured bowel portion. Access to the abdomen using a Veress needle or trocar is the main reason of this high rate. Most of the trocar-induced bowel injuries result from the first trocar placement, which is not positioned under direct vision [3].

Because of the high morbidity associated with duodenal leakage, injury of the duodenum is a very serious complication. These injuries could happen during right-side procedures, such as radical or partial nephrectomy and adrenalectomy.

Bowel injury that needs repair is rare in both laparoscopic and robotic surgery, occurring in 0.1% of cases [33]. Unfortunately, not all injuries are recognized. If a bowel injury is noticed during surgery, the required management depends on severity. Sometimes conservative

treatment may be an option, but, alternatively, laparoscopic suturing techniques may be needed to repair the injury [3]. A recognized bowel injury that occurs during dissection is treated similarly to an injury that occurs during trocar placement [14].

Thermal damage from electrocautery is the second most common cause of intraoperative bowel injury, and most of these injuries are not recognized [32]. If an injury results from electrocautery, its degree must be evaluated. If electrocautery makes an enterotomy, all edges must be refreshed before the primary repair. If the area is blanched but there is no clear enterotomy or if there is only a superficial damage, the area must be excised until viable tissue is found, and only then is the suture done [14]. Some authors conclude that intraoperative repair of the damaged bowel is significantly safer and should be performed in every electrocautery bowel injury [34]. Thermal injury prevention is mandatory. The application of monopolar energy sources should be avoided, and the location of instruments that may injure the viscera must be actively observed.

Mechanical injuries, whether sharp or blunt, occur mostly outside the laparoscopic visual field in nontarget tissues and are caused by robotic arms and laparoscopic instruments with no tactile feedback. Consequently, all tissue handling and instrument insertion into the abdominal cavity should be performed under direct vision [35]. In robotic surgery, the fourth arm, when used, should be placed in a secure and visible location.

Colon

A colon injury that is discovered intraoperatively must be repaired immediately [3]. A skilled laparoscopic surgeon can perform a direct suture, avoiding colostomy, based on the extent of the injury. A general surgeon should be invited to the operating room for advice. The most commonly injured part of the colon is the rectum, as discussed in this section.

Liver and Spleen

Most splenic injuries (0.3%) occur in left upper urinary tract surgeries during spleen mobilization to expose the retroperitoneum [14]. There is an increased risk if adhesions are present [36]. Hepatic injury is not common, and management is usually similar to that of splenic injury. Because minor hepatic injuries are generally unreported, actual incidence is difficult to estimate. Compression alone can be enough to resolve minor injuries of the liver and spleen [3]. If bleeding is difficult to control, an argon beam coagulator could be helpful [14]. Splenectomy due to a major injury with massive bleeding is unusual but has been reported [37]. A preoperative CT scan can be useful to recognize organomegaly before starting surgery.

Biliary tract injuries occur mainly in right adrenalectomy and partial nephrectomy of the upper renal pole. Because of their torpid evolution, advice from a general surgeon is fully recommended.

Pancreas and Stomach

Injury of the pancreas or stomach is uncommon but can have substantial morbidity. When these organs receive damage, it is typically during left adrenalectomy or nephrectomy (both partial and radical) [14]. The upper renal pole should be dissected very carefully to avoid damage at this level. A German analysis of the complications in 2407 urologic laparoscopic procedures showed a 0.2% rate of pancreatic injury [38]. These injuries are most commonly discovered postoperatively; however, if a pancreatic injury is suspected, an intra-abdominal drain should be placed in the left renal bed, and fluid amylase levels should be checked during the postoperative period [3]. Although most superficial pancreatic injuries can be treated conservatively with parenteral nutrition, administration of somatostatin, and drain, a major injury could require distal pancreatectomy by conversion to open surgery or a laparoscopic or robotic technique. A surgical stapler can be

used for injury repair if discovered intraoperatively [14].

Placing a nasogastric tube before surgery could help reduce gastrointestinal distention and avoid gastric injury during trocar placement and left renal dissection [33]. Small perforations can be closed by direct laparoscopic suture. A drain should be placed in the repaired area [35].

Port-Site Hernia

Bowel herniation through a trocar site after laparoscopic or robotic urologic surgery is not common. This complication was reported for the first time in 1968 in the gynecologic literature [39]. Since then, many reports have been published, mainly in the general surgery literature (with rates from 0.65% to 2.8% [40]) but also in the urology literature.

Patient factors such as obesity, diabetes mellitus, older age, malnutrition, steroid use, and wound infection have been described as increasing port-site hernia risk [3, 14].

Montz et al. described in 1994 that in gynecologic laparoscopic procedures, 86.3% of trocar-site hernias were discovered in defects >10 mm; only 2.7% were in defects <5 mm [41]. The literature shows that the 12-mm port-site closure significantly reduces development of a trocar-site hernia [42]. It is generally accepted that it is not necessary for 8-mm robotic trocar incisions to be closed. Nevertheless, there have been recent reports of robotic port-site hernias [43].

If a patient shows signs of bowel obstruction, a port-site hernia should be suspected, and a CT scan may help with final diagnosis. Urgent surgery must be performed because of the risk of bowel strangulation, necrosis, and perforation [3, 14].

Rectum

Rectal injury is the most common bowel complication during radical prostatectomy but also may occur during radical cystectomy. The incidence rate is between 0.17% and 2.5% for laparoscopic and RARP and 1% for robot-assisted radical cystectomy [14]. It is a serious complication that converts the surgery into a contaminated procedure, increasing the risk of septic complications, peritonitis, pelvic abscess, rectourinary fistula, and even death [44].

Risk factors for rectal injuries include previous radiation, scarring from previous surgery or infection, large prostate size, and narrow or deep pelvis. This complication frequently occurs during the dissection of the posterior layer of the prostate, from base to apex. A surgeon might believe, incorrectly, that liberating the distal attachments of the Denonvillier fascia is a final step, without danger, and that all difficult surgical steps have been performed [45]. Surgeon experience is an important factor. A recent analysis of the RARP learning curve estimated that 50 cases were needed to decrease estimated blood loss and transfusion rates and 150–200 cases were needed to decrease other major complications such as bowel injury [46].

Diagnosis could be made intraoperatively or in the postoperative period. If a rectal injury is diagnosed intraoperatively by direct identification of the defect, the operative field is thoroughly washed with saline or povidone–iodine, and the prostatectomy is completed. After that, the margins of the injury should be well identified by digital rectal examination or a metallic bougie. The rectal mucosa and muscular layer are individualized, and the rectal wall is closed with a 2- or 3-layer suture. The repair is checked by filling the rectum with air through a rectal catheter and looking for air bubbles in the pelvic cavity, which is filled with saline. If no leakage is identified, the vesicourethral anastomosis is performed in a watertight manner [45]. At the end of the procedure, generally, two drains are placed, and broad-spectrum antibiotics should be administered for 7 days. Historically, a diverting colostomy was recommended for rectal injury during open radical prostatectomy, but the current trend is to perform a primary closure, avoiding bowel diversion. The diverting colostomy is now reserved for cases of a massive fecal spillage, previous radiotherapy, or tense suture line [3].

If the diagnosis of the rectal injury is delayed, early postoperative symptoms of rectal injury are lower abdominal pain, fever, abnormal white blood cell count, and sepsis. If unrecognized, a larger rectal lesion may progress to septic peritonitis. Late presentation occurs as a rectourethral fistula, usually without septic complications. The most frequent symptoms are pneumaturia and/or fecaluria after a few weeks. Diagnostic confirmation is performed using imaging tests, such as contrast enema, retrograde urethrogram, urethrocystoscopy, or CT scan, which is the main test in acute postoperative cases. When the diagnosis is confirmed, management requires bowel diversion with defect tension-free closure, which is delayed in patients with fistula [47].

One of the most important series of rectal injury during RARP was reported by Wedmid and colleagues and represents the first multisurgeon, multi-institutional study [48]. In this review, with 6650 patients from 6 centers, the authors found a combined 0.17% incidence of rectal injury, of which 72.7% were identified intraoperatively, and all had full thickness lacerations. Intraoperative identification was based on direct visualization. Treatment in those cases was primary repair with a 2- or 3-layer closure, tested with air insufflation via the rectum. Thorough pelvic irrigation was performed. All patients remained on perioperative antibiotics, and a Foley catheter was left for about 2 weeks. Most patients did well with this approach. Patients in whom rectal injury was not identified intraoperatively presented with signs and symptoms of rectourethral fistula, such as rectal bleeding in the postoperative period or pneumaturia after a few weeks, and required delayed fistula repair.

Similarly, Ketherpal and colleagues [49] presented a large series with 4400 patients who underwent RARP and identified rectal injury in 10 patients (0.2%). With intraoperative recognition and management in all cases and using a 2-layer suture closure, they reached good postoperative and functional outcomes, emphasizing the importance of early intraoperative diagnosis and management of rectal injuries.

The delayed rectourinary fistula repair could be managed with different surgical techniques. One of the most important and widespread is the York–Mason technique. First described in 1960, this procedure is based on a parasacrococcygeal transsphincteric approach [50]. The incision could be performed in a midline position or in a modified 2 o'clock position, referencing the anal sphincter with matched-paired sutures. The rectal wall is then exposed, and the fistulous tract can be identified. The fistula orifice is delimited with sutures to allow better manipulation. The next step is resection of the fistula tract, including all surrounding inflammatory tissue, and creation of a good dissection plane between the rectal and bladder walls. The next steps include closing both anterior and posterior sides of the rectal wall; the anterior wall is closed in two layers and the posterior wall in a single layer. The multilayer closure of the fistula including the urinary tract could be carried out, but some surgeons do not perform this step so as to avoid potential ureteric injuries. Finally, the anal sphincter is sutured, and a subcutaneous drain is placed in all cases. In early experience, this intervention was accompanied by a diverting colostomy, but that is not currently performed on a routine basis.

The procedure allows a clear approach to the rectal anterior wall, which provides an adequate view of the fistulous orifice. The technique has proven to be safe and effective, with good results in terms of fistula resolution and postoperative fecal continence recovery [51].

Operative Diagnosis

A bowel or visceral injury during robotic surgery may be life-threatening if not recognized and repaired during the procedure.

Initially, most trocar bowel or visceral injuries are caused by the primary trocar, which is not inserted under visual guidance. For this reason, this first trocar placement must always be checked to identify potential intra-abdominal injuries.

Recognized intraoperative bowel injuries should be repaired immediately via robotic or open access, depending on the surgeon's experience. Most sharp and blunt lesions caused by mechanical injury (frequently occurring outside

the robotic field) can be primary closed. In electrocautery injuries, there is an area of surrounding tissue with necrosis and sloughing, and a wide section of tissue must be excised before the repair. Sometimes after electrocautery damage, the appearance is a blanched area without clear enterotomy, but this area must be excised until viable tissue is encountered. If an injury is extensive, bowel resection could be necessary. In cases of colon involvement, a diverting colostomy should be considered for large or multiple colonic injuries that require segmental resection [14].

For stomach injuries, intraoperative management of small perforations includes intracorporeal suturing, with nasogastric tube and drainage placement. When duodenal injury occurs, general surgery consultation is recommended. Repair of the injury should be performed immediately and under open surgery. Sometimes a duodenal resection and duodenojejunal anastomosis are necessary.

Most liver and spleen injuries are minor lesions that can be managed conservatively with simple fulguration, compression, or the use of hemostatic agents. Splenectomy or open surgical repair of the liver may be necessary in cases of uncontrolled bleeding. Gall bladder perforation is rare and generally requires cholecystectomy. If pancreatic injury is discovered intraoperatively, a surgical stapler may be used. However, if a major pancreatic duct injury is present, it could be managed with distal pancreatectomy by robotic or open technique [3].

Knowledge of the injury-scoring scale used for trauma surgery remains an important tool to assess intraoperative abdominal complications. Moore et al. [52, 53] presented injury grading by organ, which suggests an ideal approach to deal with these events in the operating theater.

The actual decision about repair and the technique to be used must be decided based on surgical experience and the patient's particular situation. Conversion should always be considered, if necessary. A general surgeon should provide advice on the management of any injuries occurring in the operating room. It can be of the utmost importance to be able to differentiate between hematomas and lacerations and the actual extension of those.

In summary, early recognition and intraoperative treatment of visceral or bowel complications during robotic surgery is essential because delayed identification could be life-threatening.

Postoperative Diagnosis

If a bowel or other solid organ injury is not recognized during surgery, the quickness of postoperative diagnosis is vital. Many of these patients will advance to a life-threatening situation that might not be easy to diagnose.

In bowel injuries, sepsis and acute abdominal pain are typically observed a few days after surgery. Other signs and symptoms are leukopenia or leukocytosis, fever, trocar-site pain, ileus, nausea, or vomiting [3]. If suspicion is high enough, the patient should be taken to the surgery room for an exploration laparotomy and injury repair [14].

If the diagnosis is less clear, a CT scan could help detect an injured site [33].

Conclusion

Despite the undeniable interest and advantages of laparoscopic and robotic approaches, there are some issues that all urologic surgeons must know before surgery. These include the most common ways to access the abdomen and the main risks associated with port placement, how to prepare the intestines, and the use of preoperative images before starting the procedure. Major and minor gastrointestinal injuries related to laparoscopic and robotic surgery must be known for immediate diagnosis and management because, although uncommon, such intestinal damage could be life-threatening.

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Ocular Complications

14

Rick Catterwell, Emad Aziz Girgis, G. Blecher, and P. Dasgupta

Introduction

Postoperative visual loss (POVL), including blindness, is a rare but devastating complication that has been reported following a wide range of procedures including robotic urological surgery [1, 2]. While patients assume a certain risk of visual loss when undergoing ophthalmic surgery, visual loss following elective non-ocular surgery is a catastrophic event for the patient, surgeon and anaesthetist [3]. Despite being a rare entity, perioperative ocular complications in non-ophthalmic surgery have become a focus for surgical, anaesthetic and neuro-ophthalmological literature and a contentious medicolegal issue.

Postoperative ocular injuries include a broad spectrum of conditions each with distinct aetiologies, risk factors, patterns of visual loss, treatment and prognoses [4]. Procedures complicated with prolonged steep Trendelenburg positioning, significant blood loss, haemodynamic perturbations and prolonged pneumoperitoneum should be recognized as higher risk for POVL and visual assessment part of the postoperative assessment [5]. When a patient reports any visual symptoms following surgery, an urgent ophthalmologic consultation should be obtained to determine its cause [6]. Initial ophthalmological assessment focuses on identifying the location of the lesion via direct examination and if no ocular injury or central retinal artery occlusion is apparent, urgent neuroimaging with MRI is recommended [3].

Corneal abrasion is the most common ophthalmic injury in the perioperative period [7]. Robotic-assisted urological surgeries, in particular those associated with Trendelenburg positioning, have been associated with a very high risk for corneal abrasion [7]. Although

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corneal abrasions generally resolve quickly with limited treatment and no long-term sequelae, they are painful and anxiety inducing for the patient [8]. In direct contrast, other causes of POVL have poor prognoses and lack of validated treatment options [9]. Although these conditions are rare, they are frequently associated with complete unilateral or bilateral visual loss with the majority of cases having permanent effects. Due to their devastating impact and lack of effective treatment, prevention of these injuries is crucial.

Causes of Ocular Injury Following Robotic Surgery

Ocular injuries following robotic surgery can be categorized into five groups. Each is associated with a degree of postoperative visual loss (POVL).

- External ocular injury (corneal abrasion)
- Retinal ischaemia
- Ischaemic optic neuropathy (ION)
- Cortical blindness
- Acute glaucoma

Each of the aetiologies will be discussed separately in relation to pathophysiology, incidence, diagnosis and management.

External Ocular Injury

Direct corneal trauma can result in irritation, abrasion or laceration. Corneal abrasion (CA) is the most common ophthalmic injury in the perioperative period. Published data report an incidence range of 0.11–4.4% [7, 10, 11]. Segal et al. reported on a retrospective series of over 78,000 patients having procedures requiring anaesthesia with 0.11% of patients suffering CA [7]. They reported the most common procedure associated with CA was robotic-assisted prostatectomy. Independent significant risk factors for CA were Trendelenburg and prone positioning, prolonged operative time, increased estimated intraoperative blood loss and general anaesthesia.

In robotic surgery corneal injury may result from direct mechanical force such as from robotic instruments or chemical interaction from gastric reflux. Trendelenburg positioning is associated with elevated intravascular, episcleral venous and intraocular pressure which may result in increased corneal thickening. Longer and more complicated surgical procedures may ultimately compromise the vitality of the corneal epithelial cells with an increased propensity for sloughing and abrasion [7, 10].

Corneal abrasion typically presents as blurred vision, tearing, redness and foreign body sensation in the eye. Diagnosis is confirmed with the aid of fluorescein staining of the cornea and examination under a cobalt blue light.

Treatment with a broad spectrum topical antibiotic is usually rapidly effective [8]. Corneal injury prevention involves taping and application of lubricants to prevent corneal dehydration and eye shields to prevent mechanical insults [12, 13].

Retinal Ischaemia: Branch and Central Retinal Artery Occlusion

Central retinal artery occlusion (CRAO) decreases the blood supply to the entire retina, whereas *branch retinal artery occlusion* (BRAO) affects supply to a portion. The majority of instances of perioperative retinal artery occlusion are unilateral and secondary to improper patient positioning resulting in external compression of the eye [4, 14]. External compression of the eye can produce sufficient intraocular pressure (IOP) to stop flow in the central retinal artery which has, in animal models, been demonstrated to result in irreversible retinal damage in 20–60 min [15, 16]. Following removal of external compression reperfusion can result in increased swelling and further increases in compartmental pressure. Orbital compartment syndrome can ensue resulting in increased retinal ischaemia and retinal cell

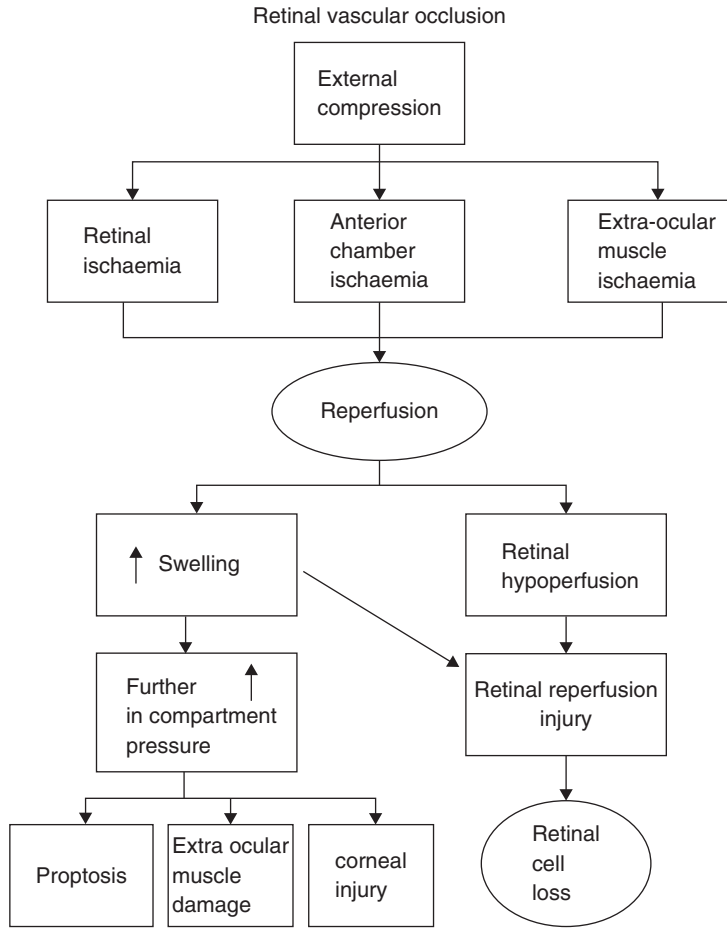

Fig. 14.1 Mechanism of injuries resulting from external ocular compression and resulting reperfusion injuries

loss [4] (Fig. 14.1). Although this cause of POVL is predominately associated with prone positioning, it can occur in any surgery where prolonged external pressure is inadvertently applied to the eye [17]. There have been no reported cases associated specifically with robotic surgery.

Other rare causes of CRAO include embolism to the retinal circulation, decreased blood flow secondary to systemic hypoperfusion, impaired venous drainage of the retina or coagulation disorder [18].

Signs and symptoms of patients with postoperative CRAO include painless unilateral visual loss, no light perception, afferent pupil defect, periorbital oedema, chemosis, proptosis, ptosis paraesthesia of the supraorbital region and corneal abrasion [19]. Diagnosis is prompted by the sudden onset of visual loss and the presence of retinal whitening with or without classical 'cherry-red' macula on fundoscopy (Fig. 14.2).

Prognosis for CRAO is generally poor and treatment inadequate. Cold compress, ocular massage and vasodilatation via induced hypercapnia have been advocated in presentations less than 90 min. Paracentesis may facilitate distal migration of the embolus limiting extent of injury. Fastidious attention to patient positioning aimed at avoiding external ocular pressure is paramount in prevention of CRAO.

Branch retinal artery occlusion (BRAO) causes permanent ischaemic retinal damage with partial visual field loss. BRAO is primarily the result of emboli. The vast majority of reported cases are associated with cardiopulmonary

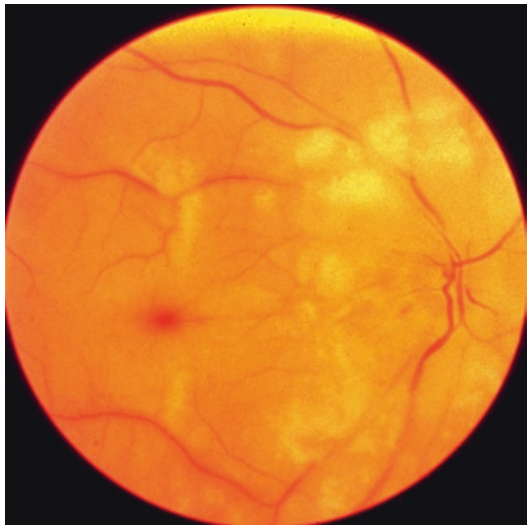

Fig. 14.2 Fundus photography of the right eye with non-arteritic CRAO demonstrating cherry-red spot and retinal opacity of the posterior fundus (Reprinted from Hayreh, Sohan Singh. Ocular Vascular Occlusive Disorders. © Springer International Publishing, Switzerland 2015. Chapter 13, Central Retinal Artery Occlusion; p. 239. With permission of Springer Nature)

bypass where circulating embolic material is implicated. Embolism passage from surgical site via the venous system and a patent foramen ovale has been reported as a cause of perioperative retinal vascular occlusion in spinal surgery [20]. BRAO is associated with painless partial visual field loss and sectoral whitening in the path of a branch retinal artery on fundoscopy.

Ischaemic Optic Neuropathy

Ischaemic optic neuropathy (ION) refers to ischaemic damage to the optic nerve itself. ION is subclassified into arteritic or non-arteritic ION. Arteritic ION is secondary to inflammation of blood vessels chiefly associated with giant cell/temporal arteritis and responds to steroid therapy. In contrast, non-arteritic ION is secondary to occlusive disease or other noninflammatory disorders. In the general population, non-arteritic ION is the leading cause of sudden visual loss in patients above 50 years of age with an annual incidence in the United States of 82 per 100,000 persons [21]. Non-arteritic ION is the overwhelming cause of POVL. It has been reported after a wide spectrum of surgical procedures, most commonly cardiothoracic surgery [18], instrumented spinal fusion [22] and head and neck surgery [23, 24]. Multiple cases following gynaecological, urological and general surgical procedures have also been reported [25].

ION is further classified by the location of the nerve ischaemia into anterior ischaemic optical neuropathy (AION) and posterior ischaemic optic neuropathy (PION). This classification is of importance due to the difference in incidences, proposed aetiologies and clinical presentations of each group. Postoperative AION predominately occurs following cardiothoracic surgeries. All reported cases of POVL secondary to ION related to robotic pelvic surgery have been PION injuries [1, 25]. Similarly the vast majority of reported ION following spinal surgery have been posterior injuries.

The exact mechanism of PION and AION is contentious and likely multifactorial. Posterior ischaemia occurs behind the globe and is probably not related to predictable increases in intraocular pressure; it may well be related to disruption of blood supply to the optic nerve from a network of very small perforating pial arteries (Fig. 14.3). In contrast AION proposed to be caused by disruption of blood supply through the posterior ciliary arteries feeding the head of the optic nerve, and this condition may be related to impaired autoregulation of flow (perfusion pressure vs intraocular pressure).

AION and PION have been reported in the setting of massive fluid replacement especially in prone-positioned patients. Excessive fluid administration could result in increased IOP or accumulation of fluid in the optic nerve or both. As the retinal vein exits out of the optic nerve, the oedematous nerve may inhibit venous outflow resulting in an internal 'compartment syndrome' [4]. Patients on the ASA Postoperative Visual Loss Registry received on average 9.7 L of crystalloids intraoperatively, suggesting that fluid replacement may play a role [26].

Key surgical factors linked to perioperative ION are prolonged prone or steep Trendelenburg positioning, prolonged overall surgical duration and massive blood loss. Possible intraoperative

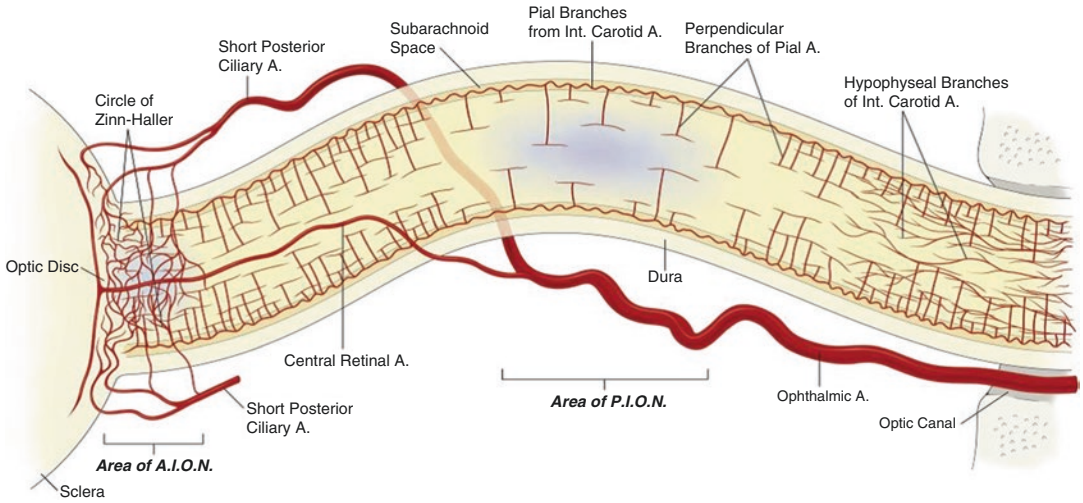

Fig. 14.3 Diagram of the orbital optic nerve and arterial supply. Areas implicated in ischaemic optic neuropathy are indicated in *blue*. The mid-orbital optical nerve has a paucity of blood supply compared to the anterior component. This area supplied by only the pial branches is the region involved in PION. The pial branches have variable density and in an unusual perpendicular T-shaped pattern, characteristic of a low pressure system. There is low density of arteriolar and capillary supply to this mid-orbital segment compared with the canalicular or retrobulbar segments of the optic nerve. Abbreviations: *A* artery, *AION* anterior ischaemic optic neuropathy, *PION* posterior ischaemic optic neuropathy

haemodynamic factors include decreased systemic blood pressure, anaemia or haemodilution, a high ratio of crystalloid to colloid fluid replacement and venous congestion. Characteristics of the optic nerve and disc may predispose to ION such as reduced flow of cerebrospinal fluid, abnormal auto regulation, anatomic variants in blood supply and small cup-to-disc ratio. Potential systemic risk factors include hypertension, diabetes, atherosclerosis, hyperlipidaemia, smoking history and hypercoagulability [4, 14, 18, 26, 27]. Minimization of these potential risk factors where possible is the basis of ION prevention.

Typically PION results in complete visual loss within 24 h postoperatively compared to AION where two thirds of cases were not evident until more than 24 h following surgery and initial symptoms more likely to be incomplete visual loss. Bilateral visual loss is more common with PION (63%) compared with AION (52%). Nearly all patients with AION have disc oedema, pallor or both on initial assessment (Fig. 14.4). In comparison PION is associated with a normal optic disc on initial fundoscopic evaluation in 92% of patients [4, 14].

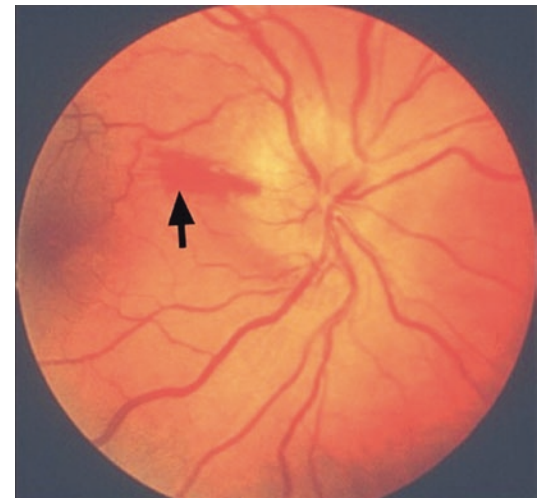

Fig. 14.4 Fundoscopy in acute non-arteritic anterior ischaemic optic neuropathy. The optic disc is oedematous and hyperaemic. Splinter haemorrhages (*Arrow*) are present

No effective treatment for ION has been proven. Only approximately 30% of patients with

either AION or PION will have any improvement. The focus of management is therefore on prevention.

Cortical Blindness

Cortical blindness is the result of decreased perfusion to the occipital cortex by tributaries of the posterior cerebral artery. The cause is either hypoperfusion or embolic phenomenon. Cortical blindness is a very rare cause of POVL that is usually associated with cardiac surgery [4, 28].

As the optic tracts and radiations are preserved, patients with cortical blindness have normal light reflexes and fundoscopic examination is normal. With unilateral involvement visual field examination demonstrates contralateral homonymous hemianopia. Bilateral involvement results in peripheral visual loss or complete blindness [28]. Diagnosis is confirmed in both unilateral and bilateral conditions via MRI with gadolinium.

Cortical blindness is usually accompanied by signs of acute stroke in the parieto-occipital region. Patients frequently demonstrate agnosia (an inability to interpret sensory stimuli) and impaired spatial perception. Focal neurological signs suggestive of stroke extension may be evident.

Treatment is aimed at preventing extension of the cerebral infarction. Most described preventative measures discuss reducing risk of embolic phenomena with cardiac surgery, but in the context of robotic surgery, prevention is via maintenance of global cerebral perfusion. Visual recovery in cortical blindness is usually prolonged and incomplete [4, 14].

Acute Glaucoma

Acute angle-closure glaucoma has been described rarely after general anaesthesia. Patients are genetically predisposed with a shallow anterior chamber and thick lens. Presentation is with a painful red eye and blurred vision usually accompanied by headache, nausea and vomiting. The pupil is mid-dilated with a pupillary block and the condition is often bilateral. It should be differentiated from corneal abrasion, which also produces pain but without papillary signs, increased IOP or headache.

Acute angle-closure glaucoma is an ophthalmological emergency as prolonged elevated intraocular pressure will result in glaucomatous damage to the optic nerve. Acute management is with topical α-agonists, β-antagonist, cholinergic agonists and steroids.

Approach to the Patient with Perioperative Visual Loss

So with all this background knowledge, the question remains…. What is the management of a patient that awakens from general anaesthesia with complains of visual loss?

Vision should be assessed early in all patients following high-risk surgery which includes robotic pelvic surgery especially if complicated prolonged steep Trendelenburg positioning, significant blood loss, transfusion or intraoperative haemodynamic instability. If there is concern regarding potential visual loss, an urgent ophthalmologic consultation should be obtained to determine its cause. If an ocular cause, such as corneal injury or central retinal artery occlusion, is not apparent, urgent neuroimaging should be obtained. Gadolinium-enhanced MRI is preferred assessing for intracranial pathology such as occipital infarction. If imaging is unremarkable, ION is the likely cause of which PION is most likely given normal fundoscopy. Additional management may include optimizing haemoglobin levels, haemodynamic status and arterial oxygenation, but little evidence exists for the efficacy of any interventions for ION.

Conclusion

Robotic urological surgery has one of the highest rates of corneal abrasion of all surgical procedures. POVL in robotic surgery is a rare but catastrophic complication. Potential causes of POVL after robotic surgery include anterior ischaemic optic neuropathy, posterior ischaemic optic

neuropathy, cortical blindness, retinal ischaemia and acute glaucoma. The vast majority of cases are related to posterior ischaemic optic neuropathy. The exact risk factors and pathophysiological mechanism of ischaemic optic neuropathy are poorly understood and likely multifactorial.

Given the complete lack of effective treatment modalities, prevention is crucial for limiting the incidence and destruction of POVL. Minimization of presumed risk factors is particularly important in robotic pelvic surgery where minimizing duration of Trendelenburg positioning, overall operative time and blood loss are likely protective.

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Part III

Complications in Specific Robotic Procedures of the Upper Urinary Tract

Adrenalectomy

15

Fabio C.M. Torricelli and Rafael F. Coelho

Introduction

The first robot-assisted laparoscopic adrenalectomy (RALA) was described in 1999 by Piazza et al. [1], and since that time, several papers have been published showing its safety and feasibility [2–4]. It combines advantages of minimally invasive laparoscopic procedures, such as less postoperative pain, shorter covalence time, and better cosmetic appearance [5], with benefits from da Vinci robotic system, i.e., three-dimensional vision, filtration of tremor, and 7 degrees of freedom (EndoWrist technology) [6]. A systematic review and meta-analysis have demonstrated that although laparoscopic and robotic adrenalectomy have similar conversion rate (odds ratio [OR] 0.82; 95% CI 0.39–1.75; $p = 0.61$) and operative time, RALA has a shorter hospital stay as well as a lower blood loss when compared to conventional laparoscopy [7].

Currently, RALA is indicated to nonfunctioning tumor >4 cm, primary hyperaldosteronism, pheochromocytoma, functioning adenomas, metastatic lesions, adrenocortical carcinoma, and rare infectious diseases. Partial adrenalectomy is also feasible and seems to be a promising application of robotic-assisted adrenalectomy especially for the treatment of hereditary pheochromocytomas [8]. Relative contraindications are large tumors (> 12 cm), invasion of adjacent organs, involvement of vascular structures, vena cava thrombus, and disseminated metastatic disease.

Conversion and perioperative complications are rare in RALA, but they have been reported in few cases. The aim of this chapter is to review and discuss these undesirable events.

Complications

Conversion

It is defined as a procedure completed using a technique different from the one initially planned, thus any surgery not robotically finished. The conversion rate of RALA ranges widely from 0 to 40% in the literature [9]; however, in most of the published papers, it is low. In a meta-analysis including nine studies and 600 patients comparing robotic with laparoscopic adrenalectomy, the conversion rate was only 4.4% for the robotic group [7]. There are many causes that can lead surgeons to decline robotic technique to complete the adrenalectomy, including intense intra-abdominal

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adherence due to previous surgery or tumor infiltration, unexpected bleeding following vascular or organ injury, and patients' hemodynamic alterations (i.e., pheochromocytoma). Although the reasons to conversion may vary, most of the time, they are related to surgeon inexperience with da Vinci system, as described by Morino et al. that reported four conversions in a series of ten cases, three of them among the first five cases [10]. These authors noted a statistically significant decrease in the conversion rate with increasing surgical experience.

Minor Complications (Clavien I and II)

Most of the complications after RALA are Clavien grade I or II, including fever, hydroelectrolytic disorders, nausea and vomiting, wound infections, urinary tract infection, pneumonia, and blood transfusion. The overall complication rate for RALA has been reported between 0 and 20% [9]. In a recent publication describing the main steps of RALA and analyzing the authors experience with 30 procedures, the overall complication rate was 20% [11]. Five of six complications were minor, including one case of hyponatremia, an episode of nausea and vomiting, a postoperative bleed requiring blood transfusion, a wound infection, and an atrial fibrillation. In a systematic review and meta-analysis comparing robotic and laparoscopic adrenalectomy, the complication rate was higher in the laparoscopic group (6.8% vs. 3.6%), although it did not have achieved significant statistical difference (OR 0.04; 95% CI −0.07 to −0.00; $p = 0.05$) [7].

Major Complications (Clavien III–V)

Severe complications after RALA are extremely rare and do not achieve 5% of cases. A meta-analysis comparing laparoscopic and robotic adrenalectomy showed that there are more severe complications in the laparoscopic group, according to the Clavien grading system, including three deaths (Clavien grade V), two resulting from respiratory failure due to severe pulmonary hypertension [3, 12] and one from cardiac arrest [13]. You et al. reported two grade IV complications in the laparoscopic group (acute kidney failure and cerebral infarction) requiring intensive care unit treatment [14]. In the robot-assisted group, there was only one grade III complication in two studies [3, 15]. Brandao et al. reported only one major complication in 30 RALA, and it was also classified as a Clavien grade III, an extensive postoperative bleeding that required surgical intervention under general anesthesia [11]. Asher et al., in a study including 15 cases of robot-assisted laparoscopic partial adrenalectomy for pheochromocytoma, a disease with an intrinsic higher risk of perioperative complications, reported also only one major complication [16]. There was one conversion to open partial adrenalectomy due to severe adhesions to the liver and repeated vena cava injuries requiring initially robotic and then open repairs. The same patient had a bile leak that required a temporary drain for 5 days.

Most of the complications after RALA appear to be related to the pathology (pheochromocytoma and adrenal cortical carcinoma) and patient's medical condition prior to surgery (severe systemic disease), rather than to the procedure itself [9].

Table 15.1 summarizes conversion and postoperative complication rates.

Risk Factors for Conversion and Complication

- Inexperienced surgeon
- Prior abdominal surgery (adherence)
- Severe medical condition (pulmonary or cardiac disease)
- Pheochromocytoma or adrenal cortical carcinoma
- Large adrenal tumors

Preventing Complications

In order to avoid complications, it is important that patient and surgeon are prepared to the procedure. Patient need to have all his/her comorbidities well evaluated and appropriately treated before the adre-

Table 15.1 Perioperative complications

Study	Year	No. of cases	Operative time (min)	Estimated blood loss (ml)	Conversion (%)	Postoperative complications (%)
Agcaoglu et al. [17]	2012	24	159.4 ± 13.4	83.6 ± 59.4	1 (4.1%)	0
Agcaoglu et al. [18]	2012	31	163.2 ± 10.1	25.3 ± 10.3	NA	0
Aksoy et al. [3]	2013	42	186.1 ± 12.1	50.3 ± 24.3	0	1 (2.4%)
Aliyev et al. [13]	2013	25	149 ± 14	26 ± 12	1 (4.0%)	0
Brandão et al. [11]	2014	30	120 ± 33	50 ± 50	0	6 (20%)
Brunaud et al. [15]	2008	50	189 ± 43.7	49	4 (8.0%)	5 (10%)
Karabulut et al. [12]	2012	50	166 ± 7.0	41 ± 10	1 (2.0%)	1 (2.0%)
Morino et al. [10]	2014	10	169 ± 19.7	NA	4 (40%)	0
Pineda-Solis et al. [19]	2013	30	189.6 ± 32.7	30 ± 5	0	0
You et al. [14]	2013	15	183.1 ± 48.7	NA	0	2 (13.3%)

NA not available

nalectomy. Aldosteronoma can result in hypokalemia that may require potassium repletion and administration of potassium-sparing diuretic. Hypertension should also be treated before surgery. With a pheochromocytoma, α-adrenergic blockade should be started 2 weeks before surgery. Some patients with tachycardia may benefit from concurrent β blockade. Alternatively, an α1-selective blocker such as prazosin or doxazosin can be used. Intraoperatively, high blood pressure can be treated with nitroprusside or a short-acting β-blocker like esmolol. Volume repletion is important to prevent the postoperative hypotension secondary to loss of tonic vasoconstriction after removal of a pheochromocytoma. Patients with Cushing's syndrome require correction of electrolyte abnormalities and hyperglycemia before surgery. These patients may benefit from administration of adrenolytic agents such as mitotane or aminoglutethimide.

Bowel preparation is not routinely necessary and should be performed only in cases of complex surgeries (i.e., large mass or intense intra-abdominal adherence). Retroperitoneal surgery may not require this bowel preparation. All patients should receive appropriate preoperative antibiotics. A nasogastric or orogastric tube should be placed. The placement of a urinary catheter to help measure urine output and to decompress the bladder is mandatory.

Surgeon must have experience with the robotic system. If he/she is not familiar with the robotic adrenalectomy technique, a proctor is strongly recommended.

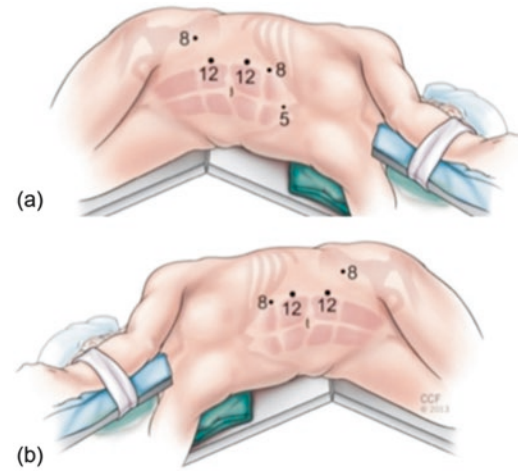

Fig. 15.1 Patient's position and port placement. (**a**) Right and (**b**) left adrenalectomy [11] (*Reprinted with permission from Elsevier*)

Patient positioning, port placement, and docking are all important steps that have to be carefully done. Patient is placed in a 60° flank position and appropriately draped. Port placement is illustrated in Fig. 15.1. An extreme flank position, with axis of the shoulders close to a 90° angle to the operating table, is an option for large tumors. The robot is docked over patient's shoulder, so its axis makes an obtuse angle in relation to patient's axis. Figure 15.2 shows operation room setup.

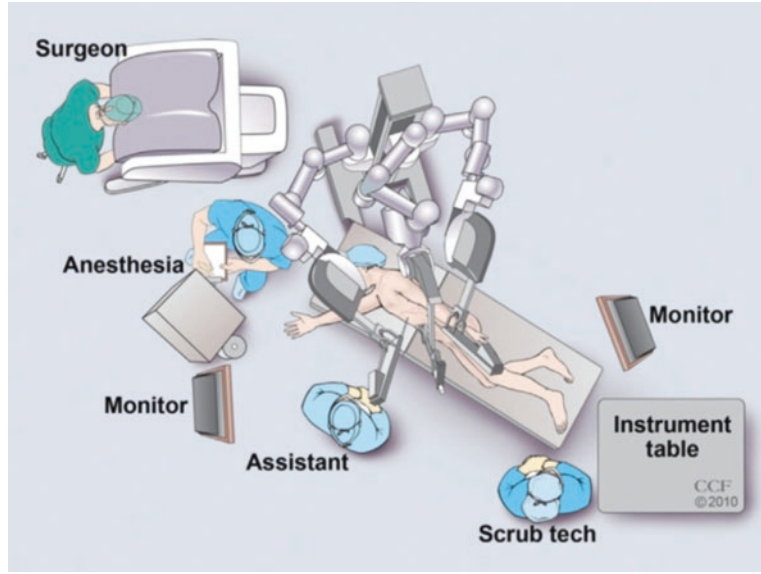

Fig. 15.2 Operation room setup [11] (*Reprinted with permission from Elsevier*)

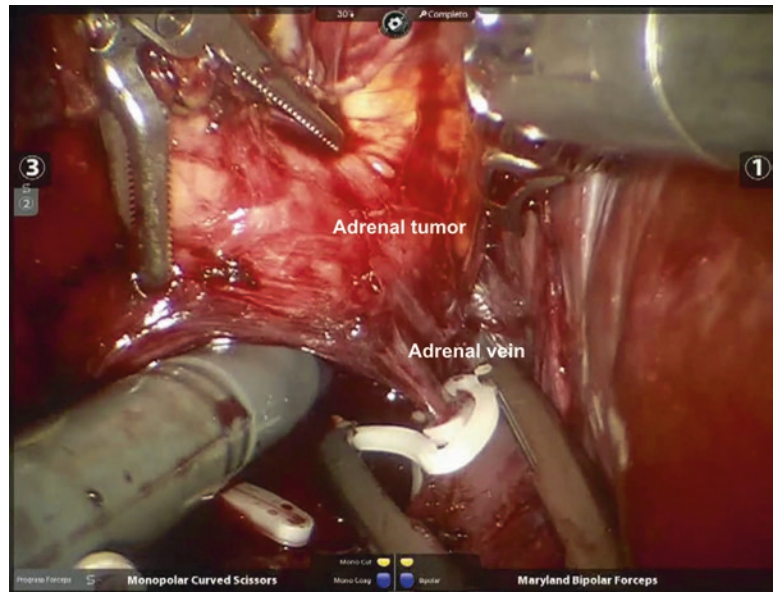

Fig. 15.3 Intraoperative view

Initially, spleen, bowel, and pancreas have to be mobilized to expose the left adrenal gland. Attention must to be paid to the tail of the pancreas because it can be mistaken for the adrenal gland. On the right side, liver, colon, and duodenum have to be mobilized to expose the vena cava and the right adrenal gland (Fig. 15.3). The next step is the adrenal vein identification and control. The left adrenal vein is a branch from the left renal vein, whereas the right adrenal vein is a short and oblique branch from the vena cava. Careful dissection, followed by clipping and resection are important steps for a safety procedure with no bleeding. Once the adrenal vein is properly controlled, the adrenal gland is circumferentially dissected off, close to kidney upper pole, diaphragm, and psoas muscle. Then, the specimen is placed in a laparoscopic bag and removed. Lastly, hemostasis is checked by lowering the pneumoperitoneum,

and all ports are removed under direction vision. Following all these surgical principles, the chances of intra- or postoperative complications are minimized.

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Nephrectomy

16

Benjamin T. Waldorf and David Canes

Introduction

Renal surgery and nephrectomy, specifically, have undergone a significant evolution since Robson, Churchill, and Anderson first described the major principles of radical nephrectomy in 1969 [1]. Major technological advancements on two separate fronts have driven change in the epidemiology, surgical techniques, and ultimately the morbidity and mortality associated with nephrectomy. The advent and increasingly widespread use of cross-sectional imaging in the form of computed tomography (CT) and magnetic resonance imaging (MRI) resulted in an increase in the overall incidence of renal cell carcinoma (RCC) as well as a downward stage migration toward smaller, localized masses [2]. Increased incidental detection of RCC at earlier stages has led to increased survival. From 2004 to 2013, incidence of RCC has risen on average by 1.1% each year, with a concomitant annual decrease in death rate of 0.7% [3]. Along with an increase in RCC detection has come an understanding for the need for maximal preservation of normal renal parenchyma [4, 5]. Whereas partial nephrectomy for malignancy was once a radical concept, it is now the standard of care for T1a renal masses [6, 7].

A second driver of change in the approach to kidney removal has been the adoption of minimally invasive surgical techniques by practicing urologists. Laparoscopic nephrectomy, first described by Clayman et al. [8] in 1991, and robot-assisted radical nephrectomy, first described by Klingler et al. [9] in 2000, have become the standard surgical approaches for all but the most complex situations where nephrectomy, both simple and radical, is required. With a paradigm shift in surgical technique, there have been changes in the frequency and type of complications associated with nephrectomy. In this chapter, we discuss complications of robotic nephrectomy, highlighting problems unique to minimally invasive approaches as well as those faced by all surgeons contemplating surgical removal of the kidney.

Background

There is a paucity of literature focusing purely on the complications of robotic nephrectomy. However, inferences can be drawn from complications presented in large series of patients

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who underwent laparoscopic nephrectomy at high-volume institutions. Permpongkosol et al. [10] reported on complications in 2775 laparoscopic procedures from 1993 to 2005 at Johns Hopkins Hospital. Overall complication rate within the laparoscopic radical nephrectomy subgroup was 20%, with the most common complication being injury to adjacent organs (2.37%). When broken down by Clavien classification, the majority of complications (76%) were classified as Clavien I or II. Pareek et al. [11] performed a meta-analysis of 56 articles published between 1995 and 2004 and found an overall major complication rate of 10.7% for laparoscopic radical nephrectomy, with the most common major complication being venous and arterial bleeding (1.8%). Finally, Asimakopoulos et al. [12] performed a systematic review of the available literature on robotic radical nephrectomy, searching all articles published between 2000 and 2013. Ten articles were included in the final analysis, each of which reported complications, the most common of which was wound infection or breakdown.

Preoperative Considerations and Evaluation

Despite its minimally invasive approach, robotic nephrectomy is a major surgical procedure, and a thorough evaluation of a patient's overall medical state is mandatory prior to proceeding with surgery. In 2016, the average American initially diagnosed with renal cell carcinoma was 64 years old, and many patients are being considered surgical candidates well into their 80s [13]. In addition, the only known modifiable risk factors for RCC, tobacco smoking and obesity, are associated with numerous medical comorbidities. In considering robotic nephrectomy, special consideration should be given to the following patient populations.

Cardiopulmonary Disease

For any urologist contemplating robotic nephrectomy, the presence of any chronic lung disease in the patient should prompt evaluation of the cardiopulmonary system with a low threshold for referral and preoperative evaluation by a specialist. For several reasons, robotic nephrectomy places significant stress on the cardiopulmonary system.

Like any abdominal laparoscopic procedure, robotic nephrectomy requires insufflation of the abdomen with carbon dioxide gas, which is absorbed into the systemic circulation. Compromised ventilatory function, as is found in diseases such as chronic obstructive pulmonary disease, can result in dangerous hypercarbia. This situation is compounded by the fact that robotic nephrectomy is typically performed with the patient in some variation of the flank position. This positioning results in decreased diaphragmatic contraction in the depended side, thereby causing less-effective ventilation and oxygenation in the adjacent lung. For these reasons, preoperative medical optimization of the pulmonary system, and, if possible, smoking cessation, is crucial.

Cardiovascular disease is the leading cause of death in the United States, and a majority of Americans over the age of 60 have at least two risk factors for cardiovascular disease [14]. The combination of abdominal insufflation and flank position places significant pressure on the inferior vena cava and aorta, decreasing cardiac preload and increasing afterload, respectively. The end result is a decrease in cardiac output, which, in an already compromised circulatory system, can produce end-organ ischemia. Added to this situation is the not insignificant risk of major blood loss with robotic nephrectomy. Given the patient population frequently undergoing robotic nephrectomy, preoperative cardiac evaluation is often prudent. If needed, nephrectomy for benign disease, and even for some malignant masses, can be postponed for needed revascularization procedures.

Obesity

A majority of Americans, estimated at 69% in 2016, are overweight or obese [14]. In addition to be a risk factor for both RCC and cardiopulmonary disease, obesity presents the surgeon contemplating robotic nephrectomy with several technical considerations and risks. Multiple publications in

the robotic partial nephrectomy literature have shown this to be a feasible technique for the obese patient, especially at high-volume robotic surgical centers [15–17]. Given that robotic nephrectomy is generally considered a more straightforward procedure than robotic partial nephrectomy, it can be inferred that obese patients can safely undergo robotic nephrectomy. However, as compared to the patient with a normal BMI, there is an increased risk of some perioperative complications, including wound complications and rhabdomyolysis [18, 19].

Laboratory and Imaging Evaluation

Preoperative laboratory evaluation should include, at a minimum, an assessment of the patient's renal function via measurement of the serum blood urea nitrogen and creatinine levels as well as measurement of hemoglobin and/or hematocrit level. At our institution, serum electrolyte levels, platelet count, and urinalysis are also routinely checked. Evidence of chronic renal insufficiency should prompt evaluation by a nephrologist. A history of known bleeding diathesis, abnormal bleeding with prior surgery, or use of anticoagulant medications should prompt evaluation of the prothrombin time and partial thromboplastin time. Blood typing is also routinely obtained prior to nephrectomy at our institution.

Quality cross-sectional imaging, in the form of CT or MRI, should be obtained preoperatively and should be readily available to the surgeon in the operating room. Radioisotope renography can be especially useful for surgical planning in the setting of an atrophic or otherwise abnormal-appearing contralateral kidney. If there is suspicion for renal vein involvement by a tumor thrombus, MRI of the abdomen with gadolinium is useful to detect the uppermost portion of the thrombus.

Surgical Prophylaxis

Our practice is to follow the 2008 AUA best practice policy on antimicrobial prophylaxis [20], which recommends an intravenous first-generation cephalosporin given immediately prior to initiating the procedure for laparoscopic procedures without entry into the genitourinary or gastrointestinal tract. An exception to this situation is in the performance of robotic simple nephrectomy when there is a strong history of urinary infection and high likelihood of entry into the urinary tract. In this situation, antibiotics are tailored to prior urine culture results in addition to skin flora.

For prevention of venous thromboembolism, all patients receive a single dose of subcutaneous heparin, unless there is a history of allergic reaction or heparin-induced thrombocytopenia. Placement of bilateral lower extremity compression sleeves is also standard.

Perioperative Considerations, Injuries, and Management

Patient Positioning

Robotic nephrectomy may be performed in a transperitoneal or retroperitoneal manner. At our institution, we place the patient in a modified (45°) and full lateral decubitus position, respectively, for these approaches. The upmost care must be taken when the lateral decubitus position is utilized in robotic nephrectomy. The lateral decubitus, or flank, position has been associated with an increased risk of pressure ulceration, skin breakdown, and rhabdomyolysis [21–24]. Nerve injuries are also a major risk with this position, due to both stretch- and compression-mediated mechanisms [25].

Our preference is to position the patient so that the top of the dependent iliac crest lies at the table break. If possible, the table is broken submaximally; however, full flexion is often necessary to gain proper exposure, especially with obese patients. We do not utilize a kidney bar or rest. As the lateral decubitus position is associated with an increased risk of brachial plexus injury, an axillary roll is always placed underneath the dependent axillae [26]. Typically, this consists of a 1-liter IV saline back covered with protective padding, but in smaller patients, this is often substituted for a cylindrical piece of soft foam. Padding is placed along the patient's back,

Fig. 16.1 A patient placed in modified lateral decubitus position prior to robotic nephrectomy. The upside arm can be extended and placed in a sling or, as in this case, left at the patient's side (Image courtesy of Daniel D. Eun, M.D)

in the form of either foam pads or cloth rolls, which are held in place with positioners attached to the operating table. The dependent leg is flexed, and the upside leg is left straight, with pillows placed between the legs for padding. The dependent arm is secured to a padded arm board. When placing tape across the chest, hips, and lower extremities, care must be taken not to overtighten restraints as this can lead to an increased risk of skin and muscle injury. The upside arm can be placed in a padded sling or left at the patient's side. Our positioning setup can be seen in Fig. 16.1.

Abdominal Access, Insufflation, and Port Placement

Prior to accessing the abdominal cavity and establishing pneumoperitoneum, the bladder and stomach are decompressed with a Foley catheter and orogastric tube, respectively, to decrease the risk of inadvertent injury. Access to the abdomen is via one of these two methods: placement of a Veress needle or direct open visual entry (Hasson technique). A recently published review by Ahmad et al. [27] involving 28 randomized controlled trials and 4860 patients concluded that no single abdominal entry technique provided an advantage regarding major vascular or visceral complications. A second review, specifically focused on injuries incurred with Veress access, covered 38 studies and 696,502 laparoscopic operations and found 1575 injuries (0.23% injury rate) [28]. For Veress placement in the lateral decubitus position, a periumbilical puncture represents the shortest path from the skin to the abdominal cavity. Our feeling is that abdominal entry method should ultimately be based on surgeon experience and discretion.

Once abdominal access is obtained, pneumoperitoneum is established with insufflation of carbon dioxide gas into the abdominal cavity. Excessive insufflation pressure should be avoided as this can cause reflex bradycardia from stretch placed on the vagus nerve. Once a camera port is placed, the remaining working and assistant ports are placed under vision, taking care to avoid the inferior epigastric vessels. Various port placement configurations for upper tract robotic procedures have been described [29–31]. See Fig. 16.2 for details of our typical port layouts for transperitoneal robotic nephrectomy. We consistently employ a fourth robotic arm in upper tract surgery as it allows the console surgeon to perform a two-handed hilar dissection while placing the hilum on stretch. For improved intraoperative mobility and vision in the obese patient, we often

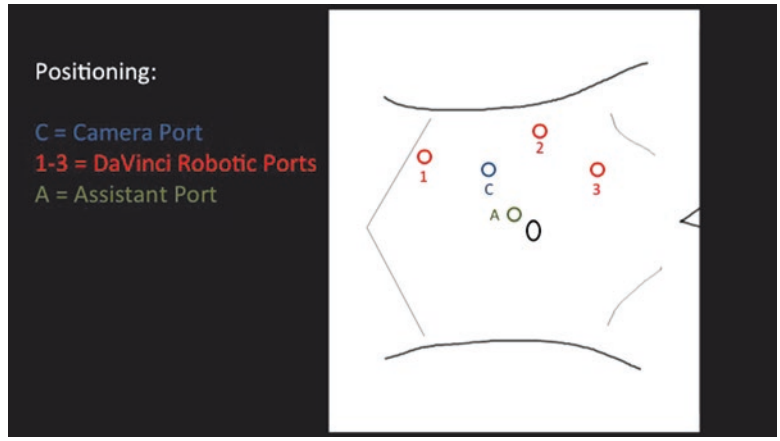

Fig. 16.2 One example of port placement layout for robotic nephrectomy (Image courtesy of Daniel D. Eun, M.D)

shift robotic and assistant port positions laterally and slightly cephalad, thus moving them away from the thickest portion of the patient's pannus.

Intraoperative Complications

Colonic and Small Bowel Injury

From initial abdominal entry until fascial closure, the possibility of inadvertent injury to the bowel is a potential risk for the surgeon undertaking robotic nephrectomy. Bowel injury is a relatively rare complication, occurring in 0.1–0.75% of cases in several large, retrospective series of minimally invasive urologic operations [32–35]. However, when missed intraoperatively by the surgeon, the consequences are grievous. A history of prior abdominal surgery, with intra-abdominal adhesions, increases the risk for bowel injury in minimally invasive surgery [36, 37]. Injuries occur via one of two general mechanisms: direct traumatic injury or inadvertent transmission of electrocautery. A high degree of suspicion for bowel injury must be maintained by the surgeon, especially for cautery injuries, as they are especially likely to be missed intraoperatively. Extreme care should be taken when activating an electrocautery instrument in the vicinity of a metal instrument or trocar, as there is a high risk of conduction and inadvertent tissue injury. If colonic and/or small bowel adhesions are present in the planned operating field, they should be taken down sharply with minimal, if any, use of cautery.

In transperitoneal robotic nephrectomy, access to the contents of Gerota's fascia and the renal hilar structures requires negotiating the ascending or descending colon, depending on whether a right or left nephrectomy, respectively, is being attempted. Most commonly, the white line of Toldt is incised, allowing medial mobilization of the colon along an avascular plane between the mesocolon and Gerota's fascia. During this maneuver, the colon is at risk for inadvertent injury as from excessive medial traction placed on the colon and/or mesocolon as well as from the indiscriminate use of electrocautery. Development of this surgical plane can frequently be done primarily in a blunt manner, especially in a patient without prior ipsilateral retroperitoneal or colonic surgery, thus avoiding the need for significant amounts of electrocautery. Additionally, the use of the fourth robotic arm for posterolateral renal retraction decreases the risk of a colonic traction injury. A transperitoneal, transmesenteric approach to the kidney has also been described, which decreases the need for colonic mobilization [38]. However, the utility of this approach is often limited in the adult, Western population due to poor visualization of the underlying retroperitoneal structures due to abundant mesenteric fat.

Any suspected colonic or small bowel injury should be promptly repaired. Depending on the degree of injury and the causative agent, this can

encompass a range of repairs from simple tissue approximation to major bowel resection and fecal diversion. Early involvement of a general or colorectal surgeon is prudent. The decision to perform intestinal repairs robotically, laparoscopically, or with an open conversion is dependent on the injury incurred and the comfort level of the involved surgeons with minimally invasive techniques. Sharp, seromuscular injuries not breaching the intestinal lumen can be approximated, whereas full-thickness, sharp colonic, or small bowel injury requires two-layer repair [37]. Bowel repairs should be completed using absorbable 3-0 suture material. Small thermal injuries can often be reinforced using imbricating, absorbable suture. However, extensive thermal injuries generally require segmental bowel resection and primary anastomosis [39, 40]. Hematomas should be opened and drained, with inspection of the underlying tissue for injury. Postoperatively, a high index of suspicion should be maintained for a missed bowel injury, as these patients present with myriad symptoms. Classic signs and symptoms such as fevers, leukocytosis, and abdominal pain with peritoneal findings on examination are not always present [41]. Concern for occult bowel injury should trigger urgent evaluation, with a low threshold for obtaining CT with oral contrast material and general or colorectal surgical consultation. Confirmation of an injury, or signs of overwhelming peritonitis, should prompt urgent surgical intervention.

Duodenal Injury

The duodenum is primarily encountered during robotic right nephrectomy, when it is frequently necessary to medially mobilize its second portion off of the anteromedial surface of Gerota's fascia and the inferior vena cava to access the right renal hilar structures. Performance of the so-called Kocher maneuver (see Fig. 16.3) should be done using a combination of blunt and sharp dissection as well as minimal electrocautery. Less commonly, the fourth portion of the duodenum, just proximal the ligament of Treitz, is occasionally seen when the colon and small bowel are medially

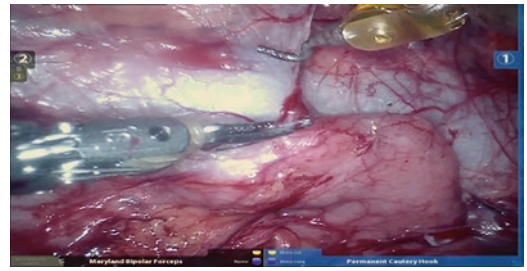

Fig. 16.3 The Kocher maneuver for medial duodenal mobilization. The duodenum is not directly grasped with the left hand. Instead, tension is applied to the surrounding connective tissue (Image courtesy of Daniel D. Eun, M.D)

mobilized during left nephrectomy. This is particularly true when the medial bowel mobilization is extensive, as is needed with large left-sided tumors and left nephrectomies requiring concomitant retroperitoneal lymph node dissection.

Injuries to the duodenum during renal surgery are rare, with few published reports in the urologic literature. Meraney et al. [42] reported a single, minor duodenal injury requiring serosal repair in a series of 404 retroperitoneal laparoscopic renal and adrenal surgeries. Ono et al. [43] and Joshi et al. [44] each reported single instances of duodenal injury with laparoscopic nephrectomy. In both cases, the injury was extensive, requiring laparotomy and duodenojejunostomy.

Repair of duodenal injuries should be approached in a manner similar to that described above for other small bowel or colonic injuries. Small cautery injuries, or those limited to the serosa, may be oversewn with absorbable suture. Full-thickness injuries are repaired in two layers. Omental patches may be used to buttress duodenal repairs. Extensive injuries, especially if cautery was involved, may require resection and duodenojejunostomy and should involve a general surgical team.

Vascular Injury

Under normal physiologic conditions, the kidneys receive 20% of total body cardiac output, equating to approximately 982 ml/min and 1209 ml/min in the average woman and man,

respectively [45]. Such abundant vascularity makes catastrophic hemorrhage a distinct possibility. Each kidney typically is fed by a single renal artery and drained by single renal vein. However, supernumerary renal arteries are found in approximately 25% of patients, more commonly on the left side. These arteries may insert into the renal hilum or directly into the renal parenchyma. Accessory renal arteries are end arteries, and transecting these vessels will result in ischemia to a portion of the kidney [46]. Accessory renal veins are less common, seen in approximately 1% of patients. While the right renal vein is not typically fed by smaller branches, the left adrenal, gonadal, and a posterior lumbar vein all drain into the left renal vein. All of these vessels can be sources of troublesome bleeding during nephrectomy.

Since the advent and widespread use of laparoscopy, blood loss associated with nephrectomy is decreased. In a large, retrospective series involving 549 laparoscopic radical and 186 laparoscopic simple nephrectomies, vascular injury was noted in 2.2% and 1.6% of cases, respectively [10]. Within this patient population, bleeding requiring transfusion was required in 1.3% of laparoscopic radical nephrectomies and 0.54% of laparoscopic simple nephrectomies and open conversion for bleeding in 0.36% and 1.08%, respectively. By comparison, a contemporary series of 668 open radical nephrectomies yielded a transfusion rate of 15% [47].

Careful dissection of the renal hilum is critical to avoiding vessel injury during radical nephrectomy. We prefer to put the hilum on stretch prior to dissecting the renal artery and vein. This involves defining a plane between the ureter and psoas muscle and placing the robotic fourth arm with a grasping retractor under the lower renal pole and ureter. The kidney can then be lifted in an anteromedial direction. In a right nephrectomy, the gonadal vein is mobilized medially prior to retracting the kidney, whereas in a left nephrectomy, the gonadal vein is elevated with the kidney. Dissection through perihilar adipose and lymphatic tissue can then proceed toward the hilum. Lumbar veins and arteries, if encountered, should be controlled with Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC), as they can be the source of significant bleeding. The renal artery and vein should be circumferentially dissected. Care should be taken to fully cauterize the well-vascularized investing connective tissue of the renal artery. The renal artery may be ligated using Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC), a surgical stapler or nonabsorbable sutures. If access to the renal artery is difficult, it may be ligated, and transection may be delayed until after the renal vein is divided. En bloc ligation of the renal artery and vein is an option in emergency situations. In a retrospective study of 90 patients who underwent en bloc ligation of the renal artery and vein for nephrectomy or nephroureterectomy, no clinical evidence of arteriovenous fistula was seen after an average of 34 months postoperatively [48].

One distinct advantage of the robotic platform is the ability to repair both minor and major vascular injuries in an expedient manner using wristed instruments. This allows for more rapid, precise suturing and easier placement of vascular clips as compared to traditional laparoscopy. For any surgical procedure involving dissection in or near the renal hilum, we routinely have a dedicated set of instruments, vascular sutures and clips, and hemostatic agents open and available in the event of a vascular injury.

Rapid recognition and localization of bleeding by the operative team, including the console surgeon and bedside assistant, are imperative first steps in managing vascular injuries. If a distinct source of bleeding from an injured blood vessel is recognized, it can be grasped by the console surgeon using robotic Maryland forceps. Venous bleeding can often be fully or at least partially controlled, by increasing pneumoperitoneum. Intra-abdominal pressures up to 25 mm Hg are acceptable for short periods of time until major bleeding is controlled [41]. Direct application of pressure to the area of bleeding, with or without the aid of absorbent sponges and/or hemostatic materials such as Surgicel sheets (Ethicon, Somerville, NJ), can often effectively tamponade bleeding. Once temporized, the source of bleeding can be addressed with a permanent repair.

Completely or partially transected branches of the renal vein (segmental, adrenal, gonadal, lumbar) or small-caliber arteries can often be controlled with Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC). Lacerations of the main renal vein or artery, IVC, or aorta require sutured repair using 4-0 Prolene (Ethicon, Somerville, NJ). Depending on the size of the injury, this can be completed using figure-of-eight or running repairs (see Fig. 16.4). We also always keep a single, short length of 4-0 Prolene (Ethicon, Somerville, NJ) suture readily available with a tapered, vascular needle on one end and a closed Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC) on the other. The clip is held in place with a knot at the end of the suture. In the event of a major vascular emergency, the suture can be passed through the bleeding vessel, and tension applied to the clip can be used to tamponade bleeding. Regardless of the source, if major hemorrhaging cannot be quickly managed, open conversion is warranted, and open instrument trays should be readily available in the operating room at all times during robotic nephrectomy.

Hepatic and Biliary Tract Injury

Injuries to the liver primarily occur at two points during robotic nephrectomy: during passage of Veress needles and laparoscopic trocars and during hepatic mobilization for right-sided nephrectomy. Regardless, liver lacerations in minimally invasive nephrectomy are rare and are not mentioned individually in several large series of minimally invasive urologic procedures [10, 32, 49]. In one large retrospective study of 894 patients undergoing laparoscopic urologic procedures, including 313 live donor nephrectomies, 142 radical nephrectomies, and 87 simple nephrectomies, there was 1 liver injury [50]. It is possible, however, that small intraoperative liver injuries requiring minimal intervention are underreported. Patients especially at risk for hepatobiliary injury are those with a prior history of cholecystitis and/or cholecystectomy due to the presence of inflammatory adhesions in the vicinity of the right hepatic lobe, common bile duct, and, if present, the gallbladder. All adhesions should be taken down sharply before the liver is retracted away from the retroperitoneum to avoid liver lacerations.

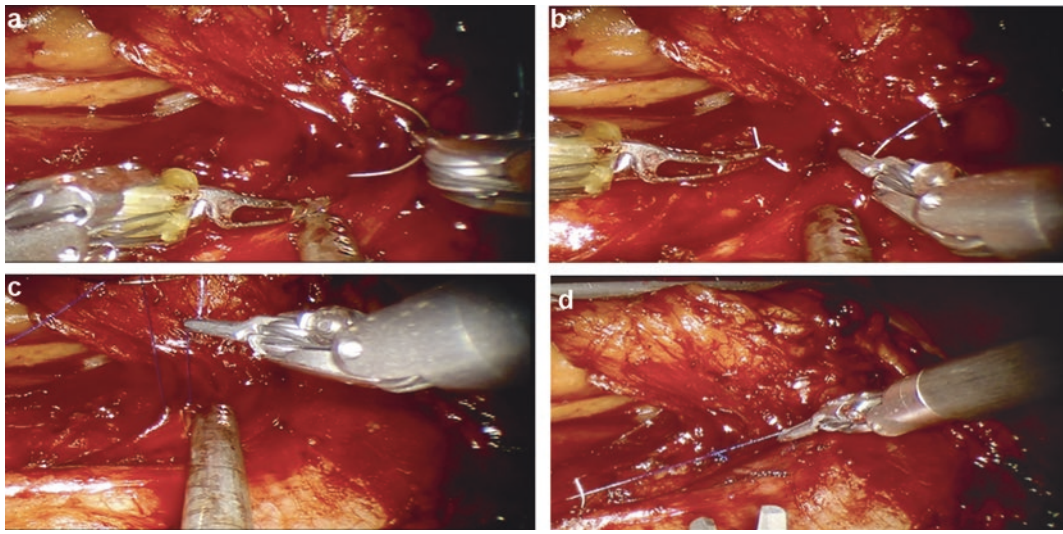

Fig. 16.4 (**a**–**d**) Sequence of steps in repairing a small tear in the inferior vena cava. (**a**) After identification, the vascular rent is grasped with Maryland forceps to slow bleeding. (**b**) A vascular repair suture on a taper needle is used to approximate the defect. (**c**) Each end of the suture is tensioned, ensuring closure of the defect prior to completing a figure-of-eight stitch. (**d**) The repair suture is tensioned and tied down (Images courtesy of Daniel D. Eun, M.D)

Small liver lacerations can often be managed with focused application of electrocautery and, if needed, argon beam coagulation. Deeper parenchymal lacerations often require packing with hemostatic material, such as Surgicel (Ethicon, Somerville, NJ), which can be formed into a bolster and placed into the wound. If direct application of pressure to the bolster does not staunch bleeding, the liver parenchyma and capsule can be approximated over the bolster using 2-0 silk or 1 chromic mattress sutures [51]. Deep parenchymal lacerations with heavy bleeding or bile leakage should prompt consultation with a hepatobiliary surgeon.

Like hepatic injury, damage to the bile ducts and gallbladder are rare, with a similar risk factor profile, specifically prior hepatobiliary inflammatory processes and/or surgery. Canes et al. [52] reported on two cases of common bile duct injury during urologic laparoscopy, one of which occurred during a laparoscopic right partial nephrectomy. In this procedure, a 63-year-old male with prior cholecystectomy required lysis of adhesions on the undersurface of the liver for exposure of the right kidney. Metal clips were placed to control bleeding on the anterior duodenum, after which leakage of bilious fluid was noted, and a pinhole injury to the common bile duct was discovered. After a general surgery consultation was obtained, the defect was oversewn laparoscopically with 5-0 absorbable suture and a drain was left in place near the bile duct. Postoperatively, an attempt at retrograde cannulation of the common bile duct via endoscopic retrograde cholangiopancreatography was unsuccessful. The patient subsequently underwent percutaneous transhepatic cholangiography, which demonstrated no leakage from the bile duct repair and narrowing of the distal common bile duct, presumably from prior ERCP instrumentation. Antegrade stenting of the bile duct was performed, and the patient was discharged thereafter.

Pancreatic and Splenic Injury

The spleen, pancreatic tail and upper pole of the left kidney are intimately associated in the left upper abdominal quadrant, and dissection of these structures away from the upper pole of the left kidney and adrenal gland is an essential step in robotic left nephrectomy. For this reason, the spleen, pancreatic tail, and the large-caliber splenic vein running underneath the pancreas are all at risk for injury, and careful dissection is critical.

While rare in large series of laparoscopic urologic procedures, pancreatic injury is a known complication of left renal and adrenal procedures. Varkarakis et al. [53] reported four pancreatic injuries from a series of 890 laparoscopic urologic operations taking place between 1999 and 2004, corresponding to an overall rate of pancreatic injury of 0.4%. All four injuries were during left-sided retroperitoneal procedures, two during laparoscopic left radical nephrectomy, and two during laparoscopic left adrenalectomy. One patient had an intraoperative parenchymal tear of the pancreatic tail with no evident pancreatic duct injury. A drain was left in place postoperatively, and serum levels of amylase, lipase, and white blood cell (WBC) count were monitored postoperatively, while the patient was maintained on nasogastric tube drainage with intravenous somatostatin. The patient was fed orally when serum WBC and pancreatic enzyme levels normalized and drain output was <40 ml/24 h. The three other patients were all diagnosed postoperatively with pancreatic injuries. Two developed clinical signs of pancreatitis, with elevated WBC and pancreatic enzyme levels. Of these two, one resolved spontaneously. However, the other was diagnosed with a fluid collection at the surgical site which was drained and ultimately became a pancreatic fistula. A final patient was found to have pancreatic tissue on pathologic specimen analysis but showed no clinical signs of pancreatic injury.

Prevention of pancreatic injury with left robotic nephrectomy primarily involves careful tissue handling and dissection within the proper surgical planes. In the absence of prior surgery or inflammation, a plane can usually be developed between the tail of the pancreas and Gerota's fascia using primarily blunt dissection, with judicious use of cautery and scissors. Forceful retraction on the pancreas and splenic vein with the surgeon's left robotic arm should be avoided,

and the pancreas and splenic vein should not be directly grasped with forceps. The use of the fourth robotic arm to place countertraction on the kidney can aid in dissecting the contents of Gerota's fascia away from the pancreas and splenic vein.

Management of pancreatic injury, if noted intraoperatively, depends on injury severity. Small parenchymal injuries may be oversewn and buttressed with omentum. Involvement of the pancreatic ductal apparatus should prompt consultation with a general or hepatobiliary surgeon. A severe injury involving the pancreatic duct may require distal pancreatectomy, which may be performed in a minimally invasive or open fashion depending on the preference and comfort level of the general surgeon. Postoperatively, serum levels of amylase, lipase, and the WBC count should be monitored. Enteric feeding should be resumed slowly, with a low threshold to begin parenteral nutrition. Clinical signs and/or symptoms of pancreatitis such as fevers, nausea, emesis, and abdominal pain should prompt imaging with a CT scan to look for fluid collections caused by pancreatic leak. Fluid collections should be drained percutaneously, with fluid examination for levels of pancreatic enzymes and triglycerides, as well as bacterial cultures. If not done previously, involvement of consulting services such as general surgery, hepatobiliary surgery, and gastroenterology is advisable.

Left nephrectomy has traditionally been one of the leading causes of splenic injury, quoted as the second or third leading cause of iatrogenic splenectomy in some studies in the open nephrectomy literature [54]. However, overall incidence of splenic injury in minimally invasive urologic surgery remains quite low, seen in 0–3.2% of cases in large series of minimally invasive urologic surgeries [10, 11, 49, 50]. Chung et al. [55] described 14 splenic injuries in a large retrospective analysis of 2260 patients undergoing laparoscopic urologic surgery at two institutions from 2000 to 2008. All injuries occurred during left renal and adrenal surgery, including six radical nephrectomies, four partial nephrectomies, and two donor nephrectomies. 13 of 14 injuries were seen in transperitoneal procedures. Of the 14 injuries, 12 were noticed and repaired intraoperatively. The authors noted eight minor and four major injuries, with minor injuries described as <1 cm in length and major injuries as >1 cm in length. All injuries were repaired using a combination of argon beam coagulation, Surgicel (Ethicon, Somerville, NJ), and FloSeal (Baxter, Deerfield, IL). In two patients, the injury was unrecognized, and both patients subsequently required exploration and splenectomy due to hemodynamic instability.

Splenic injuries during robotic nephrectomy are usually of one of two etiologies: traction injuries causing tears in the splenic capsule and direct punctures and lacerations into the splenic parenchyma caused by instruments. Prevention of splenic injury begins with adequate splenic mobilization from its surrounding structures. Incision of the splenorenal and splenocolic ligaments is an integral step in mobilizing the spleen and the attached pancreatic tail, from the upper renal pole. If present, splenic attachments to the omentum must also be released. As with mobilization of the pancreatic tail, careful retraction with the left robotic arm is key to preventing splenic injury. The splenic capsule should never be grasped directly by the surgeon or assistant. Instead, retraction may be accomplished with gentle pressure on the spleen from opened retracting forceps, provided instrument tips are pointed away from the tissue. A lap pad or radiopaque sponge placed underneath the spleen can soften the force of retraction. As the spleen is separated from the kidney and adrenal, its attachments to the diaphragm are seen. These must be taken down to fully mobilize the spleen from the left adrenal gland and upper renal pole, but indiscriminate incision of these bands can lead to diaphragmatic injury.

Many, if not most, splenic injuries occurring during robotic nephrectomy can be managed with a combination of cautery techniques and hemostatic agents. Chung et al. propose an algorithm by which active bleeding from a splenic injury is first addressed by covering the wound with Surgicel sheets. If bleeding continues, FloSeal, more Surgicel, and finally argon beam

coagulation are sequentially employed. Continued bleeding after the use of these agents prompts a general surgical consultation. Other hemostatic agents have been used in managing splenic injuries. Canby-Hagino et al. [56] and Biggs et al. [57] employed fibrin sealant and BioGlue (CryoLife International, Kennesaw, GA), respectively, to successfully treat small numbers of splenic injuries incurred during left nephrectomy. Hemostatic bolsters, with or without sutured splenorrhaphy may also be used. Methods for tensioning sutures with sliding surgical clips to prevent further parenchymal injury have been described [58]. The key decision for the surgeon comes after failure of the above methods, when it becomes necessary to perform splenectomy. This may be done robotically, laparoscopically, or open. However, conversion to open laparotomy may be necessary in the case of severe hemorrhage.

After completion of surgery, any patient with a repaired splenic injury should undergo close vital sign monitoring and serial measurement of hemoglobin and hematocrit levels to detect recurrent splenic bleeding. Hemodynamic instability should prompt an urgent return to the operating room. Delayed bleeding without hemodynamic instability can often be diagnosed via CT scan and managed nonoperatively with close monitoring. If a splenectomy is performed, appropriate postoperative immunization against encapsulated microorganisms is necessary. Specifically, vaccination should cover *Haemophilus influenzae* type b (meningitis and pneumonia), *Streptococcus pneumoniae* (pneumonia), and *Neisseria meningitidis* (meningitis) [59]. Annual influenza vaccine is also mandatory for these patients due to an increased risk of secondary bacterial pneumonia.

Chylous Ascites

The development of chylous ascites after minimally invasive nephrectomy is the accumulation of lymphatic fluid, or chyle, within the peritoneal cavity and is directly related to disruption of lymphatic channels in the retroperitoneum during surgery. Much of the available literature describing this complication comes from live donor laparoscopic nephrectomy patients. Incidence rates of chylous ascites are low in these series ranging from 0.013% to 3.8% [60–62]. Incidence of chylous ascites is significantly higher for left-sided nephrectomies. This is born out in studies of living donor transplant nephrectomies, which are typically left sided and require more extensive dissection of lymphatic tissue adjacent to the left renal vein and aorta. However, the typical periaortic location of the cisterna chyli in the left retroperitoneum makes chylous leak a risk in any left-sided renal procedure. In one study by Kim et al. [62], which included 622 transperitoneal laparoscopic nephrectomies, 270 laparoscopic radical nephrectomies, 146 laparoscopic donor nephrectomies, and 90 laparoscopic simple nephrectomies, chylous ascites developed in 7.3% of left-sided nephrectomies but only 2.5% of right-sided nephrectomies ($p = 0.010$). Aggressive retroperitoneal lymphadenectomy, as is frequently performed concomitantly with radical nephrectomy when suspicious regional adenopathy is present or with high-risk renal masses, is also a risk factor for chylous leak and ascites development. Kim et al. found a significantly higher risk for chylous ascites development in patients who underwent laparoscopic nephrectomy with lymphadenectomy (13.9%) as opposed to those who did not (4.0%) ($p = 0.027$). A significantly higher rate of chylous ascites was also seen in laparoscopic radical and donor nephrectomies as opposed to laparoscopic partial and simple nephrectomies, presumably due to the increased lymphatic disruption seen in the former procedures.

Prevention of chylous ascites is predicated on meticulous dissection and control of retroperitoneal lymphatics during nephrectomy. Visible lymphatic channels, especially those lateral to the aorta in the vicinity of the left renal hilum, should be controlled with surgical clips. (see Fig. 16.5). Fibrofatty tissue should be fully cauterized to decrease leakage from smaller, non-visible lymphatics. Kim et al. found that their rates of chylous ascites decreased significantly when they

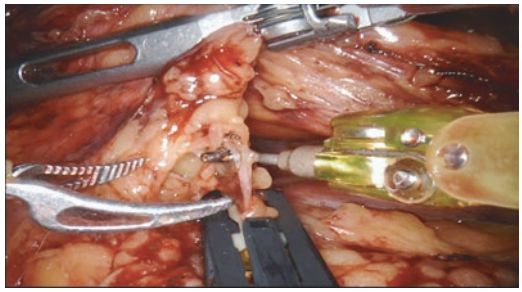

Fig. 16.5 Meticulous clipping of hilar lymphatic channels helps prevent the formation of chylous ascites (Image courtesy of Daniel D. Eun, M.D)

began controlling lymphatic channels with clips as opposed to cautery.

Symptoms of chylous ascites are nonspecific, and a high index of suspicion must be maintained for diagnosis. Abdominal distension, fullness, and discomfort are common. If prolonged, loss of protein in lymphatic drainage can produce malnutrition. Ascites may be diagnosed on cross-sectional imaging, but diagnosis of chylous ascites requires analysis of the ascitic fluid for the presence of high triglyceride concentrations.

The majority of patients who develop chylous ascites can be managed nonoperatively. Management of chylous ascites typically begins with dietary modification, with patients being placed on a high-protein, low-fat, medium-chain triglyceride diet to decrease lymphatic output. Somatostatin, or its analog octreotide, is frequently given along with this diet, and their dosages may be increased up to 200 μg/day, though the exact mechanism of action is not known [63–65]. If dietary management is successful, it should be continued for several months after resolution of ascites. Paracentesis and intra-abdominal drain placement are both therapeutic and diagnostic, though risk of infection increases with repeated episodes of paracentesis and prolonged intra-abdominal drain placement. Second-line treatment usually consists of total parenteral nutrition (TPN). Drains are typically removed when output reaches 50 cc or les per day [65]. Failure of conservative measures after 4 weeks, or drain output >1000 ml/day, is frequently indicative of a need for surgical exploration and lymphatic ligation.

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Nephroureterectomy with Bladder Cuff

17

Weil R. Lai and Raju Thomas

Introduction

Urothelial cancer of the upper urinary tract is an uncommon urological malignancy, occurring in 5–10% of all urothelial tumors in the United States [1]. In the case of high-grade urothelial malignancy and/or tumor burden not amenable to minimally invasive procedures such as endoscopic resection and/or laser versus electrocautery fulguration, the gold standard has been open nephroureterectomy with bladder cuff excision. The technique for this has always varied depending on surgeon preference and experience as well as patient's body habitus such as morbid obesity. This open surgical procedure is generally accomplished through two separate large incisions, one for the nephrectomy, and the other for the distal ureterectomy and bladder cuff excision, each with its associated morbidity. With the advent of laparoscopy and robotic surgery, nephroureterectomy can be performed in a minimally invasive fashion, with comparable oncological outcomes and with decreased morbidity [2]. We will review the technique of minimally invasive nephroureterectomy and, above all, discuss its complications, with particular focus on those associated with distal ureterectomy and bladder cuff excision.

Technique Considerations

In general, nephroureterectomy is a two-step surgical procedure involving different quadrants of the abdomen and pelvis: nephrectomy and distal ureterectomy with bladder cuff excision. The steps of nephrectomy are well known to urologists and are easily translatable to laparoscopy and robotics. Trocar placement and configuration depend on how the distal ureter is managed, the type of laparoscopic/robotic equipment available, and patient's body habitus (body mass index). Management of the distal ureter and bladder cuff depends on surgeon preference and experience with minimally invasive techniques. In open surgery, this is performed through a Gibson, Pfannenstiel, or midline incision. To minimize urine spillage into the surgical field, an extravesical technique is typically used in antegrade fashion. If there is concern for tumor involving the ureteral orifice or concomitant bladder tumor, a cystotomy is made as part of the intravesical technique to directly visualize the ureteral orifice and to free up the distal ureter in both directions.

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Prior to popularization of the robotic platform, many of the early laparoscopic series utilized a variant of the "pluck" technique to mobilize the distal ureter and the bladder cuff. These techniques were developed because antegrade mobilization of the distal ureter and the bladder cuff, combined with intracorporeal laparoscopic suturing of the bladder defect, require a high degree of laparoscopic experience and finesse. The "pluck" technique relies on transurethral incision around the ipsilateral ureteral orifice and mobilization of the distal ureter from the bladder and perivesical fat. This is then followed by pulling the ureter laparoscopically on gentle traction to "pluck" it away from the bladder. The transurethral techniques described in laparoscopic series included Collins knife [3], cutting wire electrode [4], bipolar plasma "button" electrode [5], and laser excision [6] around the ureteral orifice. To minimize potential subsequent spillage of cancer cells from the ureter, a variety of techniques have been described in the urological literature, which include endoscopic ureteral occlusion techniques such as suture ligation [7], fulguration of the ureteral lumen [7], balloon occlusion [8], and fibrin plug within the ureteral lumen [9].

Although the "pluck" technique is familiar to urologists with experience with transurethral resection, major disadvantages to this technique include the oncological concern of potentially seeding the perivesical fat with cancer cells, as the bladder defect is not closed with this technique and is left to heal by prolonged Foley catheter drainage. It excludes the possibility to instill intravesical chemotherapy immediately after surgery to decrease the rate of intravesical recurrence of bladder tumors because such instillation would potentially flow into the peritoneum and retroperitoneum. In addition, this technique usually required the patient to be placed in dorsal lithotomy position first for the cystoscopic part of the procedure, followed by repositioning, reprepping, and redraping the patient for the nephrectomy part of the procedure.

In an attempt to decrease the difficulty of laparoscopic suturing, different groups have developed variations in the laparoscopic management of the distal ureter and bladder cuff. In one of the earliest case series on laparoscopic nephroureterectomy, McDougall et al. used a titanium stapler to divide the ureter distal to the ureterovesical junction in ten patients [10]. Although the oncological outcomes were not statistically different in their updated case series [11] compared with a group of patients who underwent open nephroureterectomy, a different case series comparing the distal ureterectomy methods during hand-assisted laparoscopic nephroureterectomy found that the stapled cohort had higher than expected positive surgical margin rate at the distal ureter (29%) compared with the other techniques (i.e., "pluck" technique, open distal ureterectomy, and hand-assisted laparoscopic extravesical distal ureterectomy), which had rates less than 10% [12].

An alternative to the stapling technique was with dividing the bladder cuff with LigaSure Atlas (Medtronic, Minneapolis, MN, USA) [13]. Similar to the stapling technique, the LigaSure method seals the bladder defect with no spillage of urine into the operative field. Although this method reportedly had good outcomes with no local recurrence reported with a mean follow-up time of 11.6 months, there is no direct visualization of the ureteral orifice prior to dividing the bladder cuff. A different group reported that out of the 22 patients undergoing this technique, 4 required additional cystorrhaphy to make the closure watertight [14]. One was found to have a remnant ipsilateral ureteral orifice on cystoscopy and underwent transurethral resection with no residual tumors identified.

For urologists facile at laparoscopic suturing, Cho et al. described their technique of placing a curved bulldog clamp on the bladder cuff, dividing the cuff proximal to the clamp, and intracorporeal suturing of the bladder mucosa prior to removing the bulldog clamp [15]. Although this technique prevents urine spillage and allows for visual confirmation of the ureter specimen for the ureteral orifice, it does require advanced laparoscopy techniques for the two-layer cystorrhaphy closure.

With the popularization of the robotic platform, the learning curve for minimally invasive procedures, such as nephroureterectomy, has been decreased. The three-dimensional vision

and the articulating wristed instruments facilitate ureteral dissection and intracorporeal suturing in small working spaces. For robotic nephroureterectomy (RNU), Hemal et al., have published their experience with performing all the steps of the operation without repositioning the patient or redocking the robotic patient-side cart to the patient. This has been done for da Vinci S, Si, and Xi robots (Intuitive Surgical, Sunnyvale, CA, USA) [16, 17]. With the da Vinci S and Si robots, they place the robotic arms in a T-shaped configuration, with the camera trocar in the middle of the port configuration [16]. Upon completion of nephrectomy, the camera position is tilted to the pelvis for the distal ureterectomy. With the da Vinci Xi robot, the four robotic trocars are placed linearly over the pararectus line and can be shifted medially or laterally depending on the patient's body habitus [17]. As the camera for the da Vinci Xi robot goes through the 8 mm robotic trocar, the camera can be moved from one robotic trocar to another trocar as needed to facilitate visualization during distal ureterectomy.

Alternatively, Darwiche et al. recommended placing the Xi trocars in an oblique straight line and switch the camera to the second most caudal robotic trocar for the distal ureterectomy [18]. Most recently, Argun et al. advocated placing the Xi trocars in a T-shaped configuration [19], similar to the configuration as reported by Hemal et al. [16] using the earlier generation robots.

With the robot, the antegrade approach to the distal ureter is considerably less difficult to perform compared with laparoscopic techniques. To minimize potential cancer cell migration from the ureter to the bladder, the ureter should be clipped distal to the location of the tumor within the upper tract.

Complications of Nephroureterectomy

Complications in RNU can be divided by anatomical location and organ of interest. This is because nephroureterectomy encompasses an anatomical area from the upper reaches of the upper quadrant to the distal reaches of the true pelvis. The complications associated with the nephrectomy part of the case are identical to those encountered for radical nephrectomy and partial nephrectomy. These complications have been previously described in this book on radical nephrectomy. Complications encountered during distal ureterectomy portion of the RNU are detailed below:

Positioning Related

Positioning-related complications for RNU are similar to those noted for radical nephrectomy. Because RNU has higher operative times as compared with radical nephrectomy, prolonged lateral decubitus positioning can place the patient at a higher risk for developing rhabdomyolysis and pulmonary complications. In a multi-institutional series of 43 RNU, two patients developed rhabdomyolysis, and two patients developed pneumonia [20]. In the rhabdomyolysis cases, both patients were morbidly obese, and one required temporary hemodialysis. As neither patients developed compartment syndrome, both recovered without additional surgical procedures.

Bladder Cuff Management

Complications in distal ureterectomy and bladder cuff excision depend on the technique used. In the "pluck" technique, the resulting bladder defect is left to heal and is expected to close by prolonged Foley catheter drainage. This puts the perivesical fat and peritoneum at risk of seeding from tumor cells which may have migrated from the ureter to the bladder. In a multi-institutional, retrospective study of 2681 patients who underwent open (80.9%) or laparoscopic (19.1%) nephroureterectomy from 1987 to 2007, those who underwent the "pluck" technique had slightly higher intravesical recurrence (58% at 5 years) compared with those who underwent transvesical (42%) or extravesical (49%) techniques [21]. The median follow-up was 57.5 months. There were no differences in the overall recurrence-free survival, cancer-specific

survival, or overall survival among the different distal ureteral management techniques. Laparoscopy was associated with higher intravesical recurrence, albeit most patients who underwent laparoscopy also underwent the "pluck" technique in this study. Other similar studies, including Miyazaki et al. [22], did not find laparoscopy to be associated with higher intravesical recurrence, local recurrence, or distant metastases.

To reduce the risk of intravesical recurrence after nephroureterectomy, it is recommended to administer a single dose of intravesical chemotherapy in the early postoperative period. In the ODMIT-C trial (prospective, randomized, nonblinded), patients either receive one dose of intravesical mitomycin C (MMC) prior to Foley catheter removal (at least 1 week postoperatively) or standard postoperative care without MMC. This study included open and laparoscopic techniques [23]. A pretreatment cystogram was not required prior to administration of MMC. At 1 year after surgery, the intravesical recurrence rates were 17% and 27% in the MMC and standard treatment arms, respectively. No serious adverse events were reported. The number needed to treat to prevent one bladder tumor was 9.

Although the "pluck" technique is now uncommonly used in RNU, we do recommend closing the bladder defect with a two-layer closure. Having a watertight closure gives the urologist the option of administering MMC earlier in the postoperative period. An alternative is to instill MMC at the time of surgery. In a retrospective study of Moriarty et al. [24], intravesical MMC or doxorubicin (when MMC was in supply shortage) was instilled in the bladder at the beginning of surgery and then drained out after 1–2 h of instillation (i.e., during the nephrectomy part of the case). The distal ureter was managed with either extravesical or intravesical approaches. There were no postoperative complications directly attributed to either MMC or doxorubicin.

In the extravesical technique, it is very important to make sure that the bladder cuff excision does not extend to the trigone of the bladder, as that puts the contralateral ureteral orifice at risk for iatrogenic injury from either tissue dissection or while suturing the bladder defect. Obstruction of the contralateral ureteral orifice can present with anuria, oliguria, or flank pain. Excluding other etiologies (e.g., clot retention in the bladder, edema of the contralateral ureteral orifice, obstructing ureteral calculus), the temporary placement of percutaneous nephrostomy tube may be the best option, followed by definitive treatment (e.g., ureteroneocystostomy) in a delayed manner. If there is concern about intraoperative injury to the contralateral ureteral orifice, we would recommend the placement of a 5-French ureteral catheter immediately prior to the nephroureterectomy.

In the cases that the distal ureter breaks apart during extravesical dissection because of excessive traction, one may consider changing over to an intravesical technique to mobilize the ureteral orifice and bladder cuff in retrograde fashion to remove the ureteral stump, followed by closure of the cystotomies. In the scenario, where a ureteral stent is present within the ipsilateral ureter because of ureteral obstruction (and to maximize renal function of an obstructed kidney for neoadjuvant chemotherapy), our preference is to securely place a surgical clip distally on both the ureter and the stent and remove the specimen together with the stent intact.

Cystorrhaphy Complications

Often, the distal ureter is placed on traction when the cystotomy and subsequent bladder cuff excision are performed. One known complication is retraction of the cystotomy and subsequent difficulty in closure of the cystotomy. To facilitate cystorrhaphy, we recommend placement of stay sutures on each side of the ipsilateral ureteral orifice prior to cystotomy, as the bladder mucosa retracts into the bladder lumen after the bladder cuff is divided. Remember that the ureteral orifice and the trigone are deep in the pelvis and close to the prostate, and these recommended stay sutures can easily be used to visualize the detrusor and the bladder mucosa for secure two-layer closure of the cystotomy. The bladder cuff should be partially divided to visually confirm the presence of

the ipsilateral ureteral orifice in the specimen. This also allows the specimen to help to retract the bladder toward the camera to facilitate suturing of the bladder mucosa. The stay sutures can be also used as part of the two-layer closure. We also recommend testing the cystorrhaphy with Foley catheter irrigation to ensure that the closure is watertight and to determine the duration of indwelling urethral catheterization and the need for a postoperative cystogram. One can follow the output and fluid creatinine levels from the surgical drain, if one has been placed, to evaluate adequate and prompt bladder closure.

If follow-up cystogram exhibits extravasation of contrast, further Foley catheter drainage of the urinary bladder is recommended.

Trauma to Adjacent Organs

Other organs adjacent to the distal ureter are also at risk of injury during ureteral dissection. When freeing the ureter from the iliac vasculature, care should be undertaken to avoid direct electrocautery contact or electrocautery arcing on the vessels. In the case of venotomy, this can be tamponaded by the bedside assistant with gentle pressure with the suction-irrigator tip and with a temporary increase in the pneumoperitoneal pressure. During venotomy excursions, the assistant should be instructed to minimize suctioning and to maximize the tamponading effect. Other measures such as using a temporary sponge or mini-laparotomy pad is recommended while preparing for suture closure of the venotomy. The venotomy can then be closed with a polypropylene suture with the ends secured with Lapra-Ty clips (Ethicon, Somerville, NJ, USA). Alternatively, a 3-0 multifilament polyglactin suture on a tapered needle can be used for the ease as well as quickness of tying knots and to avoid suture memory that is commonly associated with monofilament sutures.

Additionally, trauma to the cecum and small bowel on the right side and to the sigmoid colon on the left side should be of concern.

In female patients who have not had hysterectomy, injury to the uterine vessels and adnexa should be guarded against. The key to this is adequate dissection and keeping the anatomical landmarks in clear visual acuity.

Complications of Pelvic Lymphadenectomy

If the site of the tumor is located in the distal ureter, pelvic lymphadenectomy may also be performed for staging purposes, especially for high-grade tumors. The complications associated with pelvic lymphadenectomy during nephroureterectomy are similar to those encountered during pelvic lymphadenectomy for robotic prostatectomy and cystectomy. The robotic surgeon needs to be cognizant of the techniques to prevent complications during pelvic lymphadenectomy. Further details may be found within this book on the chapter on robotic prostatectomy/cystectomy.

Other Considerations

Timing of ureteral occlusion

To prevent tumor spillage, various authors have recommended ligation of the ureter distal to the tumor burden within the urinary collecting system [25]. The preferred timing would ideally be after the renal artery has been clamped and ligated. The ureter can then be clamped. If the ureter is clamped early and there is a delay in renal hilar dissection, it is assumed that the kidney will continue to produce urine. Depending on the amount of urine produced and the time to renal arterial clamp, there is potentially a certain degree of hydronephrosis that will develop. If the hydronephrosis is significant, then subsequent dissection of the ureter with the bulky hydroureteronephrosis will make distal ureterectomy a challenging procedure. Therefore, judicious timing of the ureteral clamping is recommended.

Need for additional trocars

Though one may start with trocar placement to minimize the need and time spent on redocking, one should be ready for additional trocar placements and undocking so as to perform the distal ureterectomy in a safe and expeditious manner. Such additional trocars can increase the efficiency of the bedside surgeon, and thereby directly improve on the robotic surgical technique.

Conclusions

Nephroureterectomy is an uncommon operation secondary to the low incidence of upper tract urothelial cancer. Compared with open surgery, incisional and postoperative morbidity can be minimized with the use of minimally invasive technique. The robotic platform allows the urologist to perform RNU in an oncologically safe manner, especially with the antegrade management of the distal ureter and the bladder cuff. To reduce the complications associated with nephroureterectomy, special attention should be considered when dissecting the ureter off adjacent structures, mobilizing the bladder cuff, and performing cystorrhaphy. Given the propensity for recurrence of urothelial cancer in the bladder, intravesical chemotherapy is recommended at the time of surgery or during the early postoperative period. If the robot is not available, the alternative is to perform laparoscopic nephroureterectomy. In such a scenario, our preference would be to do the extravesical approach to the distal ureter, with laparoscopic suturing of the cystorrhaphy, so that intravesical chemotherapy can be given safely either at the time of surgery or during the immediate postoperative period. Moreover, this will enhance early closure and healing of the cystotomy.

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Partial Nephrectomy

18

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Partial nephrectomy (PN) is the recommended standard-of-care surgical treatment option for patients with a small renal mass, who are candidates for nephron-sparing surgery. PN provides similar long-term oncologic outcomes as radical nephrectomy with benefits of preserving renal function that can ultimately impact patients' quality of life and survival [1]. Partial nephrectomy can be performed by open (OPN), laparoscopic (LPN), or robotic (RPN) approaches [1]. Over the past few years, RPN has emerged as a strong alternative to OPN and LPN due to several documented advantages including less blood loss, quick recovery, less complications and similar oncologic and functional outcomes [2]. RPN is the most common PN approach since 2012 and, currently, it is estimated that 66% of PN in the USA are performed robotically. (Giovanni Cacciaman and Inderbir S. Gill; umpublished data) Nowadays, in centers with adequate expertise, indications for RPN are the same as for OPN; furthermore, contraindications for RPN are more surgeon- and patient-related, rather than being tumor-related. As such, given adequate robotic expertise, in 2017, if a patient is deemed to be a candidate for OPN, he/she is also typically a candidate for RPN, thus delivering the considerable benefits of minimally invasive surgery. Unique facets of robotic surgery include 3D visualization and magnification, endo-wrist technology with highly facile instrumentation whose seven degrees-of-freedom simulates, even exceeds, the capabilities of the human wrist.

PN is a major operation and, as such, is associated with a not insignificant complication rate (Table 18.1). Herein, we present, specific complications related to PN surgery and tips for prevention and management [19] Complications not specific to PN surgery, such as those deriving from patient positioning, port-placement, instrument insertion, or non-surgical issues are not a subject of this chapter and have been described elsewhere in this book. We divide

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Table 18.1 Complications reported in literature

Author	Year	Cases	Complication rate (%)	Timing of the complication		Bleeding (%)	Urine leak (%)	Other
				Intra-operative	Post- operative			
Gettman [3]	2004	13	2 (8%)	0	1	0 (%)	0 (0%)	1
Caruso [4]	2006	10	3 (30%)	2	1	2 (20%)	0 (0%)	2
Kaul [5]	2007	10	2 (20%)	n/a	n/a	1 (10%)	1 (10%)	0
Aron [6]	2008	12	4 (33%)	1	3	0 (0%)	0 (0%)	4
Deane [7]	2008	11	1 (9%)	0	1	1 (9%)	0 (0%)	0
Rogers [8]	2008	11	2 (18%)	0	2	0 (0%)	2 (18%)	0
Rogers [9]	2008	148	9 (6.1%)	0	9	1 (0.6%)	2 (1.2%)	6
Wang [10]	2009	40	8 (20%)	n/a	n/a	3 (7.5%)	1 (2.5%)	4
Michli [11]	2009	20	3 (15%)	1	2	0 (0%)	0 (0%)	0
Ho [12]	2009	20	0 (0%)	0	0	0 (0%)	0 (0%)	0
Benway [13]	2009	129	11 (8.5%)	n/a	n/a	4 (3%)	3 (2.3%)	4
Patel [14]	2010	71	10 (14%)	1	9	4 (5.6%)	2 (3%)	4
Scoll [15]	2010	100	5 (5%)	n/a	n/a	0 (0%)	2 (2%)	3
Petros [16]	2010	83	5 (8%)	0	5	1 (1.2%)	2 (2.4%)	2
Ficarra [17]	2012	49	15 (26%)	2	13	n/a	n/a	n/a
Gupta [18]	2013	17	1 (6%)	0	1	0	1	0

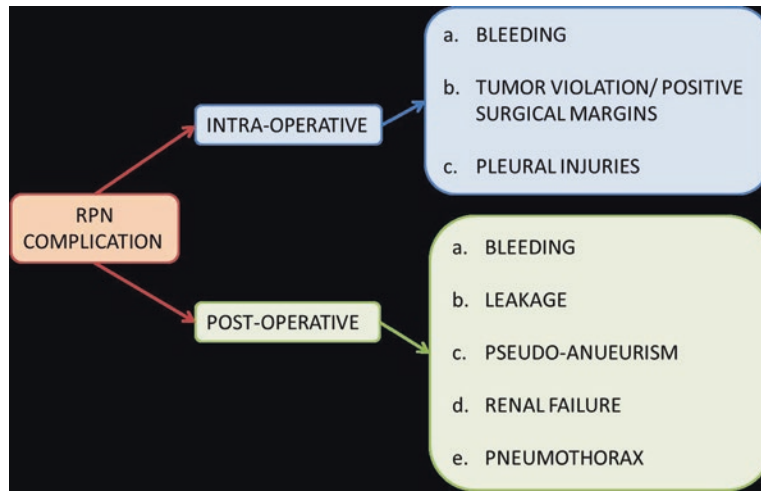

Fig. 18.1 The complications reported in the contemporary series are reported in Table 18.1

complications into intra- and post-operative categories (Fig. 18.1) and address the practical aspects of RPN surgery.

Overall, the prevention of complications begins with a detailed understanding of important landmarks and meticulous surgical planning. This is best achieved by a CT scan-based evaluation of renal, tumor and renovascular anatomy by the surgeon. In this context, we believe that the image quality afforded by a renal protocol CT scan is superior to MRI scan. At our institution, we use 0.5–1 mm slice-thickness CT scan images, with oral and intravenous contrast. Arterial, parenchymal, venous and excretory (delay) phases are generated for evaluation. Consultation with specialized uro-radiologist is advisable for detailed imaging interpretation. If available, a 3D reconstruction of the tumor, intra-renal arterial tree and kidney, and

3D–printed models can facilitate better 3D understanding of the anatomy [20, 21].

Important information for PN surgery is as follows:

- Patient characteristics: body habitus; body mass index, perinephric fat measurements and adhesiveness.
- Renal vessels: number of arteries and veins, arterial tree branching, tumor-feeding arteries, relation between the tumor, renal artery and renal vein.
- Tumor: size, clinical stage, location (anterior, posterior, lateral), relation to polar lines (upper, mid or lower pole), endophytic/exophytic ratio, proximity to the hilum, closeness to collecting system, tumor contact surface area (CSA).
- Collecting system: ureteral course, endophytic/exophytic ratio of the renal pelvis.
- Understanding the relationship of the kidney and its vasculature with: duodenum, vena cava, hepato-duodenal ligament and liver for right-sided RPN; and with the aorta, lumbar veins, renal vein tributaries (adrenal and gonadal veins), superior mesenteric artery, splenic vessels, spleen, pancreas and stomach for left-sided RPN.

Nephrometry scoring systems such as R.E.N.A.L [22], PADUA [23], Renal Tumor Contact Surface Area (CSA) [24], C-Index [25], Adhesive Probability Score [26], Renal Pelvic Score [27] are useful tools for precise anatomic understanding and sophisticated surgical preplanning for PN based on individualized, patient-specific data. This helps to predict and minimize complications related to PN surgery (Table 18.2). Nomograms are also available: http://lbs.fccc.edu/nomograms/main.php?nav=3&audience=1

Table 18.2 Nephrometric score and complication rate

Nephreometric score	Parameter analized	Grade	Overall complications (%)
R.E.N.A.L. [22, 28]	Radius (max diameter in cm), Exophytic/endophytic properties, Nearness to the collecting system, Anterior/posterior, Location relative to the polar line	Low complexity	3.4%
		Moderate complexity	5.4%
		High complexity	15.9%
P.A.D.U.A. [23]	Radius (max diameter in cm) Exophytic/endophytic Location, sinus line Renal rim Renal sinus Collecting system	Anterior low (6–7)	2.0%
		Anterior Moderate (8–9)	40.0%
		Anterior ≥ High (≥ 10)	50.0%
		Posterior low (6–7)	5.6%
		Posterior moderate (8–9)	32.0%
		Posterior ≥ High (≥ 10)	61.5%
C-index [25, 29]	Tumor centrality	Low (score 2.5 or greater)	14.7%
		High (score less than 2.5)	29.0%
Contact surface area [24]	Tumor-parenchyma contact Surface area	<20 cm^2	19.2%
		≥20 cm^2	34.5%
Adhesive Perinephric Fat (APF) score [26]	Presence of APF	None stranding (0 pt)	n/a
		Mild/Moderate stranding (2 pt)	n/a
		Severe stranding (3 pt)	n/a
Renal pelvic score [27]	Morphology of renal pelvis	Intraparenchimal	75% (urine leak)
		Extraparenchimal	6.5% (urine leak)

Intraoperative Bleeding and Vascular Injury

Intraoperative bleeding can originate from the PN resection bed, renal hilar vessels, lumar veins, or rarely, from vena cava or aorta.

How to Prevent Intraoperative Reno-Vascular Bleeding

As already discussed, understanding the interrelationships of the tumor vis-à-vis renovascular anatomy is crucial for uneventful RPN. Firstly, wide medial mobilization of the colon (and duodenum for right-sided tumors) to complete expose the kidney, identification of the renal artery and vein and their tributaries (and vena cava for right-sided tumors) is mandatory. The ureter should be identified and retracted laterally by the robotic fourth arm, and the psoas muscle is identified posteriorly. The ureter and the kidney are then retracted laterally. Dissection towards to the hilum is performed from distally to proximal. The renal vein and renal artery are dissected and vessel loops applied. Careful dissection of the tissue in layers is advised.

How to Manage Intraoperative Reno-Vascular Bleeding

It is important to keep calm, communicate with the operative team and anesthesiologist, call for any needed assistance, and ensure blood is available for transfusions, if necessary. The surgeon needs to expeditiously make a decision whether he/she has the necessary skill-level and experience to control the bleeding robotically, or whether open conversion is necessary. *Remember*: open conversion is NEVER a surgical "defeat", rather it is the smart and responsible decision to ensure patient safety, which must always be the paramount consideration. Increase the pneumo-peritoneum to 20 mmHg. Insert a mini-lap sponge (4″ × 18″ dimension) to compress the bleeding site. Suctioning should be judicious to clear the field, and also to compress the site. Change instruments for graspers and/or needle-drivers, as soon as possible, if necessary. Place additional ports if needed. After identification of the bleeding site, it should be controlled by applying weck clips or suturing. A critical maneuver in this regard is having a "rescue stitch" always ready on the back-table for prompt management of hemorrhage. The "rescue stitch" is a 15 cm long (6″), 2.0 Vicryl® suture on a CT 1 needle, with Hem-0-lock® clip tied to its end [30]. This stich is easy to handle, as it is malleable (does not have "memory") and the weck clip tied to the end allows for knotless bleeding control by merely pulling on the stitch.

How to Prevent PN Resection Bed Bleeding

Different factors impact PN resection bed bleeding such as: mass diameter, depth of penetration in the renal parenchyma and tumor contact surface area [31]. To prevent this complication it is important to:

- Obtain an adequate understanding of the renal mass characteristics as pointed previously.
- Have renal vessels accessible, ideally with vessel loops, for (re)clamping
- Mobilize the kidney properly. During PN surgery, "always mobilize the kidney more than you think it would be necessary", especially for posterior or upper pole tumors.
- First clamp the renal artery, then the renal vein.
- Consider using infra-red "Firefly" technology to ensure lack of perfusion to the kidney or to the area of interest, in case of selective/superselective clamping [32].
- Keep the field clean to allow for good visualization during tumor resection, therefore, if larger vessels from the renal sinus are encountered they can be pre-clipped prior to transecting.
- Start suturing the inner layer of the PN defect during the reconstruction/hemostasis. This step is very import to prevent bleeding from deep, therefore difficult to reassess, resection site after the clamp is released. There are many

ways to suture the PN resection bed. We prefer the horizontal mattress suture technique, which hemostatically compresses the PN bed, without closing it over, thereby still allowing excellent visualization of the entire PN bed at all times. Usually 1–2 mattress layers are used for hemostasis prior to unclamping.
- "Early-unclamping" technique. Besides the advantage of reducing warm ischemia time (WIT), the early-unclamping technique (first renal vein, then renal artery) provides direct visualization of any residual bleeding, which can then be pin-point sutured-controlled.
- To physically clear the PN resection bed of any overlying blood clots and to identify any residual parenchymal bleeders, we recommend strong irrigation rather than suctioning; the latter can cause parenchymal abrasions leading to additional oozing. .
- Apply hemostatic matrix sealants (Floasel®, Surgicel®) if necessary [33].
- Complete the renorraphy using the sliding-clip technique, which provides superior closing tension.
- Decrease the pneumo-peritoneum and evaluate for bleeding.
- Place a drain.

How to Manage the PN Resection Bed Bleeding

If during the tumor resection the bleeding is persistent:

- Irrigation could be more appropriate than suctioning, as mentioned.
- Check if the bulldog clamps are well applied or add an additional clamp on the artery.
- Clamp the vein, in case the vein was not clamped upfront; conversely, take off the renal vein clamp if it has been clamped, so as to allow unimpeded venous drainage.
- Perform further dissection and look for accessory renal arteries that may have been missed.
- If following meticulous renorraphy as described above the renal defect has persistent bleeding, re-clamp the hilum and apply additional stitches and hemostatic matrix to close the parenchymal defect. If the bleeding continues after unclamping, a completion nephrectomy might be necessary.
- Bottom line: do not conclude the operation until you have absolutely perfect hemostasis. Even a little bit of oozing is unacceptable.

Superior Mesenteric Artery Injury

Due to its course, close to the left renal artery, transection of the superior mesenteric artery (SMA) during the left renal surgery is potentially a catastrophic complication. SMA injury can rarely occur with large tumors or bulky hilar lymphadenopathy, wherein mistaken ligation of the SMA may be done instead of the left renal artery. Failure to recognize and immediately repair the SMA results in ischemic bowel and mortality. Immediate evaluation of signs or symptoms of intestinal ischemia is mandatory.

How to Manage Superior Mesenteric Artery Injury

To avoid SMA injury, it is important to keep in mind that the renal artery is directly posterior to the renal vein. Therefore, during transperitoneal left RPN, any artery identified anterior to the renal vein during hilar dissection, might possibly be the SMA. In this case, before progressing with the operation, ensure that the artery is indeed supplying the left kidney. If SMA injury is recognized intraoperatively, it should be repaired immediately. A vascular surgeon must be consulted.

Post-operative Bleeding

How to Prevent Post-operative Bleeding

The same precautions and proper surgical technique used to prevent intra-operative bleeding are applicable to post-operative bleeding as well.

Particularly important is to avoid "deep" passages of the needle and to always "follow the curve" of the needle during the renorraphy. This maneuver is critically important to avoid laceration of unseen intra-parenchymal vessels and causing parenchymal fracture lines, with subsequent bleeding from the high pressure lacerated artery into the renal parenchyma. This could lead to renal artery pseudo-aneurysm formation and delayed postoperative bleeding.

How to Manage Early Postoperative Bleeding

Immediate or early postoperative bleeding has been reported in upto 8.1% of RPN [34], although our current incidence is in the 1–2% range. Hemorrhage post PN is a life-threatening event, as such, should be promptly recognized and treated. Hemodynamic instability, decreasing hematocrit, low urine output and abdominal distention represent signs of post-operative hemorrhage. High and bloody drain output makes hemorrhage evident. Usually the source of bleeding is the PN resection bed, however, it can be from other areas including renal hilum, adrenal, lumbar veins, epigastric vessels and others.

Once hemorrhage is suspected, hemodynamic stabilization and fluid resuscitation, if necessary, are the priorities. We recommend renal angiography (Fig. 18.2) with selective angioembolization of the bleeding site(s) as the critical initial step after resuscitation. Transferring the patient to the Intensive Care Unit (ICU) for monitoring and stat blood transfusion(s) is important. If the patient responds to initial maneuvers, the vitals signs and hematocrit stabilize, and the urine output is reestablished, continue monitoring in the ICU. Typically angio-infarction definitively controls the renal bleeding. In case hemodynamic instability persists, surgical exploration is required. Usually open exploratory laparotomy is needed for clot evacuation and bleeding control. If the bleeding is from the PN resection bed and cannot be properly controlled, completion nephrectomy may be necessary. For selected cases, and depending on surgeon experience, robotic or laparoscopic re-exploration can be attempted.

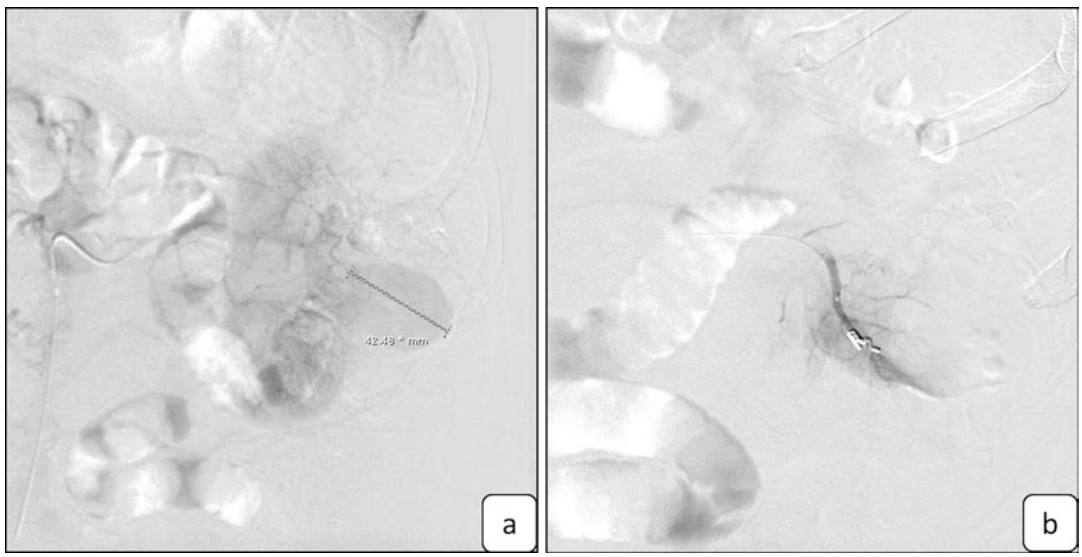

Fig. 18.2 This is is a 88 year old male that underwent uneventful RPN for incidental 6 cm left midpole lateral renal mass. On postoperative day 12, he was readmitted for clot retention. Cystoscopy showed active bleeding from left ureteral orifice. A MRI detected a 5 cm cystic lesion of left kidney. (**a**) Left renal angiogram showed large (>4 cm) exophytic pseudoaneurysm arising from a single artery in midpole of left kidney. (**b**) Embolization of superselective branch supplying left renal pseudoaneurysm with microcoils. Post embolization angiogram showed no further filling of pseudoaneurysm

How to Manage Delayed Postoperative Bleeding

In case the bleeding happens few days or weeks post PN, it might represent a renal artery pseudoaneurysm. In fact, renal artery pseudoaneurysm is an uncommon complication and is reported in around 1.7% following LPN. Usually the patient presents 15 days or more post-PN with gross hematuria, flank pain and decreased hematocrit. CT scan is diagnostic and percutaneous angioembolization is the successful treatment in most cases [35].

Intraoperative Tumor Violation

How to Prevent Tumor Violation

- Proper kidney mobilization and de-fatting the kidney are essential. In fact, de-fatting the kidney could be challenging and demanding [26]. However, it is essential to maintain fat over the tumor and only defat the non-tumor part of the kidney. This is important not only for en bloc excision for achieving negative oncologic margins in patients with unsuspected pT3a disease; the overlying peri-tumor fat also provides a nice handle for retracting the tumor away from the PN bed, thus technically facilitating the actual tumor resection.
- Intraoperative laparoscopic ultrasound (US) probe is necessary to obtain important real-time information on the renal mass, such as: size, intra-renal depth, margins, blood supply and relationship with surrounding structures.
- The tumor should be scored, under US guidance and robotic visualization, with adequate margins. And fat on top of the renal mass should be preserved for a en-bloc resection [36].
- Handle the renal mass minimally and carefully, grasping only the fat maintained on top of the tumor.
- Carefully incise the renal parenchyma maintaining a rim of normal parenchyma around the tumor to reduce risk of positive margins (PMs).
- Keep the field clean using judicious suction/irrigation. Always use distilled water for irrigation.
- Continuously assess and re-assess the tumor margin as you are slowly excising the tumor; tumor excision should be performed slowly and meticulously, always looking for any possible tumor violation.
- Infrared intraoperative optical imaging with Firefly® may, on occasion, provide some information differentiating renal tumors from surrounding normal parenchyma [37].

How to Manage the Tumor Violation

If a small tumor violation is identified during tumor excision, immediately reassess the margins, back-up, and perform a deeper, wider resection. If gross tumor violation has occurred and spread grossly in the PN bed, radical nephrectomy and complete resection of the renal fossa contents, including the perinephretic fat, parietal fat, psoas fascia and peritoneum, may be necessary. Consider open conversion, in an attempt to save the kidney, if the PN is being done for imperative or absolute indication. The renal fossa should be irrigated with distilled water; sterilization of the area using a small sponge dipped in dilute povidone-iodine and applied directly and strictly to the renal fossa only may be considered; however, beware that this can cause chemical peritonism if it comes in contact with bowel serosa, so be extremely careful. If positive margins are found on frozen section or on intraoperative pathologist's assessment, deeper and or wider resection should be considered. Overall, tumor violation during PN should be, and is, a rare event.

Postoperative Urine Leak

Urine leak is one of the common complication of RPN, with an incidence ranging from 1.2% to 18%. Urine leak may be defined as drainage greater than 50 ml per day, for longer than 1 week, with fluid consistent with urine [38].

Violation and an incomplete repair of the renal collecting system could lead to postoperative urine leak.

How to Prevent Urine Leak

Understanding the renal mass relationship with the pelvic caliceal system, and evaluating the renal pelvis anatomy and the nephrometry scores help identifying patients with increased risk for urine leak on postoperative [27, 39]. For those patients, an open-ended 5F ureteral catheter is placed cystoscopically just prior to the RPN. This catheter is secured to the urethral Foley catheter.

In case of urinary collecting system entry, it should be repaired using 4-0 Vicryl on a SH needle. A retrograde injection of highly dilute methylene blue through the ureteral catheter facilitates identifying the collecting system injury, and also confirming water tightness post-repair [40]. The ureteral catheter is kept in place along with the Foley catheter to ensure low pressure urinary drainage from the collecting system, and is usually removed on post-operative day 2.

A 19F Blake drain is left next to the PN area and secured to the skin. This drain is usually removed when the output is low and the measurement of creatinine level on the fluid is compatible with serum. It is important avoid thermal energy during the dissection close to the collecting system and the ureters. If ureteral injury is recognized intraoperatively, it should be repaired (4-0 Vicryl on a SH needle) and a double J stent should be placed.

How to Manage Urine Leak

- Post-operatively, when the drain is in place, the urine leak can be managed by:
  - Leaving the drain under gravity, without suction, and carefully shortening the drain by a few centimeters. These maneuvers would be efficient in case the drain is propagating the leak.
  - Placing "double J" ureteral catheter and a urethral Foley to facilitate drainage of urine from the collecting system to create a low-pressure system may, although not always, promote healing of the defect.
- If the drain was not placed and there is a symptomatic collection on postoperative image, a 'pig tail' catheter should be percutaneously placed in the collection by interventional radiology. If the urine leak persists, then a "double J" ureteral catheter and a urethral Foley should be considered in addition the 'pig tail'.

Thoracic Complications During RPN

Thoracic incidental gas collections, namely, pneumothorax, pneumomediastinum or pneumopericardium may occur during a RPN and may represent a significant issue. Thoracic complications are mainly due to congenital causes or intraoperative pleural injuries.

Congenital Defects

During trans-peritoneal RPN, the pneumoperitoneum can escape into the thorax via diaphragmatic defects, such as pervious pleura-peritoneal canal or thinner areas of the diaphragm, allowing CO_2 to access into the pleural spaces [41, 42].

Intraoperative Pleural Injuries

Pleural injuries may occur during port placement or during the tissue dissection. Pleurotomy may occur during kidney, liver or spleen mobilization. Most often, right sided pneumothorax happens due to the grasper used to retract the liver cephalad. This grasps the diaphragm, which can potentially create small diaphragmatic injuries that ultimately lead to CO_2 leak into the thorax due to high pressure pneumoperitoneum. On the left side, diaphragmatic injury may occur during mobilization of spleen and the upper pole of the kidney [43]. Although not directly related to RPN, central line placement may lead to intraoperative or postoperative pneumothorax.

Table 18.3 Modifiable and non-modifiable factors related to renal function decrease following RPN

Modifiable	Non modifiable
Preserve as much as possible kidney parenchyma	Baseline renal function
Perform when possible a minimal-margin partial nephrectomy, which maintains a sliver of normal parenchyma over the tumor, thus distinguishing it from straight enucleation, which is performed directly along the tumor capsule surface	Comorbidity (hypertension, diabetes, arteriosclerosis)
If possible, perform earl-unclamping or clamp-less RPN	Tumor size and location can affect the amount of kidney preservation
Reduce ischemia time, however not at the cost of a meticulous tumor excision and meticulous renal reconstruction; the latter 2 issues take priority over ischemia time	
Reduce operative time	
Suturing technique as described before in order to avoid devascularizing the renal parenchyma	

How to Prevent Thoracic Complications

Use appropriated pneumoperitoneum pressure setting.

Avoid rigorous retraction of the diaphragm by the grasper when retracting the liver.

Management

If pleural or diaphragmatic injuries occur and are recognized intraoperatively, the anaesthesiologist should be notified immediately to adjust ventilatory parameters allowing the surgeon to complete the procedure and repair the pleural or diaphragmatic defect. Strict postoperative monitoring is necessary [43]. If a large, hemodynamically symptomatic pneumothorax is identified postoperatively, thoracic drainage, usually with a pigtail is the initial treatment of choice.

Post-operative Renal Failure and Trifecta on RPN

The reason to perform RPN has supposed to preserve the renal function. In order to prevent renal failure after RAPN we have to take in consideration modifiable and non-modifiable factors (Table 18.3). A recent concept is Trifecta outcomes during robotic or laparoscopic partial nephrectomy [38] that describes negative cancer margins, minimal renal function decrease and no urological complications. The overall PMs rate is low trough the case series and complications improve regardless complexity of the cases (including tumor characteristics and patient comorbidity). Renal function decrease is the mainly driver of the Trifecta. In term of renal function preservation, there are modifiable and non-modifiable factors. Within those modifiable factors, surgical technique including clamp less PN may eliminate one of the major factors that may impact on postoperative renal function, If we avoid the ischemia, we eliminate this critical issue.

It has been shown that in the same Institution, distinguishing between four different period - discovery era, conventional hilar clamping era, early unclamping era, zero ischemia era – trifecta outcomes occurred more commonly in the zero ischemia era (45%, 44%, 62% and 68% respectively) [38].

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Robotic Donor Nephrectomy (RDN)

19

Arvind P. Ganpule and Ankush Jairath

Introduction

"Primum Non Nocere" which means "first, do no harm" aptly describes the principles and practice of donor nephrectomy. The past decade has seen great interest in the development of the technique of laparoscopic donor nephrectomy (LDN) across the globe. LDN is a unique operation as the surgeon operates in a pristine milieu, on an individual who in fact is not a patient but an individual donating from an altruistic motive. It is also unique as it is a "zero error" operation because the graft, donor, and the recipient safety are simultaneously at stake. It is of utmost importance to follow the steps and the principles and practice of laparoscopic donor nephrectomy being a zero error procedure.

Before going into the details of complications and the techniques to prevent them, we will *classify complications* as under [1–8] (Table 19.1).

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Upper Pole Dissection and Injuries Specific to Right Side

Liver is the organ most commonly injured during right robotic donor nephrectomy while doing upper pole dissection or retracting the liver [1].

Prevention

- Use of Self-retaining tooth grasper to elevate the liver, inserted via a 5 mm trocar under vision and clamped to the diaphragm or the sidewall.

Management

If there is liver laceration, most of the times it is self-limiting and stops by simple fulguration, packing alone, or by using Surgicel/flowseal. However, sometimes deeper lacerations may require suturing (horizontal mattress sutures).

After mobilization of colon medially, the *duodenum* can get injured. One should avoid cautery dissection to mobilize duodenum medially. If however duodenum is injured, primary closure is done and nasogastric tube is inserted. Patient should be closely followed in postoperative period and should be kept nil by mouth until gastrointestinal function returns to normal [1].

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Table 19.1 Classification of complications in robotic donor nephrectomy

Complications specific to right RDN	Complications specific to left RDN
Liver	Spleen
Duodenum	Pancreas
Nonside specific complications	
Adrenal gland injury or removal	
Pleural injury	
Diaphragm injury	
Bowel injury and injury to its mesentery	
Major vessel injury – renal artery, renal vein, inferior vena cava, aorta	
Minor vessel injury – adrenal vein, gonadal vein, lumber vein	
Vascular stapler and hem-o-lok clip malfunction	
Psoas sheath hematoma	
Ureteric stricture and necrosis	
Injuries during graft retrieval: bladder injury and injury to graft itself	
Lymphatic injury and chylous ascites	
Others: wound infection, orchalgia, epididymitis, medial thigh cutaneous paresthesia (entrapment of genitofemoral nerve)	

Upper Pole Dissection and Injuries Specific to Left Side

The most common intraoperative injury specific to left side donor nephrectomy while doing upper pole dissection is *splenic injury* [1].

Reason

- Too much traction applied before complete division of splenorenal ligament

Management

Low grade injury (mild to moderate lacerations) can be managed conservatively using Surgicel/flowseal (fibrin sealant) and/or by spleenorrhaphy, while for severe splenic injury (significant blood loss leading to hemodynamic instability/requiring blood transfusion) splenectomy is the preferred option.

Pancreatic tail may also get injured while doing dissection at renal hilum and medial aspect of left kidney, which can present in postoperative period as acute pancreatitis, paralytic ileus. It should be managed conservatively when not associated with complications. However, if laceration is recognized intraoperatively, it is always better to seek gastro surgeon's opinion. Rule out any injury to pancreatic duct. Non absorbable sutures should be used to repair parenchymal lesions.

Upper Pole Dissection and Nonside Specific Complication [1–3]

Robotic donor nephrectomy is an adrenal sparing surgery, where *adrenal gland* is preserved and is dissected off superior pole of the kidney using variable amount of unipolar or bipolar energy source in order to achieve hemostasis. Still, the adrenal gland and adrenal vein are sources of bleeding during the surgery. The right adrenal vein, due to its short length and direct insertion into vena cava, is more prone to injury. Severity of adrenal gland injuries varies from mild bleed, which can be controlled using simple cauterization or clipping the bleeding tissue, to major injuries requiring ipsilateral adrenalectomy.

Prevention

On left side

- The renal vein margin and its junction with the adrenal vein should be defined.
- The dissection on the adrenal vein side should extend till the point the adrenal gland is seen.
- Interlocking clips should be used for securing the adrenal vein.
- Vein stump on the renal vein side should be longer

Pleural injuries arising during dissection of superior/posterior aspect of kidney are also not uncommon and can result in pneumothorax. These can be identified as a curling of diaphragm into operative field and can be tested by asking anesthesiologist to hyper expand the lungs, while surgeon is irrigating near the diaphragm. Small injuries can be repaired using 4-0 chromic suture.

While for larger ones, low pressure pneumoperitoneum is created and infant feeding tube no 10 is used to evacuate air from pneumothorax, tear is repaired using purse string suture, and infant feeding tube is removed and purse string suture tightened as the anesthesiologist hyper expands the lungs.

Bowel injuries are also common during reflection of bowel medially from superior surface of the kidney.

Prevention

Avoid inadvertent traction, avoid use of cautery, properly identify plane superior to gerota to avoid such complications.

Mesenteric tears during bowel mobilization can occur and should be repaired to prevent internal herniation of bowel.

Lumbar Veins Dissection and Related Complications [1–3]

The lumbar veins are a common source of troublesome bleeding. Typically, the lumbar veins arise from the renal vein and enter the lumbar canal.

Reasons

- Failure to recognize the location
- Dissecting the lumbar vein to near to its confluence with the renal vein.
- Injury to the posterior wall of the lumbar vein while circumferentially dissecting the lumbar vein.

Prevention

The exact location of the lumbar vein can be ascertained on the CT workstation. The number of lumbar veins and the spatial configuration can be made out if the surgeon views the same on a CT console. Whenever present, the lumber vein enters the renal vein posteriorly. Once the lumbar veins are secured the renal artery is visualized, which lies immediately posterior to it (Fig. 19.1a–d).

As a risk reduction strategy, the lumbar veins should be secured after the upper pole is dissected. In case of troublesome bleeding from these vessels, the surgeon can quickly secure the lumbar vein and retrieve the graft.

The lumbar veins can be secured with interlocking hem-o-lok clips. The controversy revolves around as to whether interlocking clips should be used or hem-o-lok clips should be used; the interlocking clips can be easily removed on the back bench. The lumbar veins should be secured keeping a cuff near the vein.

Management

The key and measures in the management of lumbar vein injury is decided

Is the upper pole is dissected?
Is the renal artery dissected?
Is the graft ready for retrieval?

If the artery is not dissected and the upper pole is not yet free, then all attempts should be made to control the bleeding. If patient is haemodynamically unstable and the graft salvagability at stake, open conversion should be on the cards.

Hilar Dissection Related Complications

Hilar dissection in order to obtain vascular control is associated with maximum incidence of complications related to bleeding. Usually the renal vein is identified by tracing the gonadal vein upwards, and the renal artery is identified after dividing the gonadal vein, the lumber vein (if present) lies inferoposteriorly to the renal vein usually. Preferably, only the proximal part of the renal artery is mobilized to prevent needless vasospasm. To maximize the length of the renal vein on the left side, dissection is done towards the interaortocaval area and should be mobilized

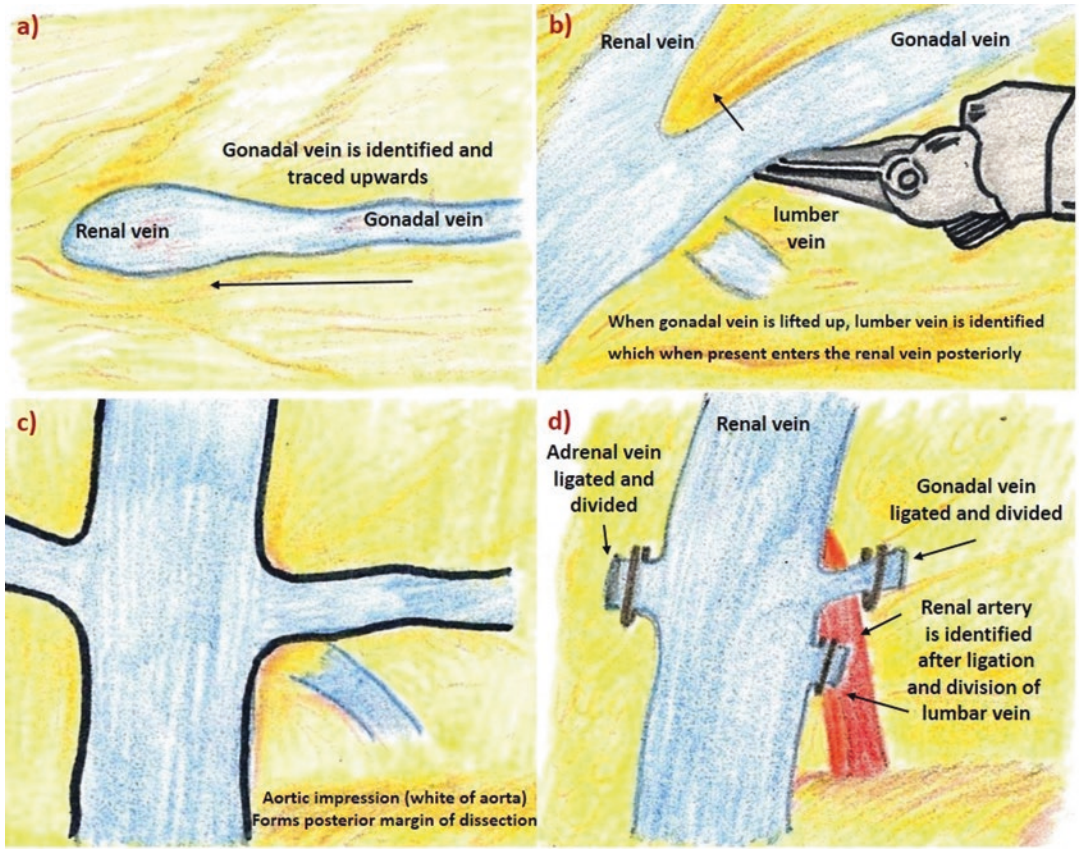

Fig. 19.1 *Steps in lumber vein dissection* (**a**) gonadal vein is traced upwards up to its insertion into renal vein. (**b**) Only when gonadal vein is lifted up surgeon can identify lumber vein, which enters renal vein posteriorly (**c**) diagram illustrates importance of recognizing glistening white layer over the aorta (which forms deep/posterior margin of dissection) in order to prevent major vessel injury (**d**) only after ligation of lumber vein (if present) the surgeon is able to identify and dissect renal artery accurately, which lies posterior to it

until right lateral border of aorta is reached. Great care must be taken during reteroaortic or circumaortic renal vein dissection in which dissection should be limited up to left lateral border of aorta to minimize vascular complications. During dissection, small vessels can be secured using ligamax metal clips or bipolar devices, while for major vessels vascular staplers or hem-o-lok clips are used. Utmost precaution should be taken while dividing renal artery and vein in case of multiple renal vessels. Figure 19.2 depicts how the surgeon inadvertently cuts the upper pole vessel at its base while dividing renal vein. It is always better to partially divide the vessels after clipping to check for any active bleed from the remaining stump.

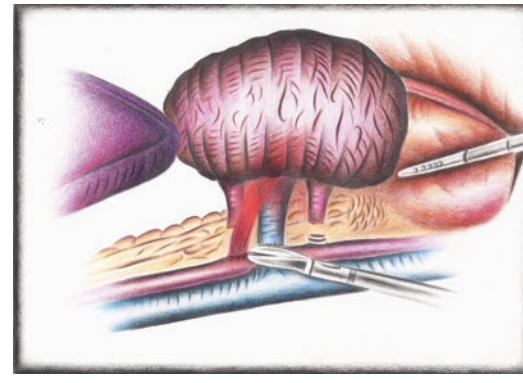

Fig. 19.2 Care should be taken while transecting renal vessels after clipping in case of multiple renal vessels. Figure depicts that while transecting renal vein, upper polar renal artery got inadvertently snipped at the base

Vascular Stapler Malfunction [1–5]

Generally GIA™ and TA™ staplers are used for closing of the renal arterial and venous stumps, respectively. Staplers are used more often during right donor nephrectomy in order to get an adequate length of renal vein. Cost is the major limitation factor for their use. The most common mechanism of failure is malformed or leaking staple line after firing, followed by locked stapler with failure to release from the tissues, handle breakage during firing. Endo-GIA stapler works by placing six rows of overlapping staples and cutting in the middle, thus three rows of staples on each side. So, there is a necessity to remove rows of staple which remain on the graft side leading to loss of around 1 cm of vessel length. However, Endo-TA staplers (nonarticulating, noncutting) do not leave lateral rows of staplers which need to be removed so a net gain of 0.5–1 cm of length in comparison. As it is a noncutting stapler, so by partial cutting of vessel with the scissors complete ligation of artery can be confirmed [4].

Prevention

- Examine stapler prior to firing.
- Careful use of clips so as not to interfere with stapler deployment later on
- Staplers should not be fired across any previously placed clips or an existing staple line.
- Small vessels (e.g. adrenal vein) should be ligated and divided using bipolar sealing device, which eliminates the presence of clips that may interfere with the stapling device.
- Never override the lockout mechanism.
- If applying a stapler, one should know about the troubleshooting for the instrument.
- Check the cartridge for presence of staples before using the endovascular stapler
- Proper visualizing of the tissue to be stapled
- Establish proximal control and pause ("Step Back") prior to stapling a large blood vessel
- Avoid forcefully freeing the tissue if staple locks up

Intracorporeal suturing skills are of paramount importance in managing such situations. A Satinsky clamp and a rescue stitch (CT1 needle with a hem-o-lok™ clip attached to the tail end of the suture. A knot is thrown over the hem-o-lok clip to prevent its slippage) are key requirements on the rescue tray. One should have a low threshold for conversion to open in managing such a situation.

Some authors partially staple left renal vein (covering two third of total width) intentionally, thus avoiding complete retraction of transected left renal vein in case of malfunctioning of Endo-GIA staplers. It also minimizes chances of injury to superior mesenteric artery which lies in close proximity to left renal vein.

Hem-o-lok Clip and Related Complications [1–5]

Most of the complications related to the use of hem-o-lok clip are due to limited knowledge on how to apply the clips properly, so most of the related complications are preventable.

Reasons

- Failure to follow cardinal rules during application of hem-o-lok clips.

Prevention

- One should follow these cardinal rules before application of hem-o-lok clips
- Always circumferentially dissect the vessel in concern prior to application so that additional tissue does not interfere with clip closure
- Listen for the click of the knob after application of the clip
- Always check the knob of the clip prior to application
- Always apply two clips on the patient side, while no clip is applied on graft side
- Always apply clip at right angle to vessel surface with 1 mm gap between two clips
- Leave at least leave 2 mm cuff beyond the cut end of the clip to prevent slippage

- If diameter of vein is large, reduce the diameter by using vascular bands before applying the clips
- Hem-o-lok clips should be removed either by hem-o-lok clip remover or the clips can be cut open with a harmonic scalpel.

Ureteral Dissection and Related Complications [1, 6]

Ureters may not be injured directly but are commonly stripped of their blood supply, mainly at the time of dissecting the ureterogonadal packet, during lower pole dissection, or finally at the time of division, leading to distal ischemia and thus ureteral stricture.

Reasons

- Failure to recognize exact location of ureter and gonadal vein
- Dissecting inadvertently between ureter and gonadal vein thus stripping off periureteric fatty tissue
- Overuse of cautery during dissecting or division of ureter
- Dissection of the renal artery too near the ureter

Prevention

Before lifting ureterogonadal packet, we should ascertain exact location of gonadal vein and ureter (by observing peristalsis). In order to lift both ureter and gonadal vein as a unit to preserve the normal blood supply to the ureter, avoid dissection between gonadal vein and ureter or the use of cautery nearby. The best way to avoid this is to identify the gonadal vein. The ureter invariably flows below this structure. (The mnemonic "water flows below the bridge" is useful to remember).

Avoid giving too much traction during lifting of ureterogonadal packet. The ureteral packet (intact ureteral sheath, adventitia with substantial periureteric fatty tissue) is dissected up to the level of iliac vessels and the gonadal vein is clipped and divided where it crosses over the ureter. Avoid the use of cautery during final division of distal ureteric end.

Avoid dissection of the renal artery too near to the renal hilum as there usually arises a ureteral branch supplying the upper ureter, this may cause compromised state of blood flow in the area supplied [3].

Psoas Sheath Hematoma [1]

Most of the time it occurs at the time of lifting up the ureterogonadal packet over the psoas, when the surgeon inadvertently lifts psoas sheath along with ureterogonadal packet.

This can be prevented by dissecting layer by layer, avoid going too deep during lifting of ureterogonadal packet, and recognizing the glistening layer over psoas muscle which is not to be lifted along with ureterogonadal packet.

Injuries During Graft Extraction [1–3]

After ligation and division of renal vessels and ureter, our aim is to retrieve the free graft from the peritoneum and to place it in ice slush for reperfusion as soon as possible. In our center, kidney is retrieved from a preplaced Pfannenstiel incision or an iliac fossa incision (choice of incision depends upon the patient's characteristics).

Bladder Injury

Reason

- Inability to recognize bladder while placing Pfannenstiel incision
- Placing Pfannenstiel incision in full/partially filled bladder (noncatheterized patient/blocked catheter)
- Placing Pfannenstiel incision in very obese or previously operated donor

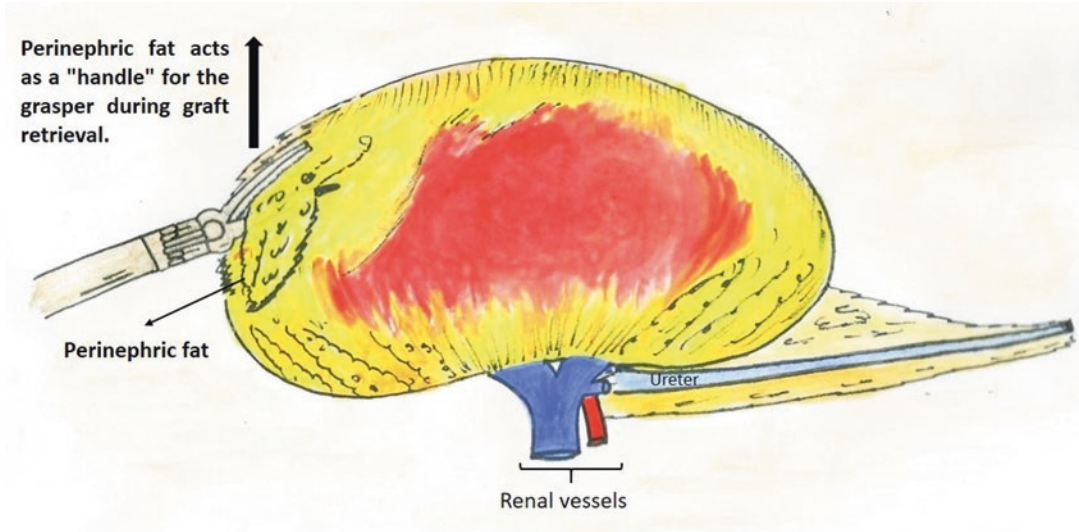

Fig. 19.3 Line diagram depicting importance of preserving perinephric fat which can be used as a handle during graft retrieval

Prevention

- Always make Pfannenstiel incision before the ligation of renal vessels, preferably at the start of surgery itself.
- A meticulous dissection should be done with pneumoperitoneum on and under vision,
- with surgeon watching from camera through peritoneal cavity.
- For very obese patients or patients having past history of pelvic surgery, the preferred choice of incision is the iliac fossa incision [7]

Graft Injury

Graft is retrieved either through endoextraction bag or through hand assistance via Pfannenstiel or iliac fossa incision. The extent of injury varies, ranging from superficial/capsular tears to grade IV lacerations.

Reasons

- Inadequate length of retrieval incision
- Inability to completely free the kidney from its surrounding attachments before retrieval (mostly posterior or superior)
- Direct injury to kidney by endoextraction bag when the kidney gets entrapped between peritoneal edge and endobag firm ring
- Lost/misplaced graft in peritoneal cavity (during hand assistance technique)

Prevention

- Ensure before retrieval that kidney is free from all its attachments.
- Retrieval of kidney graft under direct vision of camera.
- Always leave some perinephric fat to hold the kidney with the grasper, until it is secured with hand during hand-assisted technique of retrieval (Fig. 19.3).
- Placing an adequate length of retrieval incisions.

Lymphatic Injury and Chylous Ascites [8]

Chylous ascites is the accumulation of chyle in the peritoneal cavity. Reported incidence after donor nephrectomy varies in different studies ranging from 0.6% to 5.9%. At risk Patients are those in whom extensive dissection is done over

great vessels (aorta or inferior vena cava) with the intention of gaining maximum length of renal vessels. Most common mode of presentation being abdominal distention with decreased appetite and average length of time from nephrectomy to symptoms is around 4 weeks [8].

Reasons

- Inability to tie all the lymphatics while dissecting around great vessels and renal vasculature.
- Extensive use of unipolar cautery to clear fibro fatty tissue around renal vessels

Prevention

- Oozing lymphatics encountered intraoperatively should be weck clipped
- Fibro fatty tissue around great vessels and renal vessels should be clipped
- Use split and clip technique during lymphatic tissue dissection
- Flowseal and surgicel can also be used adjuvant to vicryl on CT1 needle to tie all the oozing lymphatics

In high risk individuals (obese donors, evident leaking lymphatics during surgery, donor undergoing extensive lymphatic dissection), a check laparoscopy should be done at the end of surgery and a drain can be kept in these patients.

Risk Reduction Strategies

Finally, following are certain strict operative protocol and risk reduction strategies that we applied while doing laparoscopic donor nephrectomy:

- Transperitoneal route
- Judicious planning for the port placement
- Proper plane of reflection of the bowel, including early division of the splenorenal and renocolic ligaments
- Identification of the ureter at the level of gonadal vein crossing, taking care not to disturb the plane between ureter and the gonadal vein
- Tackling the adrenal vein and upper pole first and reserving the lumbar vein dissection for the end
- Extensive use of energy devices in and around the hilum
- Manual removal of the kidney

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Robotic Kidney Transplantation

20

Rajesh Ahlawat and Sohrab Arora

Since its inception, kidney transplantation has seen minimal changes in technique. Carrel's technique of vascular anastomosis [1] has endured for a century. This has resulted in a constant rate of surgical complications over the decades. The use of minimally invasive surgery in kidney transplant opens up a new realm and is fast evolving. The theoretical advantages and the initial results have been promising. In this chapter, we focus on the surgical complications of robotic kidney transplant (RKT) with a review of literature.

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Brief Summary of Innovation, Development, Exploration, Assessment, and Long-Term Follow-Up (IDEAL) as Applied to Robotic Kidney Transplantation

The idea of robotic kidney transplantation with regional hypothermia started in 2012, with collaboration between Vattikuti Urological Institute (VUI), Henry Ford Hospital in Detroit (USA), and Medanta hospital in India. Few attempts at minimally invasive recipient surgery had been made using a laparoscopic or robotic platform in the past without regional hypothermia. Inherent technical limitation of laparoscopic instrumentation, and Ischemia times with slow graft functional recovery restricted the adoption of minimally invasive surgery for recipient operation until the development of RKT with regional hypothermia. Balliol Collaboration recommendations for safe development of new procedures were followed using the IDEAL platform (acronym for Idea, Development, Exploration, Assessment and Long-term follow-up) [2].

VUI technique of regional hypothermia was tested in RALP model during IDEAL phase 0 studies. It was found that by using ice-slush, local hypothermia could be induced with no

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change in the core body temperature [3]. Subsequent phase 0 studies were based on robotic kidney transplantation in fresh cadavers to standardize the technique of RKT [4]. The main modifications included patient positioning and robot docking in standard prostatectomy position, use of gelPOINT™ at umbilicus to incorporate the lens and assistant ports, and fixing of graft in the iliac fossa using peritoneal flaps to decrease the risk of torsion and to make subsequent graft biopsy easy. The umbilical port was also used to access the peritoneal cavity to deliver the ice for local hypothermia as well as the graft. This phase also led to standardization of instruments and vessel clamps for the procedure. The choice of suture was Goretax PTFE CV-6, which slides through the tissue easily, has no memory unlike prolene sutures, and has sufficient strength to be used with robotic instruments. During phase 1, seven patients underwent RKT successfully at Medanta hospital after institutional review board clearance [4]. The phase 2a consisted of the next 43 patients, which further refined the procedure [5]. Currently, the development of RKT is in phase 3, which consists of comparison with OKT in a prospective fashion.

General Considerations

Minimally invasive techniques, including robotic and laparoscopic surgery, have been shown to have better outcomes when compared to open surgery for most surgical procedures. The theoretical benefits of minimally invasive surgery are smaller length of incision, decreased blood loss, less postoperative pain and analgesic requirements, and early convalescence. Kidney transplant recipients are ideal candidates for minimally invasive surgery, as they are at a higher risk of complications due to frail health and immunosuppression. The perioperative morbidity affects not only the short-term convalescence, but also long-term graft survival.

Minimal Surgery Benefits

Postoperative Pain and Analgesic Requirements

A large Gibson incision has been the standard access for kidney transplantation over the decades. With robotic kidney transplantation, the length of incision has been reduced significantly (6.1 cm vs. 15.6 cm; $p = 0.001$) (Fig. 20.1).

Unpublished results from the IDEAL stage 2b/3 prospective nonrandomized trial comparing RKT with OKT reveal lower postoperative pain scores after RKT, and a corresponding decrease in analgesic requirements.

Blood Loss

Minimally invasive surgery has been associated with decreased blood loss as compared to open surgery. This is both due to shorter length of incision, pneumoperitoneum reducing venous blood loss, and decreased vascular complications. Our experience showed an average 151.7 ml blood loss in RKT as compared to 296.8 ml in OKT

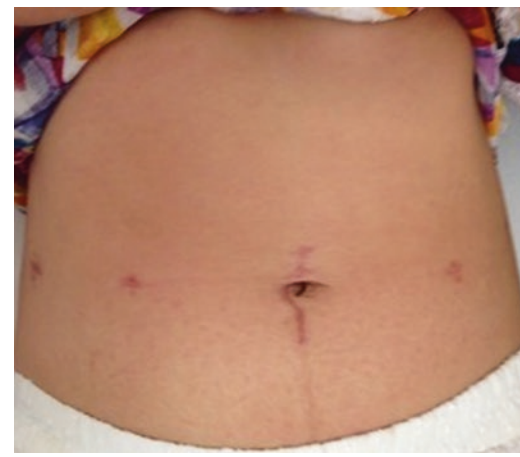

Fig. 20.1 Incision at 1 month after robotic kidney transplantation

($P \leq 0.001$). Methods to decrease vascular complications and blood loss during surgery are discussed later in the chapter.

Renal Function and Outcome Measures

Results of open kidney transplant have improved with improvements in perioperative care and better immunosuppression. Our recent comparison of 125 RKT and 543 OKT in eligible patients performed over 3 years showed no difference in fall of serum creatinine postoperatively, at discharge, as well as at 3 and 6 months after surgery. Delayed graft function was seen in 1.6% (2/125) patients in RKT group, compared to 3.13% (17/543) in OKT group ($p > 0.05$). The data comparing RKT vs. OKT has found no significant difference in graft survival as well as patient survival.

Preventing Blood Loss and Vascular Complications During RKT

Blood loss and vascular complications are important causes of morbidity and graft failure following kidney transplantation. 3-D magnified vision and dexterity of instruments provide an opportunity for a foolproof vascular anastomosis using a robot. Vascular complications have been reported in 2.6% patients after open surgery. Prevention of vascular complications during RKT starts with a careful preoperative assessment. Vascular anatomy of the donor is equally important. In general, all parameters being equal, left donor nephrectomy is preferred over a right due to its longer renal vein. The vascular anatomy is reassessed on the bench to look for atheromas, intimal flaps, or accessory renal arteries which may have been missed. Any reconstruction to minimize the recipient arterial anastomoses is also done at this stage. Any small hilar vessels or vein tributaries are ligated. A careful bench preparation is an essential investment to prevent bleeding on removal of clamps after anastomoses in the recipient surgery robotically. We recommend following a defined sequence at certain steps to prevent bleeding and vascular complications after RKT.

1. The graft kidney, after harvest, is prepared by enclosing it in a jacket made of surgical gauze and enclosing within it with some ice slush. A hole in the jacket allows vessels to be brought out medially. A long silk suture is left at the upper pole for correct orientation of the graft while placing it intraperitoneally. The jacket helps maintain intracorporeal cooling as well as enables holding and moving the graft atraumatically. It also helps retract hilar fat, presenting the vessels for a hassle-free anastomosis.
2. Ice slush is placed over bladder flap in pelvis before placing the prepared graft and starting vascular anastomoses. Local hypothermia using ice slush brings down pelvic temperature to approximately 20 °C, without any significant change in core body temperature [5]. This prevents any ischemic injury to the graft, since surrounding temperatures faced by kidney during RKT within peritoneal cavity are higher (at 32 °C), compared to significantly lower OR temperature (22 °C) which surrounds the kidney during OKT. Pneumoperitoneum, with constant hot gas flows, may otherwise bring up the graft temperature rapidly.
3. The dissected length of the external iliac vein is isolated with bulldog clamps proximally and distally. Renal vein is anastomosed to the clamped external iliac vein in an end to side fashion. The graft renal vein is then clamped and the continuity of the iliac vein is restored by removing the proximal clamp, then observing for any leaks before releasing the distal clamp. A small gauze pack or a surgicel piece may be packed at the site before proceeding to arterial anastomosis. The bulldog clamps removed from the external iliac vein are now applied on either end of the dissected external iliac artery.
4. A small arteriotomy incision is made using robotic Snapfit® or a Pott's scissor and a desired rounded opening is then created using 3.6 mm vascular punch. The graft artery is

anastomosed end to side with the external iliac artery. A small bulldog clamp is now placed on the renal artery. The distal bulldog clamp is removed from the external iliac artery to check anastomotic integrity. Any small bleeding points in arterial anastomosis may be managed at this point. The graft is then perfused removing the clamps from the renal vein and renal artery, while the proximal clamp on the external iliac is still in place. The proximal clamp is now slowly released while watching for any brisk bleed or abnormal blood filling of field. This last clamp may be applied back on the external iliac artery proximally to reduce the bleed and to manage it with packs, diathermy or additional sutures, while the graft is still being perfused from the distal end with back perfusion. The iliac artery may also be clamped both proximally and distally for control of significant bleeding, especially a major hilar arterial repair.

5. The graft jacket is now released cutting it from its hilar opening proximally and distally to bare the graft and allowing its visual inspection for color and turgidity. Small bleeding perforators are managed with bipolar diathermy at this point.
6. The revascularized graft is flipped from the pelvic hollow to the right iliac fossa, turning it at 180° around the external iliacs. The proximal and distal peritoneal flaps prepared during the bed preparation are brought together over the graft. The external iliac vessels and both anastomoses may again be inspected before proceeding to ureterovesicostomy.
7. An on table vascular Doppler of the graft is obtained to confirm its vascularity before shifting the patient out to the transplant ICU.

Hematoma

Hematoma in an RKT is heralded by falling hemoglobin or increased drain output. This hematoma is intraperitoneal, in contrast to the hematoma in an open transplant which is retroperitoneal. The intraperitoneal location theoretically limits the pressure effect on the transplanted kidney and thus causes minimal effect on renal blood flow or ureteral compression. On the other hand, it requires a high index of suspicion. One case of re-exploration has been reported due to increased drain output during IDEAL stage 1 of development of RKT (Clavien-Dindo grade 3b). The patient had a recent coronary angioplasty and was on antiplatelet agents (aspirin and clopidogrel). On exploration, the vascular anastomoses were intact, and only generalized bleeding was noted. This case was managed by topical hemostatic agents and blood transfusion.

Transplant Renal Artery Stenosis (TRAS)

TRAS occurs most commonly 3 months to 2 years after renal transplant. This complication may present as an incidental finding on Doppler ultrasound, refractory hypertension, or graft dysfunction [6].

For diagnosis of TRAS, Doppler ultrasound is an appropriate screening test. A peak systolic velocity of >2.5 m/s with downstream turbulence and spectral broadening is suggestive of TRAS. Intrarenal flattening of early systolic peak with a low resistive index is also suggestive of TRAS. Doppler ultrasound can be very accurate in diagnosing TRAS, but is highly operator dependent. Helical CT angiography or contrast enhanced MRI are good alternatives, but conventional contrast angiography remains the gold standard for diagnosis.

Hypertension secondary to TRAS is treatable, and the initial treatment is usually percutaneous transluminal angioplasty (PTA). The success rate of this modality exceeds 80%. In patients in whom PTA is not an option surgical correction may be done, with options including excision of stenosed segment with reanastomosis, saphenous vein interposition, or deceased donor artery graft.

The surgical causes of TRAS include kinking or twisting of anastomosis and are usually identified within 6 months posttransplant. The incidence of TRAS varies from 1% to 23% in various [7, 8] OKT series. In RKT trials, TRAS has not been reported so far, at a median follow-up of 19.1 months.

Vascular Thrombosis

Open kidney transplant series have reported a 2% incidence of renal artery or vein thrombosis [9]. This complication presents with drop in urine output or as graft dysfunction. It is often too late to salvage the kidney when this complication is detected. Thrombosis is an interplay of three factors – stasis, hypercoagulability, and endothelial dysfunction. Stasis after a kidney transplant is largely technical in nature, and is preventable. Other causes may be damaged intima or intimal flaps, and low blood flow secondary to decreased cardiac output and hypovolemia. Acute vascular rejection and acute tubular necrosis may also present as thrombosis.

Endothelial dysfunction and nonmodifiable causes of thrombosis are beyond the scope of this chapter. Technical factors include intimal damage during preparation of graft vessels, poor anastomotic technique, kinking of anastomoses and incorrect positioning or rotation of graft. The RKT series so far have not reported any arterial or venous thromboses.

Lymphocele

A major theoretical advantage of RKT is the reduction in incidence of lymphocele. During preparation of the recipient bed, lymphatics along the iliac vessels are divided, and with the limited extraperitoneal space for the kidney, lymph from these divided lymphatics may accumulate after an OKT. Another source of lymphatic fluid may be the graft itself. In an open kidney transplant, the surgical treatment of lymphocele is unroofing or fenestration into the peritoneal cavity. RKT, on other hand, is performed transperitoneally and the peritoneum is loosely apposed over the graft, technically "deroofing" the extraperitoneal space. OKT series have shown an incidence of 20% ultrasound detected lymphocele [10], and a 2.5% incidence of symptomatic lymphocele, while all the RKT series so far have reported no lymphoceles.

Deep Vein Thrombosis (DVT)

The kidney transplant recipient is at a similar risk of DVT after major surgery as general population, unless complicated by pelvic pathology such as a lymphocele. Accordingly, the need for DVT prophylaxis is guided by the patient risk factors like obesity, or diabetes mellitus. The semi-lithotomy, steep Trendelenburg position during RKT may increase the risk of DVT, but supine position with a side docking of robot, as routine with newer generation, may negate the need for lithotomy and docking of robot between the legs. Prophylactic measures like calf compression stockings attached to a DVT pump are used during the procedure as a part of protocol for any pelvic surgery. Postoperatively, patients are encouraged to start calf exercises on the day of operation, and ambulate early.

Other Surgical Complications

Surgical Site Complications

OKT series have reported a varying incidence of wound complications. The incidence of surgical site infections (SSI) is reported to be around 15%, out of which 53% are deep incisional or organ space infections [11]. This incidence is even higher in morbidly obese patients and patients with peripheral vascular disease. The rate of wound-related complications is expected to be low in RKT due to the small midline incision in contrast to the long Gibson incision in OKT.

In the IDEAL phase 2 studies of RKT by Menon et al., surgical site infections or wound complications have not been reported so far [5]. Oberholzer et al. also reported a dramatic reduction in wound complication rate in their series of RKT in morbidly obese patients denied open KT [12].

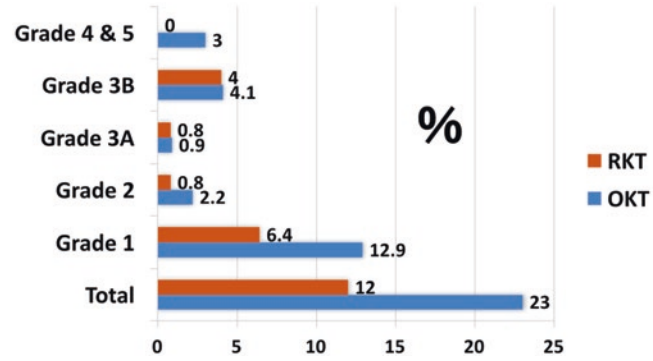

Fig. 20.2 Clavien-Dindo grading of complications of RKT ($n = 79$) as compared to OKT ($n = 350$) in IDEAL stage 2b/3 trials

Ureteral Leak/Obstruction

The blood supply of transplanted ureter relies on the anastomosed renal artery. Therefore, the longer the ureter, the more tenuous its blood supply is. Therefore, excessive ureteral length should be avoided. On the other hand, the ureterovesical anastomosis must be tension free. Also, during donor nephrectomy, excessive dissection of periureteral tissue must be avoided. Classically, a "golden triangle" is described, bordered by the ureter and the lower pole of the kidney [13]. Perirenal fat in this triangle must be preserved. Typical presentation of an early ureteral leak can be a sudden decrease of urine output with increased drain output with drain fluid creatinine being diagnostic. The presentation may be more subtle in delayed leaks as after removal of the drain or in cases of delayed graft function, and may present as decreased urine output, perigraft fluid collection, or graft dysfunction. Diagnostic modalities may include a dynamic renal scan or a cystogram. If a stent is in situ, prolonged per urethral catheterization and a CT cystogram before its removal is the protocol. If there is no stent, either a percutaneous nephrostomy followed by antegrade stenting or a surgical repair may be necessary. Retrograde placement of stent is technically challenging, but may be possible. Ureteral necrosis must be suspected in leaks which do not heal with conservative management, and operative management should be done. The options include a cutback to healthy ureter with reimplantation, psoas hitch, or a Boari flap.

Ureteral obstruction may have an external or internal etiology. Common causes of external compression may be hematoma or a lymphocele. Intraluminal obstruction may be caused by ureteric stricture with compromised blood supply, papillary necrosis, or a ureteric calculus. Endoscopic management is usually successful. Recurrent strictures are managed with surgery.

In OKT series, ureteral complications have been reported in 1–3% of transplants [13]. In IDEAL Phase 2b/3 studies of RKT, one ureteral complication has been reported at 4 months, presenting with gradual hydroureteronephrosis. Obstruction at UV junction was successfully treated with revised ureterovesicostomy following initial percutaneous nephrostomy.

Conclusion

The development of RKT is associated with a trend toward reduction in postoperative complications when compared to OKT. Figure 20.2 summarizes the Clavien-Dindo grading of complications of RKT as compared to OKT in IDEAL stage 2b/3 trials.

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Pyeloplasty

21

Igor Sorokin and Jeffrey A. Cadeddu

General Considerations

Minimally invasive pyeloplasty (MIP) has seen a dramatic increase in utilization for definitive management of ureteropelvic junction (UPJ) obstruction [1]. In 1999, the initial experience with robotic-assisted laparoscopic pyeloplasty (RALP) was reported in a porcine model [2], and the first human series was reported by Gettman et al. [3] in 2002. With increasing experience, RALP is commonly offered as the initial treatment for UPJ obstruction in both adults and children. In fact, it is the most common robotic-assisted procedure performed in pediatric urology [4]. It remains one of the ideal procedures for laparoendoscopic single-site surgery (LESS) as it does not need an extraction incision and occurs in a younger patient population likely more interested in aesthetic outcomes [5, 6].

A meta-analysis on eight studies on adult patients comparing RALP to conventional laparoscopic pyeloplasty (CLP) noted comparable rates of postoperative urinary leaks, hospital readmissions, and success rates [7]. The level of evidence of this analysis was only modest as there are no randomized controlled trials (RCT) comparing the two techniques. Nonetheless, the robotic platform has made this procedure more reproducible and available to more surgeons [8].

In an attempt to improve cosmesis, postoperative pain, and recovery after pyeloplasty, conventional laparoendoscopic single-site surgery (C-LESS) was developed. It is a technically difficult procedure given the loss of instrument triangulation, difficulty of cross-handed surgery, and intracorporeal suturing. Complication rates early in the surgical experience approached 50% in one C-LESS series [9]. The learning curve from this series was estimated to be ten cases, as this was when the vast majority of complications occurred. A meta-analysis on five studies comparing C-LESS to CLP noted higher postoperative complication rates in the C-LESS group, but this was not statistically significant (C-LESS 10% vs. CLP 8.5%; $P = 0.22$) [10].

Use of a robotic surgical platform can potentially minimize some of the limitations with C-LESS and decrease complications. During robot-assisted laparoendoscopic single-site

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Table 21.1 R-LESS pyeloplasty

	Buffi et al. [12]	Khanna et al. [5]	Law et al. [13]	Olweny et al. [14]	Tobis et al. [15]
No. of procedures	30	7	16	10	8
Mean procedure time (mins)	170	247	225	226	181
Failure rate	2 (6.7%)	0 (0%)	1 (6.3%)	0 (0%)	0 (0%)
Complication rate	8 (26.7%)	2 (28.6%)	5 (31.3%)	1 (10%)	1 (12.5%)
Intraoperative	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Postoperative	8 (26.7%)	2 (28.6%)	5 (31.3%)	1 (10%)	1 (12.5%)
Conversion rate (lap/standard robot)	2 (6.7%)	2 (28.6%)	0 (0%)	0	0 (0%)
Urine leak	1 (3.3%)	0 (0%)	0 (0%)	1 (10%)	0 (0%)
Clavien 1	4 (13.3)	1 (14.3%)	0	0	0
Clavien 2	3 (10%)	1 (14.3%)	5 (31.3%)	0	0
Clavien 3	1 (3.3%)	0	0	1 (10%)	1 (12.5%)

(R-LESS) surgery, the robotic console can be configured to increase the range of motion of the instruments internally [11]. This is just one example of how the robotic platform is an enabling technology over conventional laparoscopy. In the selected R-LESS series in Table 21.1, Clavien grade 3 complications were minimal with a low failure rate. Operative times ranged from 170 to 247 min, with a mean operative time of 209.8 min (± 32.8 SD) among the series. No open conversions occurred and the rare conversions to RALP or CLP/C-LESS occurring either due to malfunctioning of the robot system, patient anatomy, arm clashing, or difficulty with the ureteral anastomosis.

Robotic pyeloplasty may be approached either through the transperitoneal or retroperitoneal space. Most series describe using the transperitoneal approach as proper identification of anatomic landmarks as being more difficult through retroperitoneoscopy. Advantages of the retroperitoneal approach include direct access to target structures (especially in patients with large body habitus) and minimized risk of injury to intraperitoneal organs [16]. Furthermore, the retroperitoneal approach may be safer in patients with extensive prior abdominal surgery, but at the expense of a limited worked space and potential steeper learning curve [17]. A recent nonrandomized comparison of retroperitoneal vs. transperitoneal RALP by Cestari et al. [16] showed no significant surgical complications between the two approaches; however, two failures occurred in the retroperitoneal group vs. none in the transpertioneal group. Ultimately, the decision for the proper approach mainly depends on the surgeon's comfort and preference.

Common complications of robotic surgery, such as bowel and other visceral injuries, vascular injuries, wound infections, abscess, port-site hernias, pulmonary embolism, and deep venous thrombosis among others, occur just as often in RALP. In this chapter, we focus on the breadth of complications unique to RALP (i.e., urinary leak, stent migration) and discuss the risk factors, prevention, diagnosis, and treatment of such complications.

Prevention and Risk Factors

Appropriate preoperative planning and meticulous surgical technique is paramount to preventing complications. All patients should have ultrasound, MRI, or CT imaging prior to repair. It is most helpful to have axial imaging to identify potential crossing vessels or aberrant vasculature at the renal hilum. Alternatively, a laparoscopic Doppler probe can be used to detect aberrant vessels [18]. Retrograde pyelography or a CT urogram prior to repair is important not only to define the character and extent of UPJ stenosis

but also to document a normal distal ureter. In rare cases, retrograde pyelography may pick up a fibroepithelial polyp mimicking a UPJ obstruction. A mechanical bowel prep is helpful to increase working space and improve exposure. Placement of a preoperative or intraoperative stent or nephrostomy tube may be detrimental, especially to a novice robotic surgeon, as the specific site and length of obstruction may be difficult to identify and reconstruction of a decompressed renal pelvis becomes difficult.

A surgeon in the early phase of the RALP learning curve should use caution when taking on secondary UPJ cases. These can be difficult with significantly increased operative times and trends towards higher estimated blood loss (EBL) from inflammatory tissue and fibrosis in a previously operated field [19, 20]. However, in experienced hands, secondary pyeloplasty repairs using the robotic platform have shown equivalent success and complication rates as primary repairs [20]. The robot may be actually advantageous in the secondary repair cases as it offers better visualization and delineation of tissue planes when severe scarring is present. Unlike primary repair, a ureteral stent may be beneficial in the secondary repair to aid in ureteral identification intraoperatively [21]. Retrograde pyelography is mandatory to identify the location and extent of obstruction. Caution should be utilized when dissecting around the region of the UPJ as missed lower pole vessels (from previous pyeloplasty) have been noted in 22.2% of revision RALP surgery [22].

RALP is a delicate operation with few critical steps. In the most common transperitoneal approach, the colon and its mesentery are reflected medially to reveal the underlying kidney, renal pelvis, and ureter. The renal pelvis and ureter are freed of their surrounding attachments with care to avoid manipulation of the ureter and preserve periureteral blood supply. Once spatulated, the diseased UPJ segment can remain on the ureter as a handle to avoid touching the healthy ureter. Alternatively, a stitch can be placed near the apex of the spatulated ureter and used as a handle (Fig. 21.1). Once the renal pelvis is opened, a thorough irrigation should be performed intermittently to prevent the possibility of blood clot causing early obstruction in the postoperative period [23]. An intraabdominal drain should be placed at the conclusion of all procedures.

The robotic platform allows a surgeon to overcome one of the most technically challenging aspects of laparoscopy, which is suturing. The

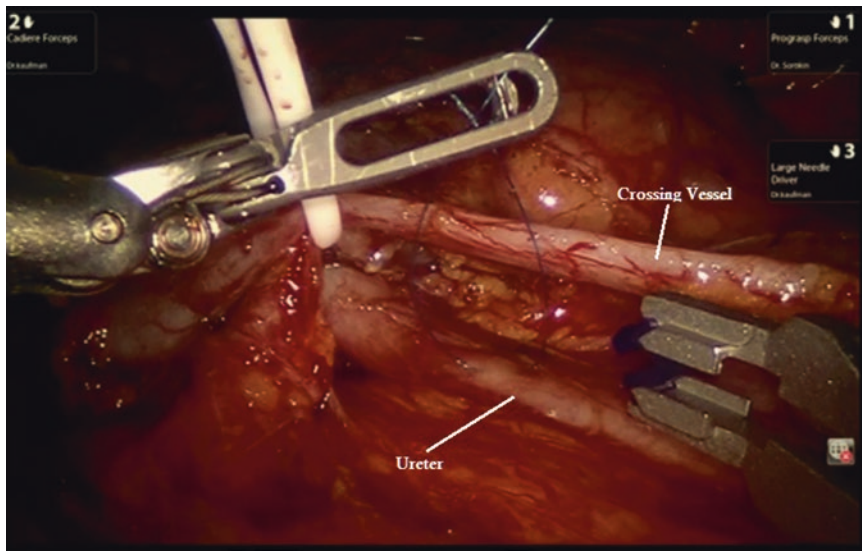

Fig. 21.1 No touch technique by placing a stitch near the apex of the spatulated ureter to use as a handle

material of the suture itself may contribute to anastomotic strictures. Recently, barbed self-retaining sutures have been introduced to distribute tension equally throughout the anastomosis and overcome technically challenging aspects of laparoscopic suturing [24, 25]. However one report by highly experienced laparoscopic surgeons using a 4-0 Quill™ (Angiotech, Vancouver, British Columbia) showed 5/6 failures with UPJ stenosis after 1 month [26]. On the other hand, the RALP series, employing a 4-0 V-Loc™ (Covidien, Mansfield, MA), have shown successful results with this type of barbed suture [27, 28]. Investigators have hypothesized that the failure of the Quill suture report may lie in its bidirectional barbs design causing greater degrees of fibrosis compared to the unidirectional designed barbs on the V-Loc [27].

Ureteral stenting is important to minimize the risk of urinary leakage and failure. Antegrade placement (Figs. 21.2 and 21.3) can be easily performed over a guide wire. Prior to placement, we recommend that the Foley catheter be clamped in order to distend the bladder. If there is concern, a flexible cystoscopy can be performed to ensure placement in the bladder or a KUB prior to waking up the patient. As depicted in (Fig. 21.4) from a case report by Stravodimos et al. [29], a postoperative KUB on day 1 showed the ureteral stent not residing in the bladder from antegrade misplacement through the posterior anastomosis. In review of their own video, the authors attribute the complication to lack of proper visualization of the surgical field, overconfidence in stent placement, and lack of tactile feedback.

The instrumentation for RALP may make antegrade stent placement much easier than CLP. However, stent migration with the antegrade compared to the retrograde approach appears to be similar. Stent migration can be mitigated by erring on the side of using longer rather than shorter stents [23].

There are several technical points to consider in R-LESS for successful completion of the procedure. The robot should be docked more cephalad, which helps aim the camera directly at the UPJ. Maximizing instrument mobility is key and involves placing the robotic arm and camera ports slightly staggered from one another, as well as the use of a 30° lens in the "up" position, which allows the camera to reside inferior to the working arms inside the patient [15]. Range of motion can be increased by the "chopstick" technique described by Joseph et al. [11], where crisscrossed instruments are reprogrammed for intuitive instrument control such that the left

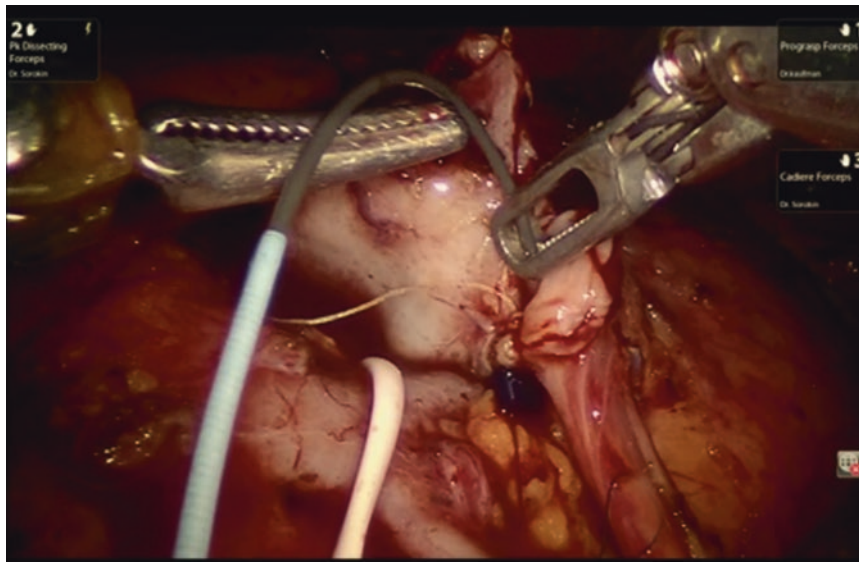

Fig. 21.2 Antegrade wire insertion by hand over hand technique

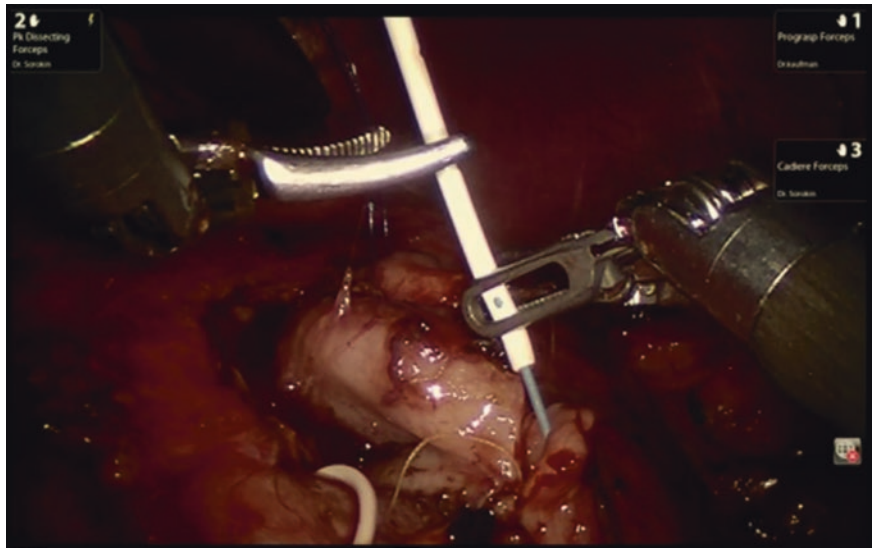

Fig. 21.3 Antegrade stent placement after adequate length of wire placed in the bladder

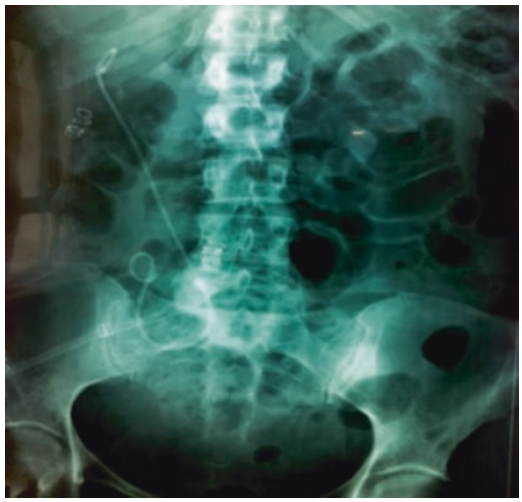

Fig. 21.4 KUB X-ray depicting misplacement of double-J ureteral stent (Reprinted with kind permission of © Konstantinos Stravodimos [29])

instrument is controlled by the right hand effector and vice versa. The robotic camera lens and instruments must be moved synchronously, given their coaxial orientation relative to each other. Meticulous attention is paid to scaling down the degree of excursion of the instruments relative to the camera with each move. It is important to maintain hemostasis throughout the procedure as the surgical assistant is only able to provide limited help given the space constraints at the bedside.

Access may be obtained either by placing ports through separate fascial incisions, using a GelPort (Applied Medical, Rancho Santa Margarita, CA) device, or the Intuitive Surgical single-site port (Intuitive Surgical, Sunnyvale, CA). The advantage of using a GelPort includes reduced gas leakage, larger extracorporeal profile for port spacing, greater flexibility in port positioning, and the ability to have a small bedside assistant port [30]. The GelPort does require a slightly larger skin incision and could be potentially better for surgeries that involve eventual specimen retrieval.

Diagnosis

All videos of RALP procedures should be recorded and easily retrieved for review. Intraoperative complications may not be recognized until the postoperative period and reviewing the video may identify a critical error. CT evaluation should be requested when the patient's clinical status (pain, fever, leukocytosis, or decreasing hematocrit) cannot be explained by

physical examination or routine clinical studies [31]. CT is the study of choice when evaluating a patient for decreasing hematocrit as it can help localize the site of bleeding. Although pneumoperitoneum is common after open surgery, if it is identified more than 24–48 h after robotic surgery, the possibility of a viscus injury in the proper clinical setting must be considered [31].

During early surgeon experience, certain postoperative complications may be noted more frequently, namely, urine leak and ureteral obstruction. Urine leak rate can range from 1.4% to 8.8% in RALP series (Table 21.2). Lower rates are seen in R-LESS series; however, the number of cases is much lower and the surgeons are highly experienced. Urine leak will usually manifest in the early postoperative period by persistently elevated drain output and this should be followed up by checking a drain creatinine level. If the level is higher than serum, urine leak should be confirmed by CT scan with delayed images. Of note, urine leak is associated with future pyeloplasty failure and should be managed urgently.

Flank pain may be indicative of ureteral obstruction from stent occlusion or migration. Stent obstruction can occur from blood clots and anastomotic edema. We recommend obtaining a CT scan in this scenario, where unresolved hydronephrosis will be seen. Both scenarios can lead to anastomotic urine leak and increased drain output would be indicative of this.

The ureteral stent is usually maintained for 4–6 weeks postoperatively, although a recent prospective randomized trial showed good outcomes with 1 week stent duration [37]. Diuretic renogram (DRG) is usually obtained 6–8 weeks after stent removal. Failure rates are variable throughout the literature and certainly depend on how stringent the definition is. Some authors have strict definitions of success requiring a DRG with t½ less than 10 min plus symptomatic relief

Table 21.2 RALP pyeloplasty

	Etafy et al. [32]	Gupta et al. [33]	Hopf et al. [34]	Mufarraij et al. [23]	Niver et al. [20]	Schwentner et al. [35]	Sivaraman et al. [36]
No. of procedures	57	86	129	140	117	92	168
Mean procedure time (mins)	335	121	245	217	218.5	108.3	134.9
Failure rate	11 (19%)	3 (3.5%)	4 (3.1%)	6 (4.3%)	4/93 (4.3%)[a]	3 (3.3%)	4 (2.4%)
Complication rate[b]	7 (12.3%)	7 (8.1%)	19 (15%)	14 (10%)	17 (14.5%)	3 (3.3%)	11 (6.6%)
Intraoperative	0	0	5 (3.9%)	1 (0.7%)	–	0	0
Postoperative	7 (12.3%)	7 (8.1%)	18 (13.9%)	13 (9.3%)	–	3 (3.3%)	11 (6.6%)
Conversion rate (open/lap)	0	2 (2.3%)	1 (0.8%)	0	0	0	0
Urine leak	5 (8.8%)	5 (5.8%)	9 (6.9%)	2 (1.4%)	–	2 (2.2%)	3 (1.8%)
Need for secondary UPJ procedure (endopyelotomy, redo pyeloplasty, nephrectomy)	8 (14%)	2 (2.3%)	2 (1.6%)	6 (4.3%)	4 (3.4%)	2 (2.2%)	4 (2.4%)
Clavien 1	3 (5.3%)	0	3 (2.3%)	0	2 (1.7%)	0	0
Clavien 2	2 (3.5%)[c]	2 (2.3%)	5 (3.9%)	3 (2.1)	2 (1.7%)	0	11 (6.6%)
Clavien 3	3 (5.3%)[c]	5 (5.8%)	10 (7.8%)	10 (7.1%)	14 (12%)	3 (3.3%)	6 (3.6%)

[a]Based on available radiographic data
[b]Calculated based on patient complication rate
[c]One patient had two complications (clavien 2 + 3)

with a validated pain analog score of 2 or less [32]. Others recommend DRG as well as a retrograde pyelogram at the time of stent removal to ensure a patent anastomosis [26]. It is important to remember that the DRG is affected by patient position, size and compliance of the system, and response to diuretic. An asymptomatic patient after repair with a questionable study should be followed with serial imaging. It is important to note that failure usually manifests in the early follow-up period (12–18 months) and late failures are rare [16].

Treatment

Hematoma formation is common and can be managed conservatively. It is extremely rare that patients suffer hemodynamic instability and require intervention likely given the general young age of the population undergoing UPJ repair. Hemorrhage into the collecting system is rare and can be managed conservatively as well; however, one series noted that this complication lead to pyeloplasty failure [35]. Blood clots in the renal pelvis can lead to stent occlusion, symptomatic obstruction, and anastomotic urine leak. In this scenario, immediate PCN avoids premature stent manipulation, which can compromise anastomotic integrity.

If the stent is found to be migrated, ureteroscopic stent exchange has been shown to be successful [20]. However, if stent migration below the anastomosis is identified late, the stenosis may require reoperation [38].

Urine leaks may be managed conservatively by urethral catheter reinsertion while keeping an intraabdominal drain in place until urine output from the drain ceases. Although prolonged periureteral and/or urethral catheter drainage is adequate to manage anastomotic leak in a conservative manner, neither technique ensures complete drainage. Persistent exposure of perianastomotic tissue to extravasated urine may induce fibrosis and could compromise surgical outcomes. We recommend more aggressive management of this complication by immediate placement of a PCN which has shown to successfully preserve outcomes after pyeloplasty with long-term follow-up [39]. In our experience, all cases of urine leak had stopped after PCN placement and surgical drains may be removed within 48 h. The PCN can be subsequently removed after antegrade nephrostogram demonstrates resolution of the complication and the patient has remained asymptomatic after clamping the PCN for 12–24 h [39].

The data on secondary UPJ procedures after RALP are scarce as the failure rate is quite low. Early restricturing has been managed with replacement of the ureteral stent, but this is not a long-term solution. Successful long-term management with laser and balloon endopyelotomy has been reported. Patients who fail and have poorly functioning kidneys should be offered a nephrectomy if the contralateral kidney is normal.

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Ureteral Reconstruction Surgery

22

Jatin Gupta and Ronney Abaza

Introduction

Robotic surgery in Urology has become widespread since the introduction of the da Vinci robotic system (Intuitive Surgical, Sunnyvale, California) with robotics becoming a standard approach for certain procedures (i.e., prostatectomy). As robotics has gained popularity, so has its uses, especially in the treatment of upper ureteral and lower ureteral pathologies. Although conventional laparoscopy is still utilized in the treatment of such conditions by some surgeons, the short learning curve, the seven degrees of freedom with respect to suturing, and the high definition three-dimensional view has made robotics a preferred platform amongst many urological surgeons [1, 2]. Nonetheless, complications such as vascular/bowel injury, urinary leak, and stent migration can arise, and recognizing these risk factors and management options are critical in ensuring the continued success of robotics in ureteral reconstructive surgery.

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Robotic Surgery for Upper Ureteral Pathologies

Robotic surgery has demonstrated extreme versatility in ureteral reconstructive procedures. The various procedures performed today can be divided based upon upper and lower ureteral pathologies.

Common upper ureteral pathologies include ureteropelvic junction obstruction, strictures of the proximal ureter, and conditions of the mid ureter (i.e., retrocaval ureter, retroperitoneal fibrosis, or stricture of the mid ureter). Additionally within the spectrum of ureteropelvic junction, there are abnormalities such as duplicated collecting system with obstruction of either the upper pole or lower pole moiety and ectopic duplicated system with dysplasia of the upper pole moiety. However, irrespective of the spectrum of conditions involving the ureteropelvic junction, proximal ureter, and the mid ureter, the current application of robotics in the management of such conditions includes (1) robotic dismembered pyeloplasty, (2) robotic ureterocalicostomy, and (3) robotic ureteroureterostomy, as well as less common procedures such as ureterolithotomy, polypectomy, and ureterolysis for retroperitoneal fibrosis.

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Robot-Assisted Laparoscopic Pyeloplasty (RALP)

Description of Procedure

Ureteropelvic junction obstruction (UPJO) has traditionally been managed with a variety of procedures including endopyelotomy, open pyeloplasty, and laparoscopic pyeloplasty. However, with minimally invasive options becoming more popular, there are certain challenges surrounding laparascopic pyeloplasty that have made its acceptance challenging, namely, intracorporeal suturing. With the use of the robotic platform, the anastamotic time has been a clear advantage, as demonstrated by numerous studies [3, 4].

The indications for pyeloplasty are well established and can be applied to any surgical approach for the treatment of UPJO. The main indications for pyeloplasty are worsening hydronephrosis, deterioration of renal function, recurrent urinary tract infection secondary to obstruction, and symptoms related to obstruction (e.g., flank pain, nausea/vomiting, Dietl's crisis) [5]. Although there are certain challenging scenarios such as small intrarenal pelvis and long ureteral strictures that may impact the application of robotic pyeloplasty, the broad capabilities of robotics allow alternative procedures in such circumstances such as robotic ureterocalicostomy.

Positioning and approach are similar for all robotic upper ureteral reconstructive procedures. RALP is most commonly performed transperitoneally, although a retroperitoneal approach may be applied, especially if the patient has an extensive history of prior abdominal surgery. Elective criteria for transperitoneal approach includes h/o previous renal surgery, a wide pelvis (>6 cm), presence of large and/or multiple renal stones, pelvic/horseshoe kidney, and presence of crossing vessel [6]. The patient is placed in a modified lateral decubitus position with the ipsilateral side up. The robot is docked posterior to the patient and 2–3 robotic trocars are placed [2]. Additional 5 mm assistant trocars can be placed for retraction or suction. Depending on the presence of crossing vessels or redundant renal pelvis vs. high ureteral reinsertion, reconstruction can be accomplished by Anderson–Hynes dismembered pyeloplasty or Y-V plasty, respectively [4, 7]. If preoperative imaging demonstrates presence of renal calculi, a flexible cystoscopy or nephroscope can be utilized to remove stones with a nitinol stone basket.

The anastomosis is performed with vicryl or monocryl suture in running or interrupted fashion with barbed suture also described. The stent can be placed in antegrade fashion robotically or retrograde cystoscopically. A suction drain can be placed or omitted if the repair is watertight. Ureteral stent removal typically takes place 4–6 weeks postoperatively followed by reimaging at 3–4 months.

Complications of RALP

Postoperative complication rates for RALP have generally been low owing in part to the advantages of robotic surgery. Complications can include all of those common to all robotic procedures, including those related to access and dissection of regional structures. Complications specific to RALP include urine leak and recurrent stricture, potentially technical in nature (e.g., back-walled suture) but typically related to ischemia or secondary to urine leak and the subsequent inflammatory response (Fig. 22.1).

In the largest series to date, an overall 6.6% complication rate was reported by Sivaraman et al. in 168 patients over a 6-year period from three academic centers. A total of 17 complications occurred in 11 patients (6.6%). The most common complication was postoperative ileus followed by blood loss requiring transfusion. Of the three patients that suffered blood loss requiring transfusion, one was due to liver laceration. One patient developed pyelonephritis, which required treatment with parenteral antibiotics. Three patients developed a postoperative anastomotic urine leak, which was managed with prolonged foley catheter and suction drain. All three patients that developed a postoperative urine leak required subsequent retrograde laser endopyelotomy [8].

Hopf et al. further evaluated the long-term outcomes of RALP by retrospectively evaluating

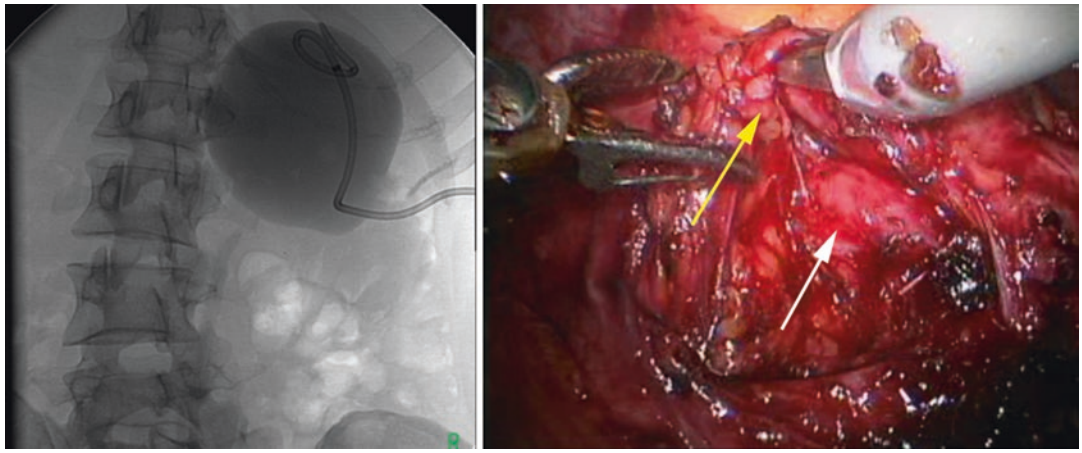

Fig. 22.1 Revision pyeloplasty after failed previous pyeloplasty. Nephrostogram (*left*) shows complete occlusion at site of previous anastomosis, and intraoperative view shows strictured ureteropelvic junction (*yellow arrow*) and previously transposed crossing vessel (*white arrow*) and surrounding fibrosis

129 cases from a single institution. Overall 5 (3.9%) intraoperative complications and 18 (13.9%) postoperative complications were identified. The intraoperative complications consisted of two bowel serosal injury, one thermal injury to the gallbladder, one airway bleed from intubation, and one unrecoverable robotic malfunction requiring conversion to a standard laparoscopic procedure. Postoperative complications consisted of nine anastomotic urine leaks, five UTIs, and four other unclassified complications. It was observed that patients who did not have a stent had a significantly increased rate of postoperative urine leak compared to patients who had stentless procedures. On long-term analysis, there were a total of four failures with two patients requiring ipsilateral nephrectomy, one patient requiring long-term indwelling ureteral stent, and 1 patient requiring long-term suppressive antibiotics. It was noted that three of the four failures occurred in patients who had not received a stent [9].

Lucas et al. reviewed factors that would impact outcomes of robotic and laparoscopic pyeloplasty and found that previous endopyelotomy and presence of intraoperative crossing vessels are associated with higher rate of secondary procedures. Interestingly, the authors found that preoperative ureteral stent placement did not impact the efficacy of performing pyeloplasties and was not associated with a higher rate of secondary procedures [10].

Robotic Ureterocalicostomy

Description of Procedure

Although a majority of ureteropelvic junction obstruction cases can be managed by RALP, there are instances such as UPJO with minimal renal pelvis, UPJO with intrarenal pelvis, obstructed horseshoe kidney, and failed prior pyeloplasty that justifies ureterocalicostomy [11, 12]. Korets et al. reported the first robotic ureterocalicostomy procedure [13].

Positioning and placement of robotic trocars is similar to that of RALP. Unlike RALP, the renal vessels are dissected for clamping during lower pole resection. Ultrasound can be used to identify the lower pole calyx. The renal artery is clamped with a laparoscopic bulldog, and the lower pole is excised to access the calyx with suturing of vessels as with partial nephrectomy followed by unclamping. The ureterocaliceal anastomosis is performed with either interrupted or running absorbable suture with antegrade stent placement prior to completion. The proximal ureteral stump is suture-ligated [11–14].

Complications of Robotic Ureterocalycostomy

Robotic-assisted ureterocalycostomies are not performed nearly as frequently as RALPs, as they are generally reserved for rare situations and are a technically more challenging procedure. Chhabra et al. reported the largest study to date, which consists of only five patients. The authors report three postoperative complications consisting of postoperative fevers in two patients and failure in one patient [11].

Further experience is required in order to establish reliable complication rates, but the complications of this procedure would be expected to include the potential complications of pyeloplasty as well as some complications of partial nephrectomy. These would include urine leak, stricture (failure), and others as well as the potential for bleeding, pseudoaneurysm, and arteriovenous malformation as can occur in partial nephrectomy. This would be expected to be more likely if a thick portion of lower pole renal tissue is excised as opposed to when chronic obstruction has led to more cortical thinning with less parenchymal excision necessary, which is more ideal and likely to be successful in ureterocalycostomy.

Robotic Ureteroureterostomy (UU)

Description of Procedure

For short strictures involving the proximal or mid ureter, robotic ureteroureterostomy is an attractive option as the techniques and principles are similar to that of robotic pyeloplasties.

Various strategies have been described for identifying the site of the stricture if an obvious transition point is not evident [15]. An open-ended or balloon catheter can be inserted to the level of the ureteral stricture as localized via retrograde pyelogram and is then secured to a Foley catheter in the bladder. A flexible ureteroscope can also be used in a retrograde fashion if urethral access is maintained during positioning for the robotic procedure, and antegrade ureteroscopy can be performed through a ureterotomy by placing the flexible ureteroscope through one of the abdominal ports.

Patient positioning is similar to that of a robotic pyeloplasty with slight adjustment of trocar placement based upon location of stricture. Mobilization of the ureter is performed proximal and distal to the ureteral stricture for a distance that will allow tension-free anastomosis without overmobilization that could threaten blood supply. The diseased portion of the ureter is then transected and excised followed by spatulation of the healthy ureteral ends and anastomosis with absorbable sutures in interrupted or running fashion with stent placement before completion.

Complications of Robotic Ureteroureterostomy (UU)

The described complications of robotic UU are limited as the procedure has not been extensively performed. Marien et al. reviewed 250 patients who underwent various robotic upper urinary tract reconstructions with a total of 8 patients specifically undergoing robotic UU [16]. Two patients experienced postoperative complications, which were not elaborated upon. Buffi et al. retrospectively reviewed 183 patients who underwent robotic pyeloplasty ($n = 145$), robotic UU ($n = 17$), or robotic ureteral reimplantion ($n = 21$) at four high-volume centers. Three of the 17 patients who underwent robotic UU suffered a postoperative complication but were only of Clavien–Dindo class 1 or 2 [17]. Nevertheless, the expected complications of robotic UU would be expected to include the complications of any robotic procedure as well as the complications of UU, such as urine leak, stricture, or stent complications.

Robotic Surgery for Lower Ureteral Pathologies and Miscellaneous Ureteral Surgery

The principles applied to robotic-assisted surgery for upper ureteral pathologies can similarly be applied to conditions of the distal ureter. Distal ureteral pathology can either be benign or malignant. Benign distal ureteral conditions consist of

distal ureteral strictures that may be idiopathic/congenital or iatrogenic (i.e., gynecological surgery). Additionally, if a ureteral complication after gynecological surgery is left undiagnosed, it can result in ureterovaginal fistulae.

Distal ureteral reconstruction can also be performed after distal ureterectomy for transitional cell carcinoma by means of ureteroneocystotomy. This can require psoas hitch or even Boari flap for larger gaps between the healthy end of the ureter and the bladder, which can performed robotically as well.

Robotic Distal Ureteral Reimplantion (RDUR)

Description of Procedure

Patients undergoing RDUR are placed in a low dorsal lithotomy position with port positioning very similar to that commonly used for robotic prostatectomy [2]. Localization of the pathology is similar to that or UU [15]. If the distal ureter is not being excised (i.e., benign disease), a clip is placed on the distal end after transecting the ureter just above the site of pathology. A direct anastomosis to the bladder dome is performed when possible in refluxing or nonrefluxing fashion at the discretion of the surgeon (Fig. 22.2).

When needed, a psoas hitch can be performed by mobilizing the bladder and if necessary dividing the contralateral bladder pedicle. When a psoas hitch is performed, it is important to identify and avoid the genitofemoral nerve prior to suturing the posterior bladder wall to the psoas muscle [18].

If a Boari flap is needed to bridge the gap between the bladder and the healthy end of the transected ureter, a broad-based flap of bladder is raised starting near the bladder neck with the base at the dome. This is tubularized and anastomosed without tension to the ureter. The bladder is filled with normal saline via the bladder catheter to test for leakage after reimplantation with or without psoas hitch or after Boari flap.

If performing distal ureterectomy for transitional cell carcinoma of the distal ureter, the above procedure is identical except that the remaining ureteric stump is then excised with a bladder cuff.

Complications of Robotic Distal Ureteral Surgery

Musch et al. retrospectively reviewed 16 patients who underwent robotic-assisted reconstructive surgery of the distal ureter with no intraoperative complications, but they had to convert to open surgery in one patient due to significant peritoneal adhesions from prior pancreatectomy. Twelve of 16 patients had postoperative complications with 10 minor complications (Clavien Grade 1–2) and 2 major complications (Clavien Grade 3b and 4a). Six had postoperative UTIs, one had a corneal abrasion, one had temporary leg weakness secondary to femoral nerve injury, and one had a silent myocardial infarction. One patient had prolonged anastomotic leakage, while another had urinary leakage with subsequent peritonitis. The patient who suffered from prolonged anastomotic leakage developed asymptomatic hydronephrosis from anastomotic stricture.

Miscellaneous Robotic Ureteral Procedures

Robotic Ureterolithotomy

Ureterolithotomy is an option for large ureteral stone burdens when endoscopic management or lithotripsy have failed or would require multiple or complex procedures [19]. Dogra et al. described robotic ureterolithotomy in 16 patients who demonstrated impacted stones within the lower ureter measuring >2 cm. Patients were positioned similar to robotic prostatectomy. A ureterotomy is performed and the stones extracted are placed into a small endocatch bag. A stent is placed as described earlier and the ureterotomy is closed in a running fashion. Dogra et al. reported the largest series of robotic ureterolithotomy to date with no intraoperative or postoperative complications (Fig. 22.3).

As centers and surgeons develop more experience with the application of robotics in the management of upper urinary tract reconstruction,

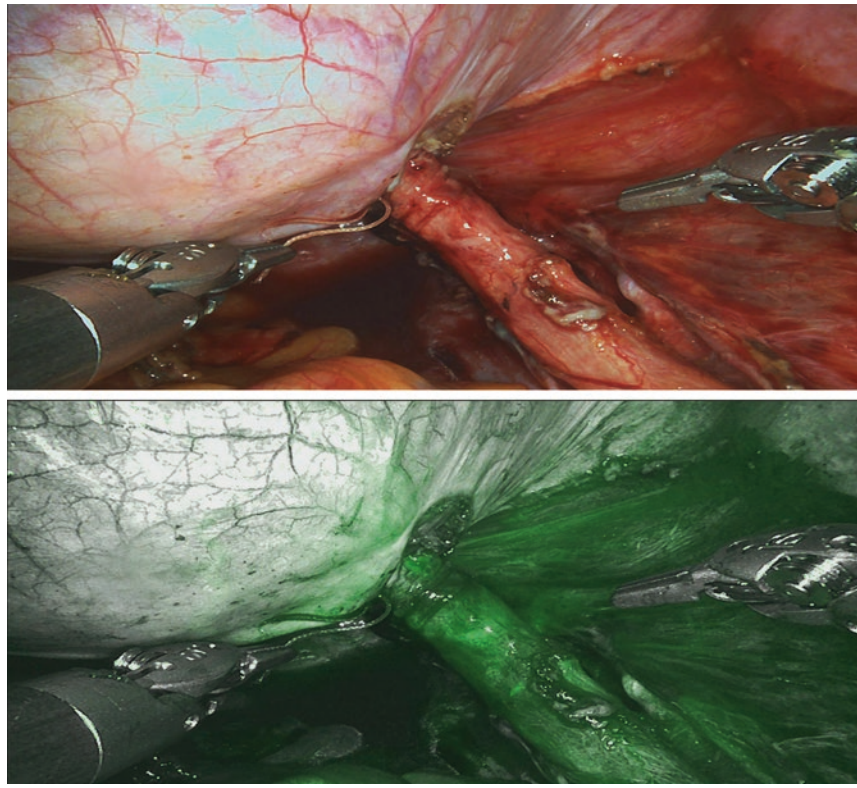

Fig. 22.2 Completed robotic ureteral reimplantation (*above*) with confirmation of healthy blood flow using fluorescence (*below*)

novel ideas are being presented to improve outcomes such as buccal mucosal graft ureteroplasty and use of near infrared fluorescence imaging (NIRF) with indocynanine green (ICG) [16] (Fig. 22.4). Marien et al. demonstrated in two patients who underwent buccal mucosal graft ureteroplasty for large proximal ureteric stricture (1.5–3.0 cm) who would not be amenable to primary ureteroureterostomy and did not suffer any intraoperative or postoperative complications.

Additionally, Marien et al. described the use of near infrared fluorescence imaging (NIRF) with indocynanine green (ICG) to assess tissue perfusion at the time of robotic ureteral surgery (Fig. 22.5). The ICG is administered via intravenous route, and the NIRF on the da Vinci console (Si or Xi) fluoresces bright green wherever there is well-perfused tissue. Poorly perfused tissue appears dark, and this technique can be utilized to identify the portion of diseased ureter that needs to be excised and after anastomosis is performed to ensure adequate perfusion of the anastomosis. This may reduce postoperative complications such as anastomotic failure and urine leak or stricture.

General Complications of Robotic Ureteral Surgery

Vascular Injury

Due to the anatomic location of the ureters and their proximity to major vascular structures such as the IVC and the common and external iliac vessels, vascular injury is a potential complication. Risk factors that may increase likelihood of vascular injury include presence of adhesions, retroperitoneal fibrosis, and retrocaval ureter. As with any surgery, appropriate preoperative imaging helps to define anatomic relationships.

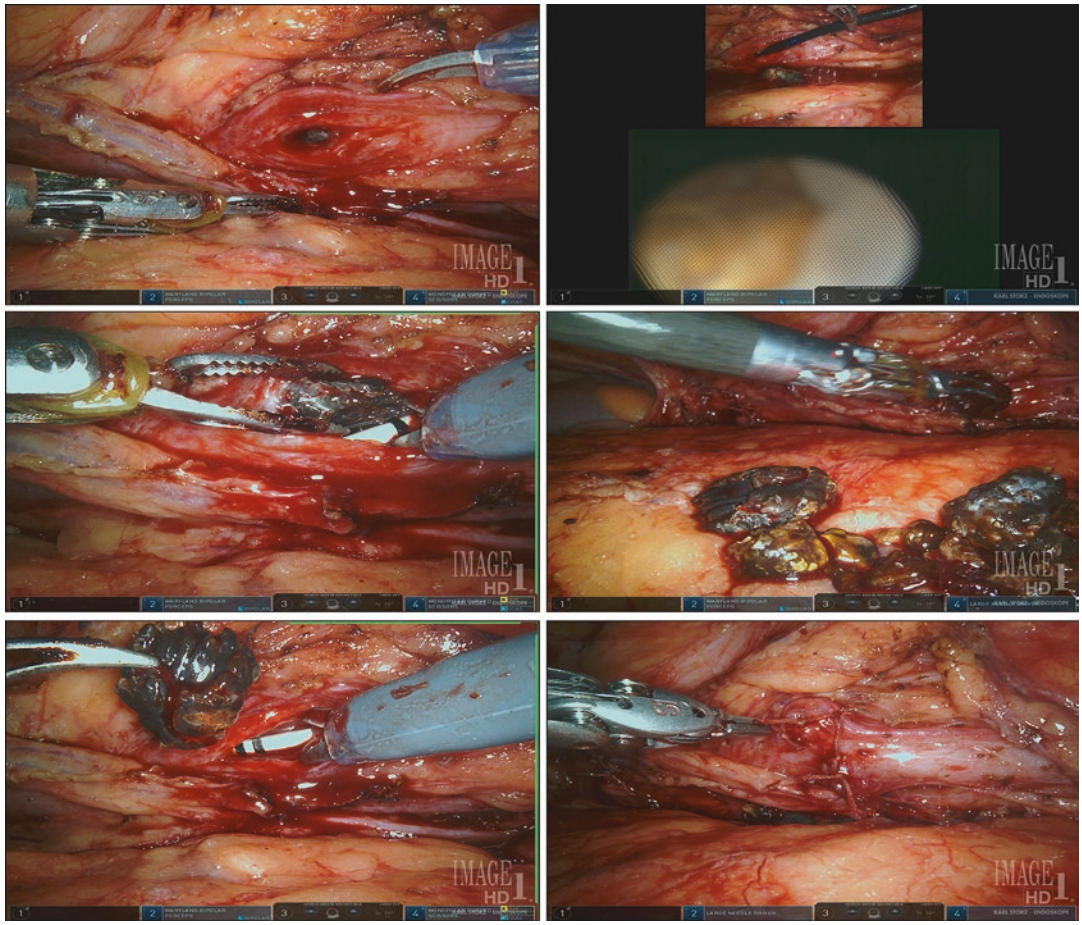

Fig. 22.3 Robotic ureterolithotomy with initial incision over largest stone (*upper left*), extraction of impacted stone (*middle left*), preplaced stent visible (*lower left*), ureteroscopy through ureterotomy to remove additional stones (*upper right*), after removal of all stones (*middle right*), and after closure of ureterotomy horizontally to prevent narrowing (*lower right*)

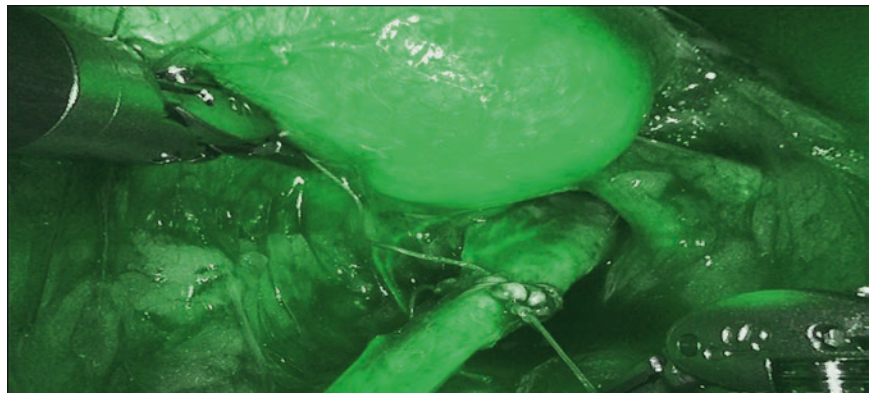

Fig. 22.4 Near-infrared fluorescence imaging of complete pyeloplasty to assess and confirm perfusion of tissues at anastomosis

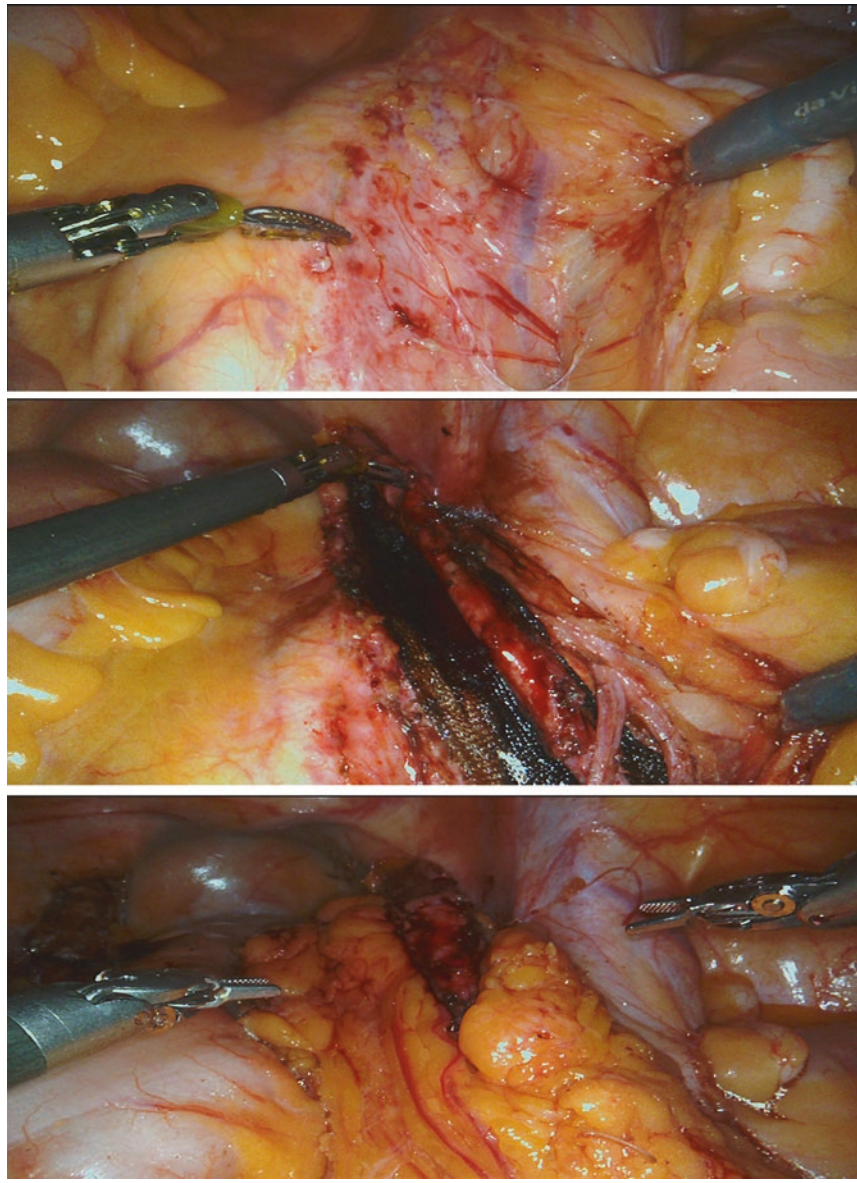

Fig. 22.5 Robotic ureterolysis for retroperitoneal fibrosis including initial view of pathology (*upper*), after completion of ureterolysis with hemostatic agent below ureter (*middle*), and after omental wrap to prevent recurrence (*lower*)

Despite proper planning, intraoperative complications such as vascular injury can occur, and adhering to basic principles is helpful in such situations. If the console surgeon can identify the source of bleeding, applying pressure with robotic instruments or grasping the vessel with a robotic instrument using it like a clamp can control the bleeding until definitive measures are possible. The insufflation pressure can be increased to help with tamponade of venous bleeding. If bleeding continues to occur despite the above measures, one can additionally employ their bedside assistant to introduce a sponge and apply pressure with the suction irrigator. Once the bleeding is initially managed and the site of injury is visualized, repair of the vessel can be performed with nonabsorbable suture. However, if bleeding persists despite the

above measures, open surgical intervention may be necessary.

Urinary Leakage/Urinoma

An inherent risk of ureteral reconstructive surgery is the possibility of a urine leak and possible development of a urinoma. With the application of robotics, the reported incidence of ureteral leak has been low. Sivaram et al. demonstrated a 1.7% risk of urine leak compared to the 10% cited risk of urine leak with laparoscopic pyeloplasty [8, 20]. Factors that can increase the risk of developing a urine leak after robotic ureteral surgery include lack of watertight closure, failure to leave a stent, and breakdown of the anastomosis usually due to infection or ischemia. The principle of a watertight, tension-free anastomosis should be applied to any ureteral reconstructive surgery. Additionally, it is important to place a stent prior to the completion of the anastomosis and to ensure adequate position.

Patients may present with symptoms of abdominal pain, nausea and vomiting, or infection. Often these symptoms are a consequence of ileus as urine is an extreme irritant to the bowel. A urinoma can become infected and lead to peritonitis or sepsis.

If a Jackson pratt drain is placed intraoperatively, the drain output can reflect a urine leak. A sample of drain output sent for creatinine will reflect a value substantially greater than the serum creatinine, but the serum creatinine may also be elevated from peritoneal reabsorption. When a urine leak is suspected, a CT urogram can identify extravasation of contrast.

Most urine leaks can be managed conservatively with adequate drainage, which may include a stent, bladder catheter, peritoneal drain, and in more severe cases possibly a nephrostomy tube. Additionally if a urinoma develops, percutaneous drainage of the collection is also recommended. If reoperation is considered when technical error is suspected, it should be immediately after the original surgery as inflammation and scar tissue will reduce the likelihood of success otherwise.

Ureteral Stricture

A late complication of ureteral reconstructive surgery is development of a secondary ureteral stricture. Ureteral strictures are often diagnosed during surveillance with either CT urography, renal functional scans, or retrograde pyelography. Persistent hydronephrosis with delayed emptying of contrast or worsening renal function after ureteral reconstructive surgery is highly suggestive of ureteral stricture disease, although hydronephrosis after chronic obstruction may not resolve and should not be assumed to represent obstruction alone.

Secondary strictures are generally difficult to manage and can include endoscopic incision or balloon dilation when short, chronic stent placement and exchange, or reoperation. Unfortunately, there are limited data on long-term outcomes of these options for secondary strictures, with management often depending upon the location and length of the stricture.

Stent Migration and Occlusion

Since stents are commonly placed intraoperatively during ureteral reconstructive surgery in order to protect the repair and provide drainage, these stents can become dislodged or may be malpositioned. Stents can be placed with the aid of guide wire introduced through the assistant port to reduce the risk of malpositioning. Stent position can be confirmed with a postoperative abdominal X-ray.

Additionally, stents can become occluded by blood clots with similar consequences. Common signs and symptoms that may indicate dislodgment or occlusion of a stent include increased drain output, increasing hydronephrosis, flank pain, and abdominal pain or ileus from urine leakage. If these signs and symptoms are present, further investigation with imaging should be performed.

Management of stent migration or occlusion may sometimes initially require nephrostomy tube drainage to decompress the collecting system followed by repositioning the stent.

Nerve Injury

Inherent to performing a psoas hitch is a risk of nerve injury, specifically to the genitofemoral nerve and the femoral nerve, which are in proximity to the psoas muscle. The genitofemoral nerve emerges from the anterior surface of the psoas major muscle. The genital and the femoral branch are responsible for sensation to the upper thigh, anterior scrotal skin, and mons pubis in females. As a result, injury to the genitofemoral nerve results in groin pain, paresthesia, or burning sensation of the lower abdomen and the medial aspect of the thigh. Paresthesia of the scrotum in males and labia majora/mons pubis in females can also occur [21].

The femoral nerve courses inferolaterally to the psoas major muscle and exits between the psoas major and the iliacus muscle [22]. Of anatomical importance, the femoral nerve is close to the external iliac artery prior to coursing to the thigh. The femoral nerve provides motor and sensory innervation to the anterior thigh and sensation to the medial aspect of the leg [21]. Injury to the femoral nerve results in anteromedial thigh numbness, lower extremity weakness on the ipsilateral side, and inability to perform hip flexion/adduction and knee extension.

The use of suture type during psoas hitch vesicopexy has been considered a risk factor in terms of short-term vs. prolonged nerve injury. Ultimately, it is recommended to use absorbable suture during psoas hitch in the event that there is nerve injury [22]. If nerve injury is suspected, often conservative management with physical therapy will help with resolution of symptoms. However, if complete denervation has resulted from ligation, then reoperation to remove the suture may be necessary to ensure recovery [22].

However, the best way to prevent such complications is to have a fundamental understanding of the anatomy of the genitofemoral and the femoral nerve so that one may carefully place sutures. Maldonado et al. [21] notes that >70% of patients have an absent psoas minor tendon, and thus placement of the psoas hitch suture in such patients directly into the psoas major muscle increases the risk of nerve injury. The author further mentions that if placing the suture through the psoas major muscle, it should be a superficial stitch (no deeper than 3 mm) and the bladder should be anchored to the psoas major muscle at or above the level of the common iliac artery bifurcation.

Conclusion

As robotics continues to be applied in the treatment of various ureteral conditions, understanding the risk of various complications and their management options is critical in ensuring success. Although data are still limited on complications specific to robotic ureteral surgery, the major complications of ureteral reconstructive surgery can also occur with open or laparoscopic approaches. Understanding the fundamentals of why these complications occur and how to manage them will ultimately decrease the morbidity of these procedures.

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Robot-Assisted Retroperitoneal Lymphadenectomy

23

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Abbreviations

IMA	Inferior mesenteric artery
IVC	Inferior Vena Cava
LN	Lymph Nodes
RARPLND	Robot-assisted retroperitoneal lymph node dissection

Introduction

Robot-assisted retroperitoneal lymph node dissection (RARPLND) is a challenging procedure and being aware of potential complications will help surgeons avoid them. It involves transperitoneal access to the retroperitoneal space and manipulation of several vital retroperineal organs such as the great vessels with its major branches, the kidneys, the ureters, major lymphatic channels, and the retroperitoneal portion of the gastrointestinal tract. The lymphatic tissue in the retroperitoneal space is commonly fibrotic and adherent to the adjacent structures, especially in post-chemotherapy patients. Early in a surgeon's experience the procedure can be long and also be associated with additional complications. All of these factors need to be taken into consideration when performing this procedure.

RARPLND is a recently developed procedure for the management of retroperitoneal disease in testicular cancer patients. All the initial studies that described the perioperative outcomes and complications of this procedure were small case series with relatively short follow-up. However, the last 2 years witnessed the evolution of larger case series that reported perioperative outcomes and complications (Table 23.1) [1–4].

The objective of this chapter is to describe potential complications, highlight associated risk factors, and discuss the prevention and management of each one of these potential complications. This will be described in a stepwise fashion depending on the step at which respective complication may arise and will be preceded by a brief description of the surgical technique.

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Table 23.1 List of large RPLND series with reported complications

Series	Year of publication	Number of cases	Primary vs. secondary RPLND	Minor complications (Clavien < 3)	Major complication (Clavien ≥ 3)
Cheney et al. [1]	2015	18	Both	17%	0%
Harris et al. [2]	2015	16	Primary	0%	6.3%
Stepanian et al. [3]	2016	20	Both	Not reported	5%
Pearce et al. [4]	2016	42	Primary	4.7%	4.7%

Preoperative Considerations

Anesthetic Risks and Preoperative Evaluation

The majority of the patients who undergo this procedure are young and otherwise healthy and can be prepared with a routine preoperative anesthetic evaluation. However, special attention should be paid to patients who had previously received chemotherapy, which commonly includes bleomycin. Although symptomatic pulmonary fibrosis most commonly takes place in elderly patients who receive this treatment, younger patients may have subtle subclinical changes. Bleomycin is responsible for the development of interstitial pneumonitis and deposition of extracellular matrix protein in alveolar wall resulting in restrictive lung disease. The effect of bleomycin is dose-dependent and may be exaggerated in patients who have other pulmonary risk factors such as smoking, asbestos exposure, etc. Symptoms of bleomycin pulmonary toxicity include cough, shortness of breath, tachypnea cyanosis, and fever. However, screening for these symptoms is not always enough as most patients are asymptomatic. It is very important to realize that bleomycin pulmonary toxicity is symptomatic in only 20% of patients and thus a high index of suspicion should be kept in mind. Preoperative assessment of pulmonary function with a pulmonary function test is necessary for preoperative planning [5–7]. Specific parameters include diffusion capacity for carbon dioxide or partial pressure of arterial oxygen, which may be a good prognosticator for anesthetic complications and death. Fatality in these cases is thought to be due to the development of adult respiratory distress syndrome which in turn takes place secondary to oxygen toxicity and fluid overload during anesthesia. The lowest possible supplemental O_2 concentration should be used intraoperatively to maintain acceptable oxygenation as these patients are more sensitive to O_2 pulmonary toxicity [8]. Furthermore, intraoperative fluid replacement in these cases should be kept to a minimum to avoid pulmonary edema, which is often mistakenly treated by increasing oxygen supplementation that leads to further pulmonary toxicity. Fluid replacement is preferably performed with alternation between colloids and crystalloids.

Risk of Bleeding and Thrombosis

Any therapeutic anticoagulation with long-acting agents should be discontinued appropriately. Blood type and screen is routinely ordered prior to the surgery whereas cross-matching is obtained only when the likelihood of significant bleeding is high, such as when a large retroperitoneal mass is seen on preoperative imaging or in post-chemotherapy patients [9]. Standard preoperative mechanical and medical deep venous prophylaxis is advised, as these patients have multiple risk factors to develop deep venous thrombosis. These factors include the presence of cancer, need for vascular dissection, and prolonged time of pneumoperitoneum. The prophylaxis can be achieved by 5000 IU of subcutaneous heparin or 30–40 mg of lovenox, as well as the use of knee level elastic stockings and sequential pneumatic compression devices. Prophylaxis should be continued throughout the hospital stay and in some cases may be continued in the postoperative setting when appropriate [10].

Bowel Preparation

The authors do not routinely use any specific bowel preparation unless the suspicion of bowel injury is high. A bowel preparation with one bottle of magnesium citrate can be given depending on surgeon preference and patients can be asked to adhere to a clear liquid diet the day before surgery. An orogastric or nasogastric tube can be inserted at time of induction and removed at the end of the case for the same reason. Although prolonged postoperative ileus is rare in cases performed robotically, if there is a high likelihood of conversion preoperative administration of μ opioid receptor antagonist (alvimopan) can potentially shorten the duration of ileus. It is not the practice of the authors to use this routinely in RPLND but this can be potentially helpful in patients anticipated to have a prolonged ileus.

Antibiotic Prophylaxis

Unless an inadvertent injury to the bowel or the urinary system takes place, RARPLND results in Class I (clean) wound. Standard parenteral broad-spectrum antibiotic such as cefazolin is given 30 min prior to incision and repeated dosing is administered based on the length of the procedure [11]. However, no postoperative antibiotic is routinely required.

Preparation for Vascular Emergencies

Although vascular emergencies are not common in RARPLND, the whole surgical team should be ready for urgent, open conversion and open surgical instruments should be available inside the operating room especially early in one's experience. Open instruments to have immediately available should include a vascular set and appropriate retractors. The console should be placed inside the operating room itself rather than in a remote location outside the operating room in order to ensure direct and clear communication. The console surgeon should be ready to switch to laparoscopy or open surgery if needed. Prevention and management of vascular emergencies are discussed in detail later in this chapter.

Positioning-Related Complications

Proper and safe patient positioning is of extreme importance in RARPLND. Most of these cases place the patient in a nonphysiological body position and sometimes require long operative times especially in post-chemotherapy patients. The patient is placed in low lithotomy, maximal Trendelenburg position and in some cases the left shoulder is tilted to the left slightly (approximately 30°), as shown in Fig. 23.1. Placing the patient in this position will facilitate exposure as gravity will retract the bowel to the left upper quadrant of the abdomen. The patient should be secured to the table using 3 in. silk tape across the chest. All potential pressure points should be padded. The head should be secured in a neutral position with a head rest on the left side in order to avoid neck flexion once the patient is tilted. Arms are tucked by the sides and the legs are spread and fixed. The peroneal nerve is prone to compression and the surgical team should try to have the legs relatively extended without full extension. In most cases, standard Trendelenburg that is used for robotic pelvic procedures is all that is needed.

Neurapraxia is one of the most commonly encountered complications after any procedure with extreme positioning and is usually self-

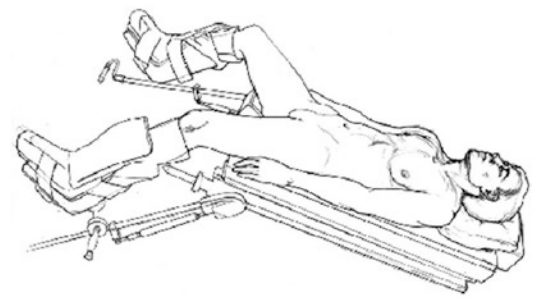

Fig. 23.1 Patient positioning. Please note the position of the left leg is slightly lower and more extended compared to the right leg to avoid clashing with the robotic arm

limiting and resolves with conservative management and physical therapy [12]. Early in one's experience, the procedures may be long and being aware of the time the patient is in extreme positioning is critical. Complications such as rhabdomyolysis are of significant concern when the patient is in extreme positioning greater than 4–6 h. Patients should be assessed in the recovery room once they are fully awake where a vigilant neurovascular examination of the extremities can be conducted. Early detection and treatment of ischemia is important to prevent consequences of this complication. Follow-up of immediate postoperative labs, physical exam, and urine output will unveil any signs of rhabdomyolysis, which can be treated with aggressive hydration [13]. If rhabdomyolysis is suspected, the extremities should be assessed with compartment pressures and consultation to orthopedics or plastic surgery.

Access-Related Complications

As in any laparoscopic intervention, visceral injuries can take place during access or trocar placement and standard measures should be taken to avoid these injuries [14]. In RARPLND, the pneumoperitoneum is established using either a Veress needle technique or a Hasson technique if intraabdominal adhesions are expected from previous surgery. This can be performed while the patient is still in a neutral position. However, trocar placement is best performed after changing to Trendelenburg position to move the bowel away and minimize the chances of injury. The trocar location varies based on surgical preference and several approaches have been described based on the template of dissection. However, when a full bilateral template is planned, we usually use the following template (Fig. 23.2). As the midline camera port is below the umbilicus, the bladder should be maximally drained with a catheter-tipped syringe prior to trocar placement.

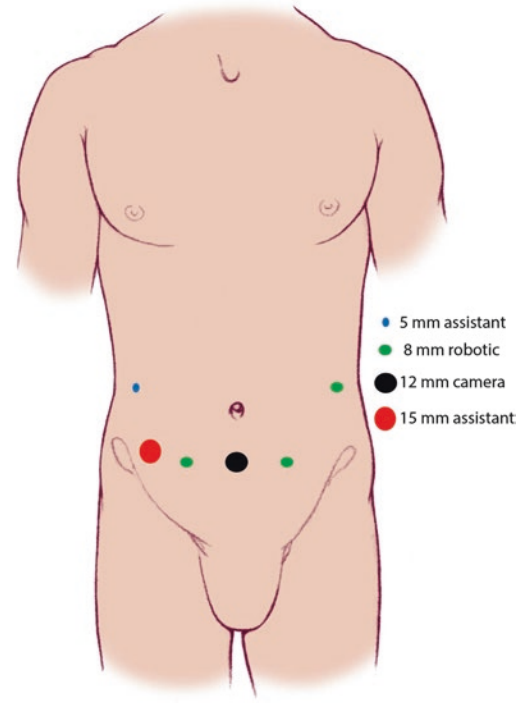

Fig. 23.2 Port template for robot-assisted retroperitoneal lymph node dissection

Bowel Retraction and Suspension Stitches

An orogastric tube is inserted to completely deflate the stomach. A urethral catheter should be inserted to monitor urine output and to deflate the bladder. The bladder should be actively drained as mentioned previously. One of the most helpful maneuvers that were developed during the evolution of this technique is the bowel retraction sutures. Once the robot is docked, the bowel is retracted toward the upper abdomen and a wide incision is made in the posterior peritoneum below the bifurcation of the great vessels. This incision is the same one that is performed during open RPLND and is started caudal to the cecum and appendix and extended medially to the root of the small bowel mesentery. The peritoneum is then lifted off the underlying great vessels and space is dissected as superiorly

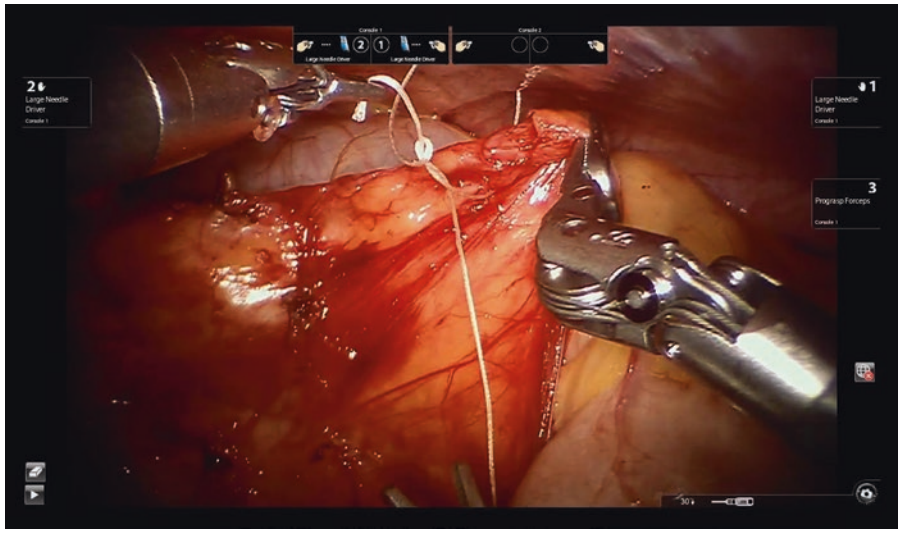

Fig. 23.3 Suspension stitch placement

as possible. This will be done by lifting the peritoneum with the left hand and blunt dissection will be done with the back of the scissors on the right hand. It should be noted that the inferior mesenteric artery (IMA) can be divided with impunity without any sequelae in this young group of patients if this will facilitate paraaortic dissection. Ligation of the IMA is usually done in post-chemotherapy cases in order to perform a thorough paraaortic dissection; it greatly facilitates the mobilization of the peritoneum and retraction of the bowel and mesentery [15]. The free edge of the peritoneum is then sutured to the anterior abdominal wall at multiple locations using 0 polyglactin suture on a curved needle (Fig. 23.3). This will help keep the bowel retracted in the upper abdomen and prevent its falling into the surgical field during later dissection, as shown in (Fig. 23.4). Care should be taken to avoid injury to the bowel and the epigastric vessels when these sutures are placed. A small abdominal lap sponge ("baby lap" – "e-tape") should be inserted and used to pack the uppermost part of the retroperitoneum where the duodenum is commonly encountered to avoid injury to the duodenum during retraction. This is very important since there will be anterior retraction on the posterior aspect of the duodenum and it will prevent serosal injury. The duodenum is very susceptible to injury from minimal traction and only sharp dissection should be used when dissecting around it.

Although not a common complication in RARPLND, bowel injuries can still occur and is a devastating complication. One should be careful with electrocautery application near the peritoneum and off-field movements as energy may be transmitted and result in delayed bowel injury. In long cases, the bowel frequently slides back into the field in the left lower quadrant and surgeon should ensure that the bowel is adequately retracted whenever this happen again. The bowel retraction/suspension stitches should help prevent these complications.

Vascular Dissection

Meticulous examination of preoperative cross-sectional imaging is important to ensure absence of congenital anomalies of the blood vessels or urinary system such as accessory renal vessels or duplicated urinary systems. Most commonly encountered vascular anomalies include lower pole renal accessary vessels. The location and size of the retroperitoneal lymph nodes/masses should be taken in consideration to plan dissection.

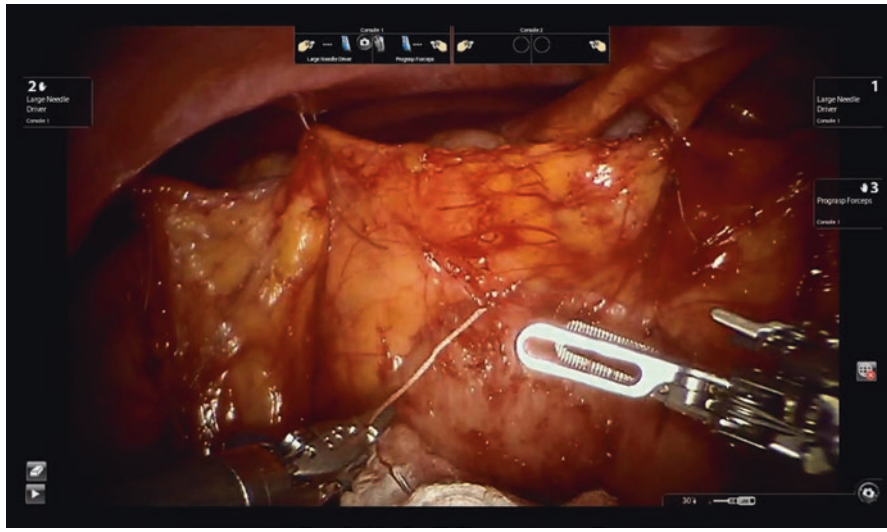

Fig. 23.4 Retroperitoneal retraction using multiple suspension stitches

It should be realized that intraoperative vascular injuries (especially venous) injuries are not uncommonly encountered in post-chemotherapy RARPLND and the surgeon should be competent in achieving vascular control robotically. Moreover, it is of great benefit to have an experienced laparoscopic surgeon to assist at the bedside to help temporize and control any bleeders in case of conversion to open. Most common bleeders are small veins that can be almost always controlled. In our experience, the most commonly encountered bleeders are lumbar veins and a small vein that commonly arises from the anterior surface of the IVC just above its bifurcation. During all the steps of vascular dissection the principles of vascular proximal and distal control with a vessel loop should be considered as early as possible to promptly control bleeding. Once the IVC is circumferentially dissected, a vessel loop can be passed around it twice and a Hem-o-lock® is applied at the free end the loop. This will fix the loop in place. If bleeding is encountered in that vessel, the loop can be used to control the vessel. This is most commonly performed on the IVC and allows for retraction of the IVC and exposure of the posterior structures (Fig. 23.5).

As mentioned earlier, there is often a small vein(s) that comes off the anterior surface of the IVC just superior to the bifurcation and feeds into the associated lymph node packet. It can be controlled with a vessel sealer or suture ligated with a 5-0 polypropylene on a 3/8c 13 mm vascular needle. This needle and suture is very delicate but is very useful to handle small vessels and prevent bleeding from the needle holes.

Inferior Vena Cava Mobilization

One of the key steps to ensure completion of a good LN dissection is complete mobilization of IVC. This will give access to lymphatic tissue behind it, which can harbor cancer and give access to the sympathetic trunk and postganglionic fibers that need to be spared in a nerve-sparing procedure. Anterior retraction of the IVC should be done with care as this may result in avulsion of a lumbar vessel. Once proximal and distal control is obtained, as illustrated previously, mobilization should be carefully performed and all lumbar veins should be identified, controlled, and divided. While lumbar veins can be controlled in a variety of ways including clips, we feel strongly that the best way to control the lumbar veins is with free silk ties as one would do in open surgery or with the robotic vessel sealer if size appropriate. This avoids inadvertent dislodging

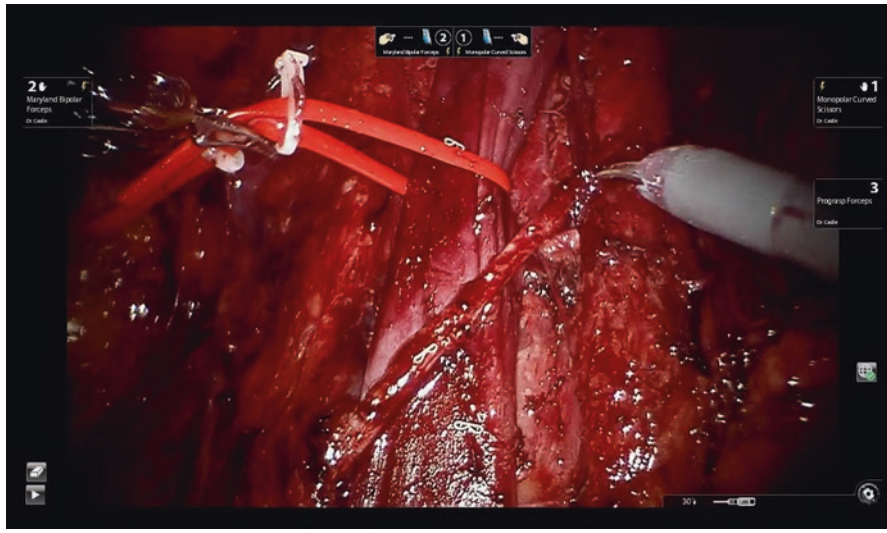

Fig. 23.5 IVC retraction using vessel loop. Please note the right gonadal artery crossing over the IVC

of clips or delayed bleeding from a sealed vein. Furthermore, controlling the lumbar veins facilitates identification of postganglionic sympathetic nerve fibers (Fig. 23.6a, b). When performing a nerve-sparing procedure, preventing sympathetic nerve injury is achieved by identifying distal postganglionic fibers in the interaortocaval below the IMA. By identifying this area the surgeon can appreciate the course of the fibers and avoid inadvertent division during dissection of the lymphatic tissue.

Interaortocaval Lymph Node Dissection

The dissection during this step starts at the bifurcation of the aorta for a full template, or the IMA for a modified template. The surgeon should be vigilant to spare any nerve structure encountered during this step and avoid use of excessive diathermy if a nerve sparing procedure is planned. During this step of the procedure one should be mindful of the right gonadal artery when working cephalad in the interaortocaval region where this artery crosses the interaortocaval field from its origin from the aorta toward the right internal ring (Fig. 23.5). The dissection then continues superiorly to the level of the right renal artery. The surgeon should be mindful of the right renal arterial blood supply when dissecting cephalad in the interaortocaval region. In some cases, identifying its origin on the medial aspect of the aorta is very helpful to avoid injury.

It is important to use locking clips while cutting lymphatic tissue in the upper most part of this filed to prevent chylous ascites. The clips in this area should be applied by the robotic console surgeon using the robotic clip applier. Meticulous and accurate placement is critical to avoid injury to the right renal artery as well as the surrounding nerve tissue while securely controlling the lymphatic ducts (Fig. 23.7a, b).

Paraaortic Lymph Node Dissection

Using the left ureter as the lateral border, the dissection is carried superiorly and medially around the aorta to free up any remaining retro-aortic tissue. The gonadal vessels are identified, traced to their origins at the aorta, IVC and left renal vein, and ligated when appropriate. The superior aspect of this dissection is the left renal hilum. It is important to remember that it has been reported that adequate dissection posterior to left renal artery and left lumbar vein has been felt to be inadequate in laparoscopic and open series.

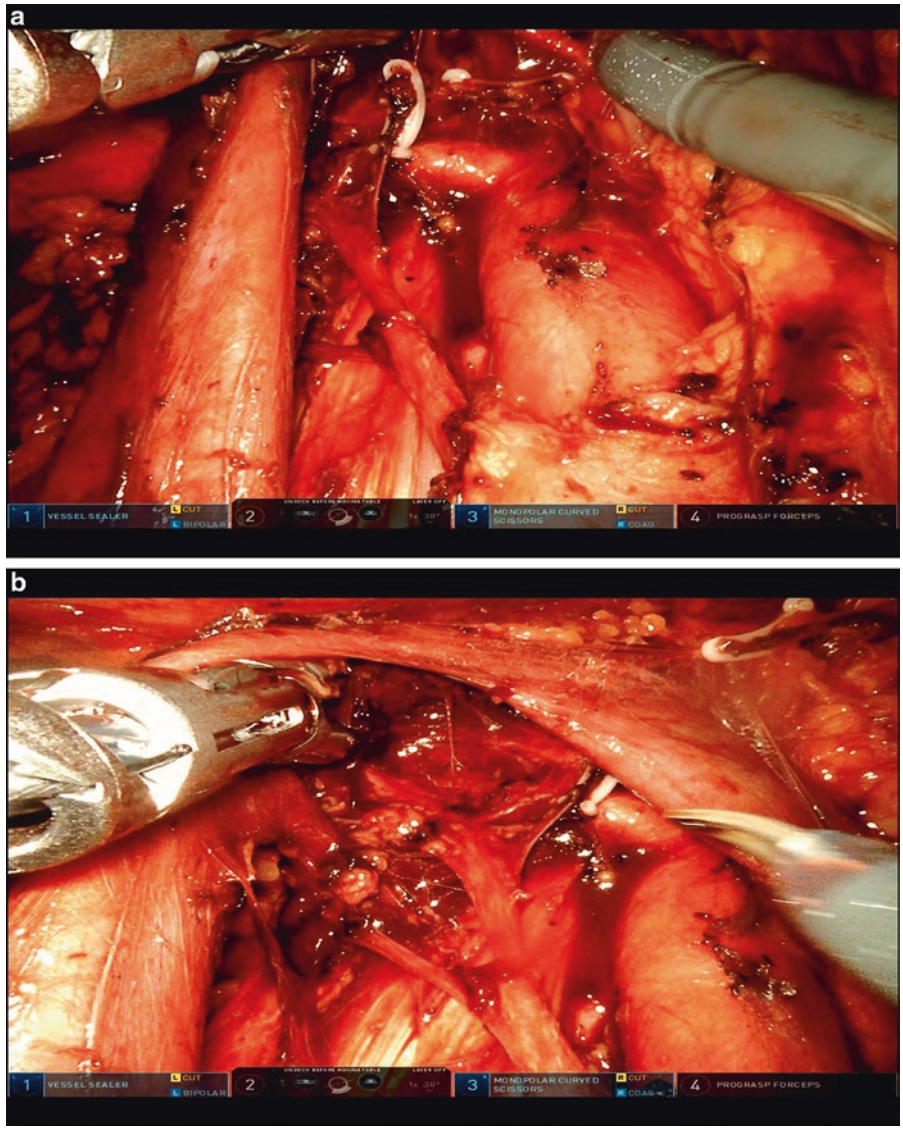

Fig. 23.6 (**a**, **b**) Exposed sympathetic nerve plexus after complete mobilization of the IVC

Therefore, meticulous dissection by ligating and dividing the left lumbar vein and removing all lymphatic tissue here is critical. Locking clips may also be used superiorly to seal all lymphatics and any large chylous reservoirs.

Management of Vascular Injuries

Vascular injuries are always a potential complication even if all of the above-mentioned measures were made. When they are venous injuries, often they can be repaired successfully without conversion to open [16]. The following steps can be undertaken to help control bleeding when a venous vascular injury is encountered:

- The pneumoperitoneal pressure can be increased to 20 mmHg, which will decrease the venous bleeding and enable the surgeon to visualize and repair the injury.

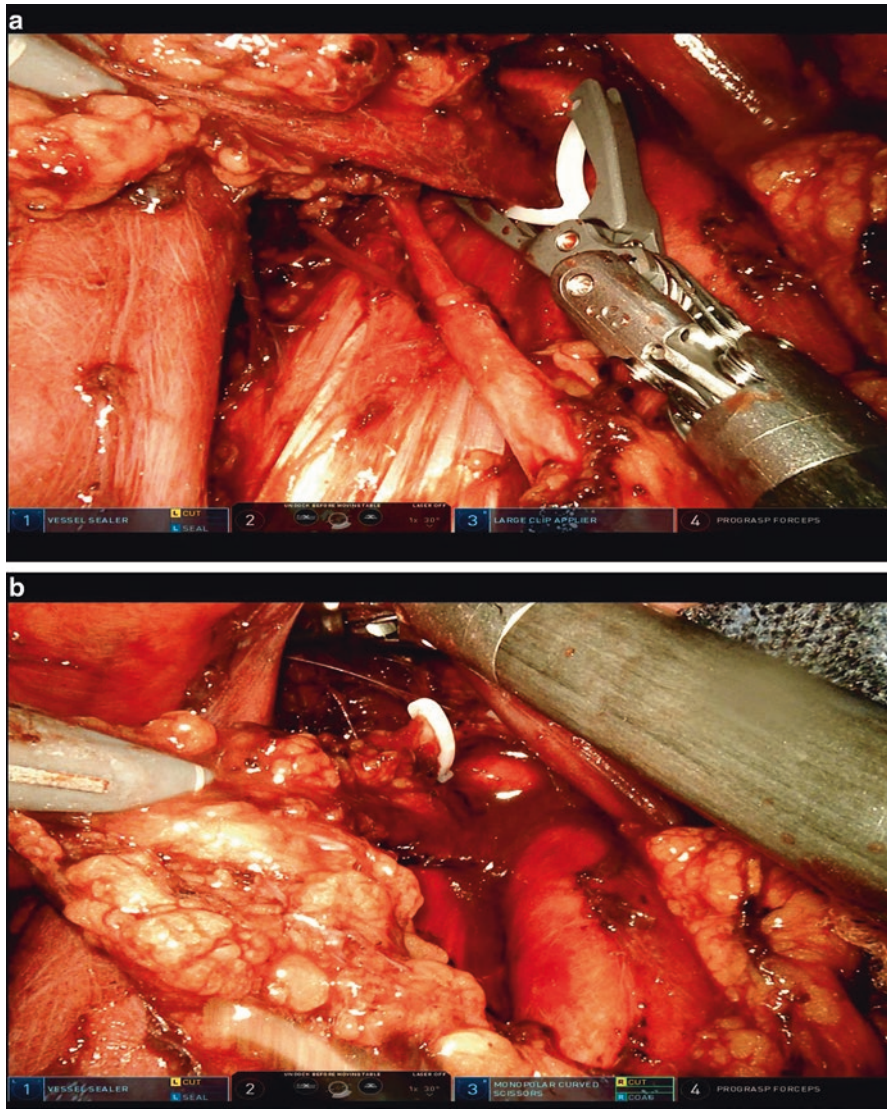

Fig. 23.7 Application of a clip using robotic clip applier to decrease chances of major lymphatic leak. (**a**) Before the application. (**b**) After the application

- If a proximal and distal control was obtained, tightening the vessels loop can significantly decrease the amount of blood loss.
- The insertion of a small abdominal lap can help apply pressure with the third arm to minimize blood loss.
- The assistant may play an important role in these situations. In order to avoid collapse of abdominal wall and complete loss of pneumoperitoneum, intermittent rather than continuous suction should be used.
- Vascular repair can be performed using 6 in. of 5-0 polypropylene sutures as indicated. This should be done in a continuous fashion and placed carefully to avoid tears in the wall of the vein during the repair.
- It is important to examine the injury after repair with low pneumoperitoneal pressures.

Ureteral and Collecting System Injuries

The ureter should be handled with care, and skeletonizing the ureter should be avoided as this can result in ischemic damage. If an intraoperative injury is identified, it should be primarily repaired and the ureter should be stented. However, at times these injuries have delayed presentation secondary to ischemia and delayed hydronephrosis. When occurs, it should be managed as one would with any ureteral injury based on location and anatomy.

Postoperative Autonomic Dysreflexia

Postoperatively, autonomic dysreflexia is not uncommonly encountered especially in non-nerve-sparing RARPLNDs and this may result in confusion with postoperative tachycardia secondary to hypovolemia [17]. This condition is usually isolated with no other signs of volume deficit. It is often short-lived and self-limited, and supportive care is all that is needed. Of note, assisted ambulation is important when this complication occurs to avoid falls as patients may feel dizzy with autonomic dysreflexia. A rate control medications can be administered in severe cases.

Chylous Ascites

Chylous ascites is a potential complication after retroperitoneal lymph node dissection [9, 18, 19]. The left ascending lymphatic trunk drains into the cisterna chyli that lies on the posterior aspect of the aorta at the level of L1-L2 vertebral bodies. These will in turn drain into the thoracic duct. Injury to any one of these major lymphatic structures can result in chylous leakage and ascites postoperatively. The leaking fluid is characteristically milky in appearance, has a low protein and high cholesterol, triglyceride, and LDH content compared to the serum. In one of the largest series that described this complication, Evans et al. retrospectively examined this complication in 329 post-chemotherapy patients with an overall incidence of 7% [20]. The risk of Chylous ascites was higher in patients who received higher amounts of preoperative chemotherapy and patient who received perioperative blood transfusion. All patients presented with abdominal fullness and distension. The majority of the patients (77%) had a successful resolution with conservative measures only. In the remaining patients, peritoneal–venous shunting had had disappointing results and required a long time for resolution.

One of the considerations that may potentially help intraoperative identification of lymphatic vessels is the administration of fatty meals that are rich in long chain triglycerides in the days preceding the surgery in order to help identification and clamping of the lymphatic channels at the time of dissection. Intraoperatively, when one of the lymphatic channels is opened the chyle can be seen as milky-whitish fluid.

If chylous ascites develops postoperatively the management algorithm usually starts with conservative dietary measures that include high protein, low fat with medium chain triglycerides diet [21]. Medium chain triglycerides get absorbed into the enterohepatic circulation, unlike like the short and long chain triglycerides that are transported through the lymphatic channels. If these measures fail, octreotide or somatostatin can be used as a second line of treatment, which is usually effective [22]. Surgical intervention is reserved as a last treatment option and is usually not needed.

Current Status

The currently reported series are small in size but have reported some of the complications observed in RARPLND [1–4]. These series were heterogeneous with regard to the patient population (primary vs. post-chemotherapy), template of dissection (full vs. modified) and surgical approach (lateral approach vs. modified lithotomy position). However, they all reported the safety and feasibility of this technique with excellent recovery. One of the main criticisms of laparoscopic RPLND was that its initial case series were performed with a sampling and not a

Table 23.2 List of specific complications in a large multi-institutional RPLND series

Type of complication	Clavien grade	Occurrence (*n*)	Incidence %
Edema	1	4	3.9
Wound infection (requiring antibiotics)	2	1	0.9
Wound abscess (with bed side drainage)	1	1	0.9
Back pain	1	1	0.9
Diarrhea	1	1	0.9
Paresthesia	1	5	4.8
Postoperative fever	1	5	4.8
Incisional hernia requiring repair	3b	1	0.9
Lymphocele	1	1	0.9
Blood transfusion	2	1	0.9
Pancreatitis	2	1	0.9
Acute renal insufficiency	2	1	0.9
Incisional hematoma	1	1	0.9
Nausea and vomiting	1	1	0.9
Ileus	1	1	0.9
UPJ obstruction requiring pyeloplasty	3b	1	0.9
Ascites	1	2	1.8
Autonomic dysreflexia	1	1	0.9
Bilateral hydronephrosis requiring stenting	3b	1	0.9
Total		31	

curative intent and many patients required adjuvant chemotherapy after the procedure. However, this was not the case in RPLND where the incidence of post RPLND chemotherapy was low.

We have recently presented the results of a large multi-institutional case series from four tertiary centers [23]. In this series, there were 103 patients who underwent RA-RPLND. The mean patients' age was 29.6 years (SD ± 9.7) and mean BMI was 26.4 Kg/m^2 (SD ± 5.1). Bilateral full template dissection was performed in 65 (63.1%) patients compared to 36 patients (35%) who had modified templates of dissection and nerve sparing was attempted in 68 (66%) patients. There were 70 (68%) patients who underwent primary RA-RPLND compared to 33 (32%) patients who received previous chemotherapy. There were six conversions (5.8%) to open RPLND. Postoperatively, there were 28 total complications (Grade I = 22, II = 5, IIIB = 1). Detailed description of these complications can be seen in Table 23.2. From oncological point of view, mean lymph node (LN) yield was 24.1 LNs (SD ± 10.8) with positive LN identified in 35 patients (33.9%). Among the primary RARPLND, adjuvant chemotherapy was given to 21.4% (3/14) of pIIA, 50% (3/6) of pIIB and 50% of pIIC patients. There were five lung recurrences (4.8%) identified at a mean follow-up of 26.9 months (±22.4). Post-chemotherapy patients had a comparable complication rates to those found in primary RPLND patients (Tables 23.3 and 23.4).

Table 23.4 Complications in post-chemotherapy RPLND in a large multi-institutional series

Grade	Occurrence (*n*)	Incidence %
Grade 1	6	18%
Grade 2	2	6%
Grade 3B	1	3%
Total	9	27%

Table 23.3 Complications after Primary RPLND in a large multi-institutional series

Grade	Occurrence (*n*)	Incidence %
Grade 1	24	23.3%
Grade 2	4	3.8%
Grade 3B	3	2.9%
Total	31	30%

Summary

Robot-assisted retroperitoneal lymphadenectomy is a complex procedure and the potential for complications needs to be considered. In general, the complications that would be observed with an open RPLND are the same in the robotic approach due to the nature of the procedure. The surgeon must be aware of the risks inherent to minimally invasive surgery including access complications, prolonged extreme positioning, and injury to surrounding structures. Nevertheless, the benefits of a short hospital stay, less open bowel manipulation, and overall minimally invasive approach will undoubtedly keep this procedure in the armamentarium of the surgical Urological Oncologist.

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Part IV

Complications in Specific Robotic Procedures of the Lower Urinary Tract

Robotic-Assisted Simple Prostatectomy Complications

24

René J. Sotelo, Raed A. Azhar, and Oscar D. Martín

General Considerations

The current surgical management options for benign prostatic hyperplasia (BPH) include endoscopic techniques such as monopolar or bipolar transurethral resection of the prostate, laser technology, open surgery and minimally invasive approaches with laparoscopic and robotic surgery [1]. Robotic-assisted simple prostatectomy (RASP) is an evolving surgical technique [1] and is particularly useful for large prostates that are not amenable to endoscopic procedures. In the last decade, the robotic approach has gained popularity because it has been found to be safe and effective with the ability to resect more tissue with less blood loss, requiring fewer days with a bladder catheter [2] and shorter hospital stays [3], while achieving the same results as conventional techniques. However, the robotic approach is not without complications. Therefore, it is important to be aware of possible complications, their associated risk factors, and understand how to avoid and manage each of them.

Techniques Originally, laparoscopic technique was described by Mirandolino in 2002 and then, the robotic technique by Sotelo in 2008. In addition to the advantages already associated with minimally invasive surgery such as less pain, shorter hospital stays, and shorter recovery time, the robotic technique also offers less bleeding but at the expense of a higher learning curve and higher cost when compared with endoscopic and open techniques [2].The robotic approach can be extraperitoneal or transperitoneal, with the incision in the prostate capsule or bladder or vesicoprostatic junction. Modifications to the conventional approach include a posterior cystotomy to gain transvesical access to the prostate as described by Aron and colleagues [4]. Modifications have also been made regarding the urethrovesical anastomosis, as described by Coelho et al. [3], where instead of performing the classical "trigonization" of the bladder neck and closure of the prostatic capsule following the resection of the adenoma, they propose three surgical steps: plication of the posterior prostatic

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capsule, a modified van Velthoven continuous vesicourethral anastomosis and, finally, suture of the anterior prostatic capsule to the anterior bladder wall. Castillo et al. [4] described a double-needle barbed suture used to create a posterior urethrovesical anastomosis using the van Velthoven technique. Being careful not to include the ureteral orifices, the posterior bladder neck and urethra were approximated between 3 and 9 o'clock positions to create a halfway urethrovesical anastomosis. And recently, intrafascial simple technique was described as shown in Fig. 24.1.

Intrafascial radical prostatectomy, initially described as a surgical technique for the treatment of low-risk prostate cancer (PC), optimizes the preservation of the neurovascular bundle and the endopelvic fascia to improve the results of postoperative continence and sexual function by being performed in the level between the prostatic capsule and the prostatic fascia [5].

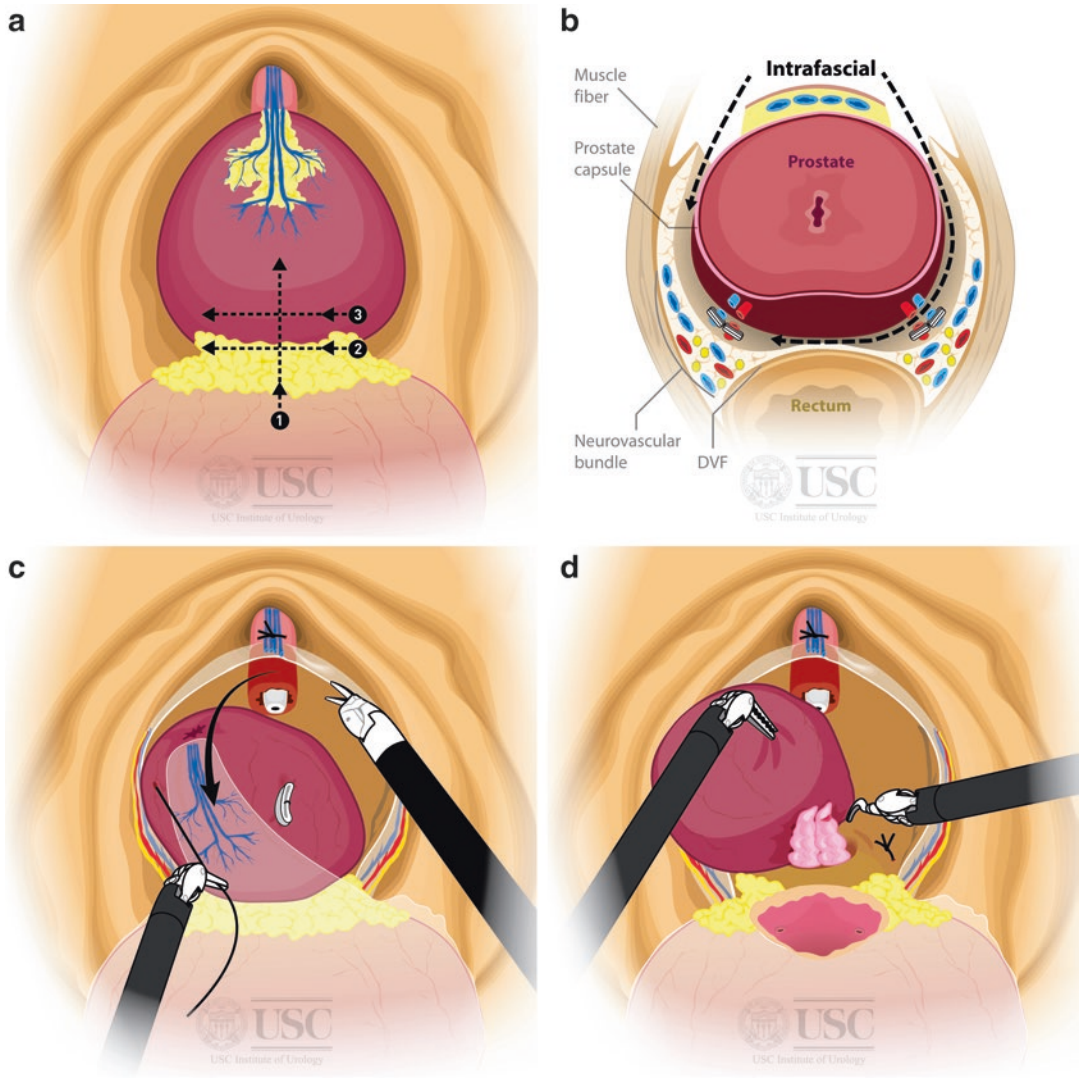

Fig. 24.1 (**a**) Incision of the prostatic capsule is "vesicotranscapsular" vertical [1], horizontal in the vesicoprostatic junction [2], or horizontally as in the Milan approach or prostatic capsule [3]. (**b**–**d**) Intrafascial single robotic prostatectomy (IF-RSP). (**b**) Front view. (**c**) Upper view. Traction of the prostate with maneuver of the "fisherman." (**d**) Upper view. Seminal vesicles-sparing

Subsequently, using this concept with modifications, including the preservation of the seminal vesicles, the Denonvillier fascia, and urethra to the veru montanum, the Robot-Assisted Intrafascial Simple Prostatectomy (IF-RSP) is introduced for the management of obstructive lower urinary tract disease by BPH with adequate results [6]. Being a controversial subject, for applying concepts of radical surgery to benign surgery, robotic technique improved the knowledge of anatomy and, together with the surgical precision that this platform offers and an adequate learning curve, it was possible to demonstrate in a study from Martin et al. [7], a better extraction percentage of adenoma, improvement in the maximum flow (Qmax), reduction of the International Prostate Symptom Score (I-PSS), and elimination of the need for bladder irrigation, with similar bleeding and transfusion rates compared to laparoscopic simple prostatectomy (LSP) and the robotic-assisted laparoscopic simple prostatectomy (RLSP), with results of continence and sexual function at 12 months, being thus equal to other laparoscopic and robotic techniques, with a greater additional advantage of increased detection of PC and high-grade intraepithelial neoplasia (HG-PIN) up to 26% and 12%, respectively, vs. 5.06–6.09% PC and 0% HG-PIN [7].

Complications

The number of robotic procedures has increased in the last 4 years in the United States and Europe. Procedures performed worldwide have nearly tripled from 80,000 to 205,000 since 2007. Between 2007 and 2009, the number of da Vinci systems, the leading robotic technology, installed in US hospitals grew by approximately 75%, from almost 800 to around 1400, and the number installed in other countries doubled, from 200 to nearly 400, according to Intuitive Surgical, da Vinci's manufacturer [8]. This increased use of the robotics platform has also been seen in benign prostatic disease. This requires that urologists better understand the prevention, diagnosis, and management of complications.

Overall complications during the simple prostatectomy are around 10.6–33% [9–12]. Complications are characterized by the time at which they occur in relation to the surgery and may be categorized as intraoperative, early postoperative, or late postoperative (see Table 24.1).

Intraoperative and Early Postoperative Complications

Intraoperative and early postoperative complications are the most common and are those that occur within the first month after the surgery. They include vascular complications, infections, urinary or intestinal injury, and cardiovascular or thromboembolic events (see Table 24.1).

Vascular Injury

Vascular injury is the most frequently occurring intraoperative complication. Both large and small vessels may be affected, resulting in blood loss during and after surgery and the need for transfusion or additional surgical intervention. Reports indicate that transfusion is required for 0–33% of cases [12, 19] while the need for immediate reoperation for bleeding complications is rare, ranging from 1% to 3.7% of cases [24].

Prevention The points of greatest risk of bleeding are the dorsal vein plexus of the prostatic segment at the time of capsulotomy and the prostatic lateral pedicles and micro-vasculature between adenoma and the prostate capsule at the moment of adenoma enucleation. The best way to avoid bleeding throughout the surgical procedure, especially at these three points, is to perform a thorough dissection with constant sealed or vessel closure (Fig. 24.2).

The best way to avoid vascular lesions of large or medium vessels is to have an adequate knowledge of anatomy, perform careful dissection of the structures near the vessels by delicate movements, and always under direct vision.

At the end of the enucleation, it is essential to review the surgical area with low-pressure pneumoperitoneum (<5 mmHg), to ensure there is no bleeding and to remove any clots in the area of the lateral pedicles (4–5 o'clock and 7–8 o'clock points).

Table 24.1 Review of the literature of the robotic-assisted simple Prostatectomy (RSP) and simple intrafascial prostatectomy series results (IF-RSP)

Author/year	N	Ultrasound prostate volume (Average ml)	Pathology weight (Average gr)	Blood loss (Average mL)	Hospital stay (Average days)	Intraoperative complication (%)	Postoperative complication (Clavien)
Sotelo 2008 [13]	7	77.66	50.48	298	1.4	0%	Grade 2: 14%
Yuh 2008 [12]	3	323	301	558	1.3	0%	Grade 3: 33.3%
John 2009 [14]	13	100	82	500	6	0%	Grade 3: 7.7%
Uffort 2010 [15]	15	70.85	46.4	139	2.5	0%	6.7%
Coelho 2011 [3]	6	157	145	208	1	0%	0%
Sutherland 2011 [11]	9	137	112	206	1.3	0%	0%
Matei 2012 [16]	35	107	87	121	3.2	NR	NR
Vora 2012 [17]	13	163	127	219	2.7	0%	Grade 2: 7.7%
Clavijo 2013 [6]	10	81	81	375	1	0%	Grade 2: 20%
Nething 2014 [18]	5	132.89	89.8	440	1.8	0%	0%
Banapour 2014 [19]	16	94.2	93	197	1	0%	12.5%
Leslie 2014 [20]	25	150	88	143	4	0%	Grade 2: 8% Grade 3: 8% Grade 3b: 4%
Elsamra 2014 [21]	15	157	110	290	2.4	6.6%	Grade 1: 6.6% Grade 2: 6.6%
Hoy 2015 [22]	4	239	123.6	218	2.25	0%	0%
Autorino 2015 [9]	487	75	110	200	2	3.2%	Grade 1: 6.5% Grade 2: 8% Grade 3a: 2% Grade 4: 0.2% Grade 5: 0.2%
Pokorny 2015 [23]	67	129	84	200	4	0%	Grade 1: 15% Grade 2: 6% Grade 3a: 4.5% Grade 3b: 4.5%
Martin 2016 [7]	79 / 75	80.3/70.5	68.5/74.5	390/535	NR	4.9 / 3.8	Grade 2: 10.6%/6.3% Grade 3a: 2.6% Grade 3b: 1.3%

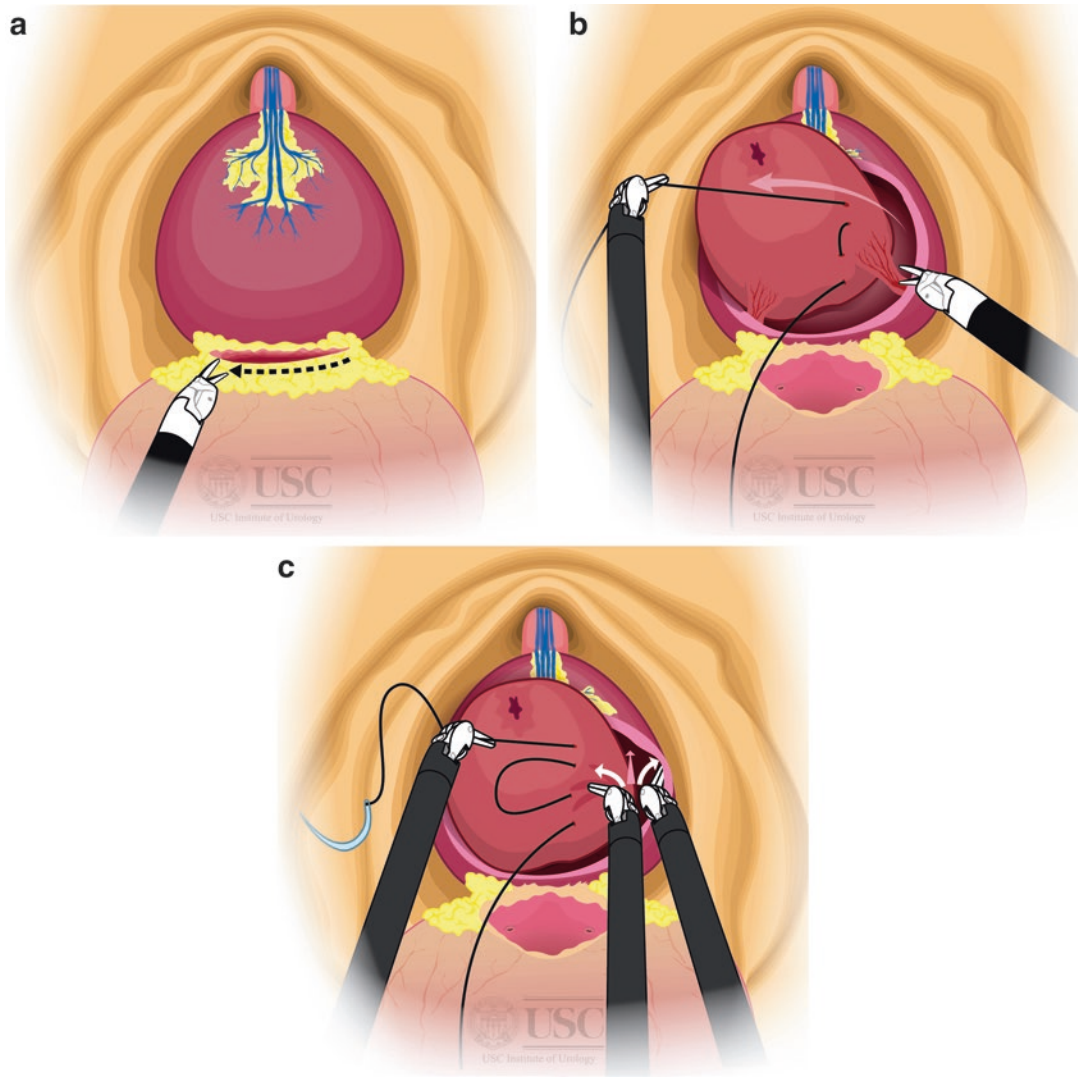

Fig. 24.2 (**a**) Vesicoprostatic junction lateral incision lateral (capsulotomy), (**b**) prostatic lateral plexus dissection and ligation. (**c**) Adenoma dissection

Although vascular injury in robotic simple prostatectomy has not been reported, it is important to have knowledge about it because it could occur at any time. Vascular injury in minimally invasive surgery has been reported to occur in 0.03–2.7% of cases [25]. It mainly occurs when the peritoneal cavity is entered [26, 27] or during the times a trocar or Veress needle or any of the robot arms is introduced [28, 29].

Risk Factors For the vascular lesions of large, medium, or small vessels, no clear risk factors have been described. Risk factors for intra- and postsurgical bleeding include obesity, previous transrectal biopsy, and previous endoscopic prostate surgery. These conditions promote an increase of the vascular network, adherence of periprostatic tissues and fibrosis, and thus bleeding and possible transfusion.

Diagnosis and Identification The majority of vascular injury lesions are diagnosed immediately after they occur; however, venous bleeding or that from very small caliber arteries is sometimes not detected because of the pneumoperitoneal pressure. Diagnosis is generally made within the first 48 h after surgery by indirect signs such as a decline in the hemoglobin and the hematocrit or blood in the abdominal drainage or urine. In some cases, CT scan with or without contrast is used to evaluate the location and amount of the bleeding.

Persistent hematuria beyond 1 week generally requires cystoscopic examination. The procedure is diagnostic and it can help in determining the need for other procedures. It also presents an opportunity for initial removal of intravesical clots.

Treatment and Control The procedures that may be used for vascular control of the prostatic capsule bleeding are:

Endoscopic. It is the first approach that you can try to control bleeding. Direct cauterization on areas of bleeding in the prostate capsule may provide effective control.

Control of the lateral plexuses. The prostatic lateral venous plexuses are generally found at the sides in positions 4–5 and 7–8 o'clock. Bleeding can be externally controlled with a lateral stitch to the prostate prior to the dissection of the adenoma. Within the prostatic capsule, bleeding may be controlled by applying mono- or bipolar energy directly over the plexus during dissection of the adenoma or by passing stitches over the plexus within the capsule, once the adenoma has been enucleated (see Figs. 24.2b and 24.3).

Ligate the dorsal venous complex. Another important vascular segment of the prostate is the dorsal venous plexus, which can be ligated distally to the prostate or proximally in a more selective way in the blood vessels with active bleeding (Fig. 24.3a).

Ligation/clamping of the hypogastric arteries. In case of persistent bleeding, one option is to ligate the hypogastric vessels. This extreme measure has a greater chance of controlling the bleeding; however, it poses the risk of tissue hypoxia and secondary lesion from necrosis. Sergi and colleagues [30] proposed occlusion of the hypogastric arteries bilaterally for 12 min during enucleation of the adenoma. The transient occlusion of the internal iliac arteries is a proven maneuver to reduce bleeding during pelvic surgery. Another alternative to control bleeding is hypogastric artery embolization by interventional radiology.

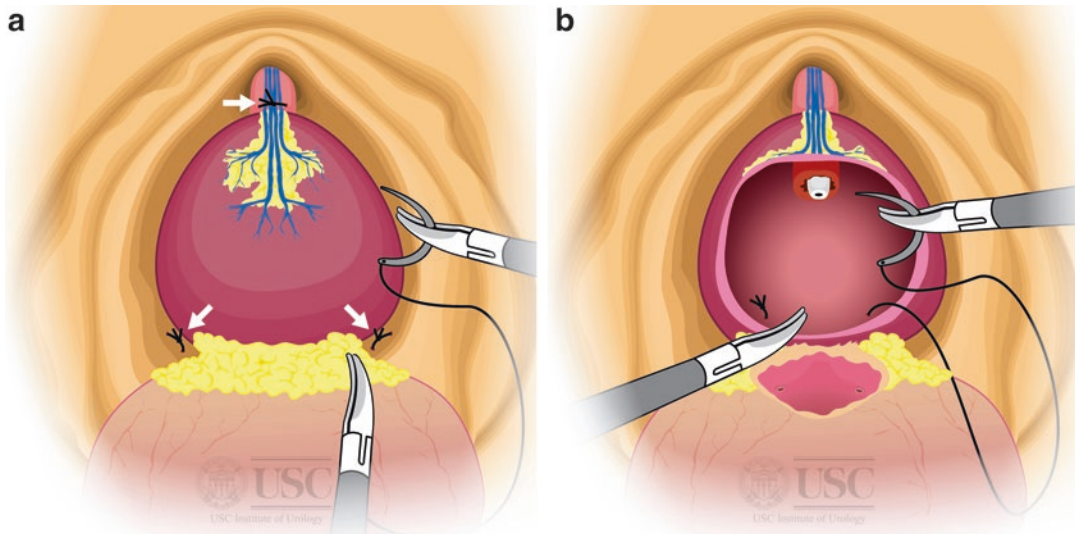

Fig. 24.3 Control of bleeding (**a**), external stitches, lateral to the prostatic capsule and the dorsal venous plexus (**b**) placement of stitches within the capsule

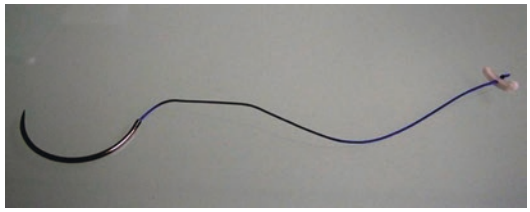

Fig. 24.4 Rescue structure, nonabsorbable stitch with Hem-o-lok at the distal end

When a large vessel injury occurs, direct compression has to be done to immediately control the bleeding. Additionally, the pneumoperitoneum should immediately be raised to 20 mmHg, and it must be determined if the injury should be repaired through robot-assisted, laparoscopic, or open surgery.

If it is decided to continue with minimally invasive surgery after the immediate bleeding is controlled with direct compression, then further dissection must be made distal and proximal to the vessel injury in order to finally proceed with the injury site closure with vascular prolene in a continuous running fashion (rescue suture, Fig. 24.4). Always bear in mind when performing the closure of the vessel that the use of suction on the injury area must be avoided since it can absorb the pneumoperitoneum and encourage bleeding. Perform continuous irrigation over the lesion to allow better visualization as well as suction within the hematic content (blood pool) so as to not absorb the pneumoperitoneum.

Infection

Along with vascular injury, infection is another relatively common complication of RASP. Common sites of infection include the urinary tract, epididymitis, and skin infections, especially at the surgical incision. Infection rates have been described in 4.1–10.6% of cases [7–9].

Prevention Adequate antiseptic use and proper aseptic technique during the surgery and in the period for recovery including the use of surgical masks and adequate hand washing is the best way to prevent infections.

All patients should have negative urine cultures prior to surgery, especially those with indwelling urinary catheter or intermittent catheterization.

Risk Factors In addition to obesity, which increases nosocomial infections and skin infections, the use of a permanent catheter prior to the surgical procedure is a risk factor for infection of urinary tracts by multiresistant pathogens.

A bad antiseptic or aseptic technique is also an important factor for the development of urinary tract infections.

Diagnosis and Identification Monitoring the blood count, acute phase reactants, such as the PCR (Polymerase Chain Reaction), the urine and/or serum cultures, and the systemic symptoms, mainly fever, or urinary symptoms help to determine the presence of an infectious process.

Treatment and Control The identification of the pathogenic organism through urine and serum cultures is fundamental. Additionally, it is important to take into account that infections that occur during hospitalization (nosocomial infections) or in patients with a permanent catheter may be due to multiresistant organisms; for this, it is recommended to start broad-spectrum antibiotics empirically until a pathogen has been identified and the specific antibiotic is adjusted.

Urinary Urinary complications from most to least common include: urinary incontinence, urinary retention, perforation of the prostate capsule, and urine leakage from the surgical wound.

The main urinary complication is incontinence; it may be of stress, urgency, or mixed. The "de novo" incontinence occurs in 2.3% [10] and the "de novo" urgency incontinence that requires anticholinergics, is lower than 1% [9]. It is important to consider that the majority of the patients may have a transitory incontinence for a few days, and it tends to be mistaken erroneously with real incontinence.

Another complication is urinary retention (need for re-catheterization after removal of the catheter). It is found in 2.7% when analyzing the total number of cases until 2015 of robotic and

laparoscopic surgery [10]. A frequent scenario is to find secondary urinary retention due to an intravesical clot.

Less frequent complications include the perforation of the prostatic capsule resulting in bleeding and further persistent leaks of urine and urine leaks resulting from inadequate closing of the cystotomy and capsulotomy. Conditions that result in increased vesical pressure and wall distension such as increased post-micturition residuals, anatomic obstruction (e.g., urethral stenosis) or dysfunction of the detrusor (hypo-contractile or noncontractile detrusor), contribute to secondary urine leakage.

Prevention It is important to perform a complete clinical history to identify additional pathologies besides obstruction of the outflow tract secondary to the benign prostatic growth, for example, hyperactive detrusor, hypo-contractile or noncontractile detrusor, and urethral stricture. Cystoscopy and/or urodynamics studies are recommended prior to surgery for this reason. The information obtained may result in a better prognosis and more satisfactory outcome for the patient.

Injury to the capsule may be avoided by performing a careful dissection between the adenoma and the capsule; it is recommended to perform it at an angle of 45° or less, taking into account that the adenoma is observed as a pearl color, different than that of the capsule (Fig. 24.5).

Urine leakage can be avoided by ensuring the proper closure of the capsule or the bladder in one or two layers, with continuous suture, leaving from 0.5 to 1 cm between the surgical wound and the surgical stitch. Also insufflating the bladder with saline solution at the end of suturing will aid the surgeon in identifying any urine leaks.

Urinary retention, secondary to intravesical blood clots, can easily be avoided with a proper closure and control of the vascular structures during surgery. Furthermore, the continue bladder irrigation and increase fluid intake from 2 to 3 liters orally day by the patient to ensure adequate urine output as long as no contraindication exist (e.g., chronic kidney disease and congestive heart failure).

Risk Factors Risk factors for urinary complications from RASP have not been described. Factors that may increase the risks are: previous endoscopic prostatic surgery or previous prostatic infectious processes. These factors could favor lesion of the sphincter, lesion of the pros-

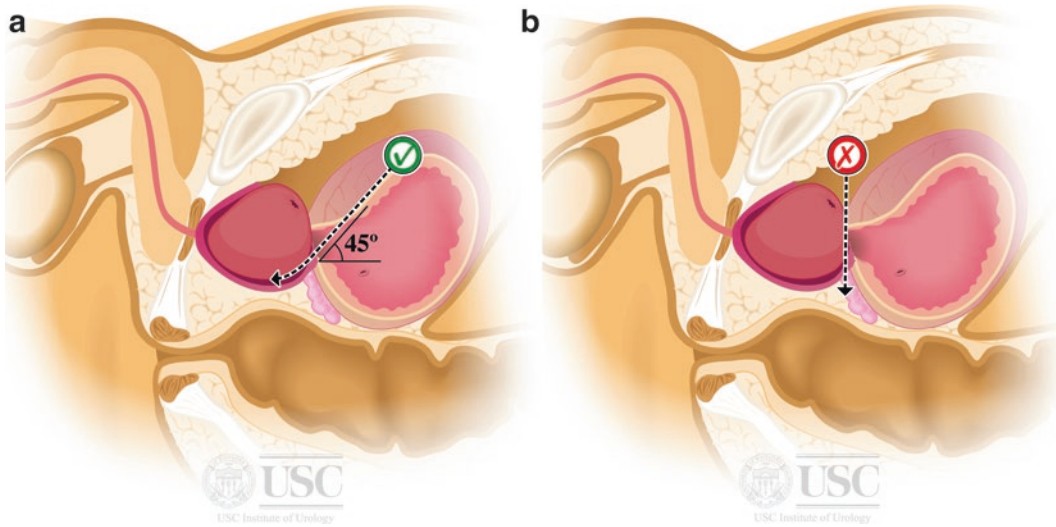

Fig. 24.5 (**a**) Correct dissection plane <45°. (**b**) Incorrect dissection plane to more than 45°

tatic capsule, and bleeding and secondary clot formation that may lead to the opening of the vesical suture.

Malnutrition and old age alter the quality of the tissue and its ability to heal, which may result in urine leakage.

Diagnosis and Identification Incontinence and bladder contractility disorders are diagnosed by the presence of symptoms and by urodynamic studies. An opening in the capsule is generally observed immediately intraoperatively level. Capsular openings not detected during surgery or urine leak through the capsule suture or vesical suture may be diagnosed through imaging such as the cystourethrogram or a cystography by tomography or by cystoscopy.

Treatment and Control In the case of urgency incontinence, it can be treated with the range of anticholinergic drugs. Stress incontinence is treated according to the whether there is damage to the sphincter or not. If there is no sphincter injury, then pelvic floor therapy may be performed with electrostimulation. In the case of sphincter injury, placement of an artificial sphincter is an option.

If damage of the contractile capacity of the detrusor has occurred, the first step is to evaluate the residual urine volume (PVR) and determine the risk of injury of the upper tract by elevated intravesical pressures and infection of the urinary tract. This will determine the need for intermittent catheterization, permanent catheter, cystotomy, or other therapies (like sacral neurostimulation). The use of drugs that improve the bladder contractile ability, like *Betanecol*, has not shown a clear benefit.

The opening of the prostatic capsule is treated through the direct suture of the lesion with continuous stitches preferably with absorbable watertight suture closure. A urine leak may be treated at first with placement of a transurethral catheter and urinary drain bag for 1 or 2 weeks. In some cases, it is necessary to catheterize the ureters and connect them along the urethral catheter to the urinary drain bag in order minimize contact of urine with the bladder and allow its closing by second attempt. If despite these procedures, the urine leak persists, it is advisable to consider the possibility of fistula of the urinary tract and the need for surgery.

Intestinal Injuries Intestinal injury is very uncommon after RASP, occurring in less than 1% of patients [9]. Patients may experience an ileus, which requires antiemetic therapy and intestinal rest. It is important to consider that the majority of the patients undergo a transitory ileus because of the pneumoperitoneum, but this is not pathologic. The most frequent cause of intestinal injury is the insertion of a bladder trocar or Veress needle (41.8%). Thermal injury secondary to electrocautery (25,6%) is the second most common cause of intrasurgical intestinal injury. The lesions related to thermal damage to the intestine are generally not detected during the surgery [31].

Prevention The best way to prevent pathologic ileus is early mobilization of the patient and initiation of enteral feeding when intestinal sounds are present. The use of the pneumoperitoneum at low pressure and the minimal manipulation of the intestine also help prevent a pathologic ileus.

Bowel injury on gaining access to the abdominal cavity can be avoided by performing careful access without excessive force and avoiding rushing this surgical step, regardless of a Veress needle or the Hasson open technique being used. Though, there has been a lower rate of intestinal injury reported with the open technique. Another important way for avoiding an injury is accessing the abdominal cavity in the superior middle abdomen toward the hypochondrium, especially when there is a background of previous surgery or intestinal adhesions are suspected. Thermal lesions are avoided by manipulating the intestine with nontraumatic forceps and manipulating the tissues that are desired, at 1 cm of the intestinal tissue to avoid lesion by thermal conduction.

Risk Factors Some experts believe that adhesions and infectious abdominal processes prior to surgery may present a risk for an intestinal injury. Fluid and electrolytic imbalance may also be a risk factor for the development of an ileus.

Diagnosis and Identification The symptoms are the main method of diagnosis for ileus and the unnoticed intestinal lesion. The main symptoms of an ileus are subjective and include nausea, vomiting, and in some cases abdominal pain and lack of flatus or bowel movements. The symptoms of bowel injury are less specific and generally expressed through systemic symptoms such as generalized illness, and fever; they may also occur with abdominal pain.

An ultrasound can provide adequate information, it is of low cost and it avoids radiation exposure; however, it has low specificity and sensitivity in diagnosing bowel injury which is why contrast-enhanced pelvic-abdominal CT is recommended.

Treatment and Control The most effective way to treat an ileus is to suspend oral intake to provide bowel rest. Medications that may slow intestinal motility like opiates should be avoided and fluid and electrolyte balance should be maintained. Patient ambulation should be encouraged in order to promote intestinal motility. Once intestinal sounds occur, initiate oral intake slowly; first with liquids, then with soft food and then with solids.

Intestinal injury should be treated according to the type and the extent of the injury. For a single small injury in the bowel, a direct suture can be used. For multiple or extensive tissue damage, resection of the infected intestinal segment should be considered in order to perform a further end-to-end or side-to-side anastomosis.

Cardiovascular or Thromboembolic Events

Cardiovascular or thromboembolic events following a laparoscopic simple prostatectomy or robotic surgery are extremely rare, <1% of cases [9]. However, they are associated with a high mortality rate [32].

Prevention The most effective way to avoid these events is to follow the recommendations of the American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. The risk of embolic events should be assessed prior to surgery for all patients using validated scales. The most commonly used scale is the Caprini scale. Pneumatic compression stockings during surgery and early ambulation during the immediate postoperative period are recommended preventative measures. In some cases depending on the risk, it may be necessary to use of thromboprophylaxis prior, during, and after surgery.

Risk Factors Risk factors for thromboembolic events are those that favor the classic triad of formation of blood clots: blood stasis, endothelial damage, and blood hypercoagulability. This includes smoking, obesity, and hypertension, among others. Each factor can be taken into account in the calculation of the Caprini score to assess the risk and the need for preventative measures prior to, during, or after surgery.

Diagnosis and Identification The means of diagnosis varies according to which organ has been affected. The main organs affected by thromboembolism are the heart, brain, lung, or peripheral arterial system. Electrocardiogram or echocardiogram, computed tomography, computed pulmonary tomography, pulmonary angiography or D-dimer, and the use of Doppler ultrasound may all be utilized.

Treatment and Control Specific management should be done by a multidisciplinary team, including intensivists, internists, cardiologists, and urologists. The American College of Chest Physicians Evidence-Based Clinical Practice Guidelines recommends, according to specific clinical case, the use of low molecular weight or unfractionated heparin. In the specific case of a brain event it should be defined the possibility of using endovascular therapies, in the same way in case of cardiovascular event define the risk and the need for endovascular or surgical procedures.

Late Postoperative Complications

Late postoperative complications are those occurring 30 days or more after surgery. These

complications occur less frequently than those in the early postoperative period and include urethral stricture, bladder neck contracture, erectile dysfunction, and retrograde ejaculation.

Retrograde Ejaculation

Although it can occur from the first postoperative day, the patient usually notices the alteration in ejaculation later in the postoperative period when they resume sexual activity. It is one of the most common postsurgical complications: 80–90% [33]. It is due to resection or interruption of the internal sphincter mechanism leading to the inability of the bladder neck to close during ejaculation, allowing the passage of semen into the bladder to be eliminated later through the urine.

To date no study of RASP has analyzed this variable.

Prevention There is no mechanism to prevent retrograde ejaculation. However, it is important to thoroughly explain this possible complication to the patient prior to surgery and emphasize that this condition is not pathologic and that it will not affect the quality of sexual intercourse or erectile function.

Risk Factors There are no known risk factors for retrograde ejaculation.

Diagnosis and Identification Most patients resume sexual activity by 1 month after surgery. Therefore, this complication is most commonly reported in the late postoperative period.

Treatment and Control To date, there has not been a procedure developed to correct retrograde ejaculation secondary to simple prostatectomy.

Erectile Dysfunction

Erectile dysfunction is defined as the inability to achieve and maintain an erection sufficient for satisfactory sexual intercourse.

Erectile dysfunction (impotence) is the inability to get and keep an erection firm enough for satisfactory sexual intercourse. Less than 1% of patients score below 21 points on the Sexual Health Inventory for Men (SHIM) score with or without the stimuli of 5-phosphodiesterase inhibitors following RASP [9, 10]. Other factors such as age and comorbidities like diabetes mellitus, hypertension, dyslipidemia, and smoking also affect the score. It is important to clarify that the intrafascial simple technique has demonstrated that at 12 months of follow-up, there is no significant difference regarding the quality in the erection in comparison with the other laparoscopic or robotic techniques [7].

Prevention Because thermal injuries may be one of the causes of postsurgical erectile dysfunction, avoiding excessive use of single or bipolar energy close to the band paths at the time of dissection of the adenoma may minimize this risk. Another strategy that may avoid the thermal damage of the bands is the use of Sotelo's prostate dissector (prostatotomo) (see Fig. 24.6).

Risk Factors Any pathology that damages the endothelium and limits the blood supply to the sinusoids of the penis can contribute to erectile

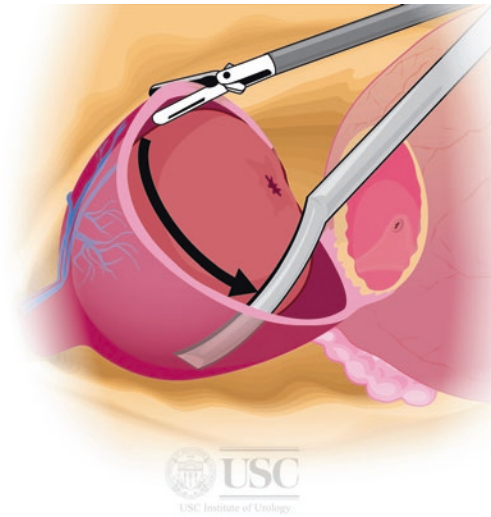

Fig. 24.6 Dissection of the adenoma with Sotelo's prostate dissector (prostatotomo)

dysfunction. These include hypertension, diabetes mellitus, dyslipidemia, and smoking.

Diagnosis and Identification Erectile dysfunction is identified by the patient. It is important to establish baseline erectile function in the presurgical evaluation so that a fair comparison may be made in the postoperative period. There are various methods to measure the seriousness of the erectile dysfunction. The scales that are most used are the Sexual Health Inventory For Men (SHIM) and the International Index of Erectile Function (IIEF-5).

Treatment and Control The current treatment of the erectile dysfunction is based in the oral use of the inhibitor of the 5-phosphodiesterase, upon the failure of oral drugs; meaning the adequate use of two different oral drugs for at least 3 months; the next line is the intracavernous therapy with one, two, or three components (prostaglandin, papaverine, and phentolamine). Upon the failure of the aforementioned therapeutic methods, the last option would be the use of prosthetic penis.

Urethral Stricture and Contracture of the Vesical Neck

Urethral stricture and contracture of the vesical neck is one of the least frequent complications. It is estimated to occur in less than 1% of patients and generally appears after 6 weeks [9]. The cause is not clear and there has not been any correlation with the size of the adenoma. It is presumed that the urethral stricture is due to the passing of the transurethral catheter, but not to the procedure itself.

Prevention Eventually, it may be prevented by minimizing the manipulation of the urethra and the vesical neck, by not using single or bipolar energy, but by making incisions with a cold cut with scissors, to minimize the inflammation and the fibrotic process of the healing.

Risk Factors The passing of any element via intraurethra represents a factor of risk for the urethral stricture, that is, the infectious processes of the urethra or of the vesical neck. Any other previous condition that favors the fibrosis of the tissues, such as the prostate biopsy or the transurethral resection of the prostate, also favors the urethral stricture or contracture of the vesical neck.

Diagnosis and Identification Once the patient expresses the reoccurrence of the low urinary obstructive symptoms, a stricture of the urethra or contracture of the vesical neck shall be suspected, and the following step is to perform a transurethral cystoscopy in order to evaluate the track of the urethra and evaluate the vesical neck. Another method that may be eventually used is the urethrography or the retrograde micturating cystourethrography.

Treatment and Control The initial treatment for urethral stricture and contracture of the vesical neck is dilation and calibration. In recurrent contractures, the endoscopic procedure with cold cuts on the fibrotic tissue is used; there is no gold standard for the position of such cuts. Upon the failure of these first approaches, the next step is to perform a reconstructive surgery, urethroplasty or a vesical neck-plasty. The reconstruction of the bladder's neck for the refractory contractures is very odd.

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Radical Prostatectomy

25

Alexander Haese and René Sotelo

General Considerations

Complications will never be completely eliminated from surgery and surgeons must learn from complications. In contrast to open surgery, routine recording of robotic surgery permits documentation and analysis of complications more thoroughly than previously possible. Due to the rapid uptake of robotic surgery in less than a decade, many surgeons underwent its learning curve in a short time. This, plus a potentially distinct manner of complications from robotic compared to open surgery, caused the complications of robotic surgery to be apparent and more frequent.

There are distinct risks from robotic over open surgery. Complications can affect structures outside the camera view. As complications are rare, and the length of hospital stay commonly is shorter for robotic than open surgery [1, 2], the treating physician has to have an even more watchful eye on those surgical steps, intra- or postoperative events and symptoms leading to or indicating complications during the surgery, hospital stay, and recovery phase of the procedure.

Routine anonymously self-reporting of complications to further patient care is useful, as large prospective national projects, such as the National Confidential Enquiry into Patient Outcome and Death (NCEPOD), have shown that confidential reporting of operative outcomes improve patient care by identifying common risk events, practices of concern, and strategies to overcome these.

Robotic-assisted laparoscopic radical prostatectomy (RALP) is the most common of all urologic surgeries [3]. Many urologists start their robotic experience with RALP. It might therefore serve as a template for other pelvic surgeries, both benign and malignant, in men and women. In this chapter, we follow the course of a RALP, demonstrate risks, dangers, and pitfalls leading to immediate or delayed complications, and highlight strategies to prevent them.

Patient Positioning

In few other surgical procedures is proper patient positioning so crucial, for both a successful procedure and low complication rate, as in RALP. The typical transperitoneal approach requires steep Trendelenburg position (20°–35°) to permit adequate pelvic exposure. Readjustment of table

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position mid-procedure is only possible in those rare situations where last-generation robotic systems equipped with table motion technology are used. Proper patient positioning can prevent countless complications that may be confused with other diseases [4]. When starting a robotic program, we suggest that positioning is always done by the same team.

Patient Fixation The most feared positioning complication mid-procedure is patient sliding, which might lead to transient or permanent severe skin, muscle, or nerve injuries, for example, incisional tear, postoperative hernia formation, and increased postoperative pain due to overstretching of the abdominal wall. Some tools such as shoulder straps, shoulder braces, restraints, body straps, or head rests intended to prevent slippage may actually contribute injury and should be avoided. A secure fixation of the patient on the table requires a soft mattress such as a Tempur – or a gel mattress, the friction of which will, in part, prevent movement [5]. Vacuum mattresses may also be used; however, when evacuated, these are quite hard, and inappropriate modeling of the mattress to the patient contour may lead to compression injuries. Another rare but critical issue of vacuum mattresses is that they might slowly lose the vacuum due to gas leakage (often unnoticed, due to the draping of the patient), and therefore their ability to maintain a stable patient position.

Face and Eye Protection Face and eyes are at risk of direct injury during robotic surgery due to the proximity of the robotic camera; the console surgeon's lack of bedside view and drapes. Particularly risky is the 30° down lens, where the camera may be only a few centimeters away from the face. Face masks, metal shields, or metal bars or foam pads protect the face. Eyelids must be tape-closed and protective goggles applied. Instruments not in use must not be placed on the drape, as the patient's face or chest are underneath and unrecognized compression injuries can occur.

Shoulder, Arms, and Chest Of utmost importance is shoulder padding with pillows specifically designed for steep Trendelenburg positioning. These should be soft, but firm, and have sufficient contact surface to evenly distribute the weight of the patient on an as large as possible shoulder area. Ideally, these pillows are in one piece for both shoulders, with a notch stabilizing the patient head without compression, which may lead to alopecia. These pillows also avoid continuous rotation and lateral flexion of the neck, which increases tension in the brachial plexus on the opposite side, and provide a firm but stable fixation of the entire shoulder, without isolated clavicular compression, both factors contribute to preventing *brachial plexus injury*. An easy and safe way to position the arms is to put a sheet of approximately 100 × 50 cm horizontally in the middle of the table, corresponding to the position of the patient's arms. Egg-crate foam or gel mattresses protect the arms when the sheet is tucked, in a way that arms are fixed closely but not tight to the patient's body. Alternatively, well-padded arm rests can be used. At the level of the elbow, the *ulnar nerve* passes through the olecranon. Care should be taken to prevent *ulnar lesions* [6] that later can present as a sensitive damage of the fourth and fifth fingers in the palmar region, which can progress to motor nerve damage and ultimately to a claw hand [7–9]. Placing the arms on the side prevents hyperabduction of the upper limb, causing *brachial plexus* injury. The hands should be in an anatomically neutral position. Improper fixation might cause the hand to drop laterally, and hyperextend causing *radial nerve injury*.

Lower Extremities Irrespective of the tools that the legs are positioned in (split leg table, stirrups), it is crucial to avoid hyperextending at the hips, which risks femoral nerve stretch injury. Compression of muscles must be avoided to prevent crushing injuries, which in its extreme form may lead to rhabdomyolysis, compartment syndrome, and ultimately fasciotomy. The risk of rhabdomyolysis is increased particular in long procedures, obese patients, and steep Trendelenburg combined with other common risk factors such as diabetes, hypertension, or peripheral vascular disease [10–12]. Gluteal, back, calves, and shoulder muscles are at par-

ticular risk [13]. Postoperative pain in these areas should serve as a warning sign. The diagnosis is confirmed if the total serum creatinine kinase level is higher than 1000 IU/L or if myoglobinuria is present. Management includes aggressive fluid resuscitation and correction of metabolic acidosis [14] and in case of a compartment syndrome, early fasciotomy.

Complications During Robotic Prostatectomy: Access

Access Complications A pre-incision checklist should include the following: availability of CO_2, insufflation settings as specified, electrocautery setting as specified, automatic function on the bipolar deactivated, and all equipment (suction, irrigation, fully functional and white balanced camera) checked and ready for immediate use. In the early experience, an open tray should be available. The first (camera) trocar for pelvic surgery is typically placed in the periumbilical region. As the other trocars are placed under visual control, the safe placement of the camera trocar is of utmost importance.

Veress needle access, optical-access trocar, and access via a mini-laparotomy using Hasson technique [15–20] are the most common access forms. Injuries during access range from mild to life-threatening [21, 22], where most injuries involve either visceral or vascular organs or a combination thereof. The surgeon should be familiar with all access forms, their advantages, pitfalls, and contraindications to be able to alter the approach when needed.

The Veress needle is inserted blindly, and this maneuver can result in injury to intraabdominal structures, commonly intestine or large blood vessels [23–26]. The Veress needle should be checked by the surgeon to ensure that the spring-loaded blunt obturator retracts when going through the abdominal wall, but also slides back into its protective position after entry into the peritoneal cavity. The abdominal wall should be lifted upward with two sharp towel clamps creating distance between the parietal peritoneum and intraabdominal structures to increase safety distance between the tip and viscera. In very obese patients, it is preferable to use points in the fascia that elevate the entire abdominal wall as lifting only the skin and subcutaneous fat tissue will not lift the entire abdominal wall. The surgeon should brace the hand on the patient while advancing the needle in a 45° direction (90° in more obese patients) to avoid inadvertently pushing the needle too deep. The double-click test indicates the two points of resistance as the needle is passed through the anterior and posterior rectus fascia. After passing through the second point of resistance, and before insufflation, a syringe half-filled with saline should be placed on the Veress needle and aspirated to identify vascular or intestinal lesions. Subsequently, saline should be passed through the needle (drop test) to verify intraperitoneal position. Opening pressure upon CO_2 insufflation should be <10 mm Hg. Flow rate should be low until well-documented, symmetrical abdominal distension. The camera trocar is then carefully introduced with a braced hand. Camera inspection should occur immediately thereafter so that early identification of injury is possible. In patients with previous abdominal surgery, an open access should be performed.

Vascular Injuries Vascular injuries during access are rare, ranging from 0.03% to 0.2% [27–29]. Most vascular injuries are caused by the Veress needle or the initial trocar placement [21, 30, 31]. The aorta and common iliac vessels are most commonly injured [32]. To minimize the risk of injury, the patient should lie without Trendelenburg in the access phase, as Trendelenburg rotates the promontory and positions the aortic bifurcation closer to the umbilicus, increasing the likelihood of vascular injury [33]. If vascular injury occurs, management should be tailored to the situation: small, non-expanding lesions can be marked with clips, monitored during surgery and be reinspected afterward with CO_2 pressures at 5 mmHg. If the hematoma expands, additional trocars should be placed and the system docked. The hematoma should be opened and the bleeding site exposed. If repair is possible, repairing with robot-assisted technique is the first approach. Inserting gauze,

compression, increased pneumoperitoneum (in venous lesions) and adequate instruments for repair (see below) should be available. If it cannot be repaired laparoscopically or robotically, apply compression and perform prompt laparotomy. Doing this is preferable to losing time trying, with potential harm to the patient.

Bowel Injuries Bowel injuries during access are rare, ranging from 0.07% to 0.09%. If viscera are injured [32, 34, 35], the trocar should be left with its obturator and shaft in place, and another trocar to explore should be inserted. Depending on surgical expertise and defect size, repair can be done with a purse string or double-layer suture. Alternatively, the bowel can be externalized and repaired through a small incision. Significant or complex tears may require laparotomy.

It is discouraged to do a Veress approach in case of previous abdominal surgery. Here, access via a mini-laparotomy [17], under vision [18], or optical entry far from prior scars should be standard of care.

Secondary Trocar Placement Subsequent trocars must always be placed under direct vision. Marking trocar sites with a pen after a full pneumoperitoneum is established is useful, as the optimal points of trocar entry with their respective safety distances are better identified in an inflated abdomen. Transillumination may help visualize subcutaneous vessels, even though the larger epigastric vessels at the lateral border of the rectus muscle are often invisible. Overly small skin incisions are to be avoided as they require excessive force for trocar insertion, which may cause injury.

Adhesions and prior open or laparoscopic abdominal surgery pose a significant challenge to trocar placement. If scars are visible, one should avoid placing trocars through or in a direction toward the scar. After placement of the camera trocar using Hasson technique, the abdomen is verified for adhesions. The degree of adhesions is unpredictable; they can be surprisingly extensive despite only minor previous surgeries, or almost nonexistent despite previous major abdominal interventions. If adhesions are present, the next trocars to be placed for any procedure are those distant of the adhesion but in a position that permits manual laparoscopic adhesiolysis. After adhesiolysis, the reminder of the trocars can be placed safely.

Vascular Injury During Secondary Trocar Placement Injury to other abdominal vessels, in particular the inferior epigastric arteries and veins, may occur during placement of secondary trocars, affecting abdominal wall vessels in 35% and the aorta or iliac arteries in 30% of cases, respectively [16]. Transillumination and dimmed OR light help identify and bypass abdominal wall vessels. At the end of the procedure, ports should be removed under direct vision and the port sites inspected for arterial bleeders. A figure-of-eight suture should be placed for adequate control, as cautery might not be sufficient.

Complications During Robotic Prostatectomy: Mid-Surgical Complications

Injuries Caused by Direct Instrument Contact A unique feature of robotic surgery is that during the procedure some crucial steps are not in the hands of the surgeon, but in those of the bedside surgeon or scrub nurse [36, 37]. This is particularly true for the insertion and change of robotic or laparoscopic instruments. Still it is the console surgeon's responsibility to guarantee the safety of the procedure. Hence, he or she must ensure that no actions are taken without adequate view. *Never should a robotic instrument be inserted without direct vision as it has no memory and can go further than desired.* During instrument change if the bedside assistant manually redirects the robotic arm, instrument position is erased and reinsertion must be done under direct vision. Intestinal loops can move during surgery, leading to possible injury during instrument exchanges.

Venous Lesions Due to their anatomically favorable position, even large venous lesions of the external iliac veins can typically be controlled by

increasing pneumoperitoneum to 20–25 mmHg, applying moderate compression and suturing. It is more difficult to control veins branching off the iliac during pelvic lymph node dissection. Suction should be reduced to the absolute minimum, because this maneuver decreases pneumoperitoneum, increasing bleeding.

Arterial Lesions Lesions of large arteries require immediate compression or clamping, for example, with a ProGrasp robotic instrument. The two other robotic arms may then be used first to identify the lesion as precisely as possible. This permits the bedside surgeon to have two hands available for (moderate) suctioning, additional compression with laparoscopic-robotic instrument with rolled gauze sponges to tamponade the bleeding, or needle insertion. Clips can be used for preliminary control, followed by definitive suturing. A rescue suture should be available. The rescue suture is a suture with Hem-o-lok at the end. Applying the suture and placing it on tension rapidly stops the bleeding by apposition of the vascular injury. It consists of a Vicryl suture with a CT1 needle with no memory (unlike monofilament) to facilitate suturing.

If robotic closure of an artery is not feasible but compression permits a preliminary hemostasis, conversion is required and the following steps, as given in Fig. 25.1, should be taken.

Bowel Injuries These are less prone to acute complications, however, as they may occur out of camera view, they may to present in a delayed fashion. Bowel injuries may be divided into perforation and abrasion, with an incidence of 0.2–0.6%, respectively. Fifty percent were a result of electrocautery and 80% required laparotomy. Critically, 69% were not recognized intraoperatively [38]. The basis of prevention is a high level of alertness when the bedside surgeon enters laparoscopic or robotic instruments as to unusual resistance when outside the camera view. If in doubt, the console surgeon must inform the bedside surgeon if he needs visual help to place the instruments into view. To maximize the safe range of instrumentation, intraoperatively detected adhesions of small or large bowel

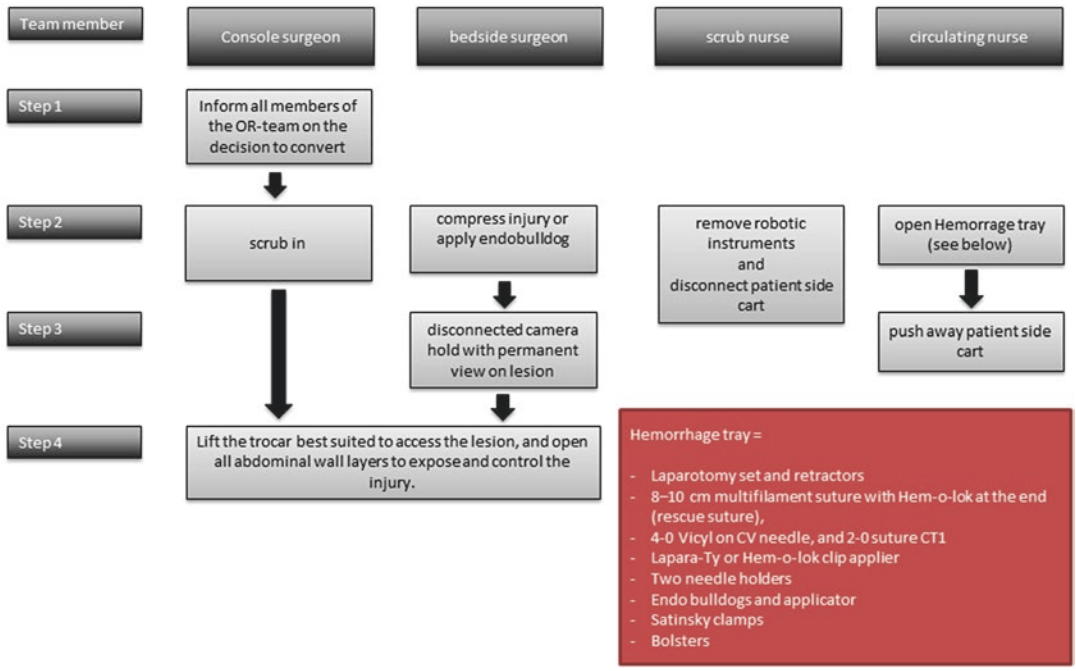

Fig. 25.1 Flow chart of emergency conversion in case of bleeding

should be freed sufficiently to drop cephalad, out of the range of both robotic and laparoscopic instruments. The additional time required for this is well invested for increased safety. If abdominal viscera are injured, repair can be done by primary robotic or laparoscopic repair. Alternatively, the closest trocar site to the injury can be opened, the bowel exteriorized for repair, repositioned intraabdominally, followed by trocar closure and continuation of the procedure. If only an abrasion of serosa is seen, a primary repair is done robotically. In doubt, the site of injury should be closed preliminarily, marked with a long thread, and the prostatectomy finalized. Intestinal injury from trocar insertion should be inspected on both sides, since the perforation can be through and through. In the extraperitoneal approach, transgression of the peritoneal reflection with a trocar can cause unrecognized bowel injury; hence, proper understanding of this potential danger is important. At the surgeon's discretion, consultation with a general or colorectal surgeon may be advisable.

Signs and Management of Undetected Visceral Injuries If unrecognized during surgery, patients with bowel injury will require laparotomy with or without fecal diversion. The patient generally is asymptomatic on the first postoperative day, as peritonitis will not yet have developed. If dissection was difficult or if significant adhesions were found and possible injury is suspected, the patient should remain hospitalized for further surveillance. Symptoms of unrecognized visceral injuries include focal trocar site pain, generalized abdominal pain, distension, fever, diarrhea, leukocytosis or leukopenia, peritoneal signs, wound succus, or elevated drain amylase levels. Diagnosis is made clinically and biochemically, but a low threshold for an abdominal CT-scan is advisable. Radiographic signs of intestinal injury include free intraperitoneal fluid, extravasation of enteric contrast, and ileus. Free intraperitoneal air is ambiguous, as even several days after a laparoscopic procedures, some free air may exist.

Pelvic Nerve Injury The most common nerve injury involves the obturator nerve [39, 40]. An incidence of 0.7% has been reported in laparoscopic radical prostatectomy and 0.4% in RALP. Injuries are caused by stretching, but more commonly by direct thermal injury, or complete transection during lymph node dissection. As the obturator nerve is highly constant, the only way to prevent its injury is a high degree of alertness during lymph node dissection and proper visualization at all times. The nodal packet should be pulled medially and not anteriorly to visualize the nerve. Hem-o-lok clips must be placed in parallel, not perpendicular to the nerve, and only after completely visualization. Likewise, electrocautery must be used carefully, rather than blindly grabbing tissue where a bleeder is suspected. Control bleeding at this level is important because it has also been reported obturator neuropraxia secondary to an expanding hematoma compressing the nerve that required surgical drainage for clinical improvement [41].

Recovery of obturator function from neuropraxia occurs spontaneously within 6 weeks. After a full unrecognized transection, however, gait disturbance will persist, followed by atrophy of the adductor muscles. If recognized during the procedure, an attempt should be made to align the ends of the transected nerve and suture it [41, 42].

Rectal Injury The incidence of rectal injury is similar with different approaches: open (0.5–1.5%) [43, 44], laparoscopically (0.7–2.4%) [44, 45] and robotic (0.2–0.8%) [44, 46, 47]. The most important point is to recognize the injury during surgery and to perform tension-free primary repair using sufficient vascularized tissue interposition [43, 45, 47, 48]. When the defect is too large or complex to be sutured tension-free, if fecal contamination is extensive or in a salvage-prostatectomy situation, a fecal diversion is indicated.

In the early postoperative phase, rectal injury may lead to major complications including septic peritonitis and death. Very small injuries may lead to rectourethral fistula development. In men with unrecognized rectal injury, rectourethral fistulae tend to persist and eventually require delayed surgical repair. The sequelae of rectal

injuries are pelvic abscess (0.1%) and rectourinary fistula (0.03–1%) [43, 45, 47, 48].

As in the open procedure, salvage RALP has an increased risk of rectal injury and should be avoided in the earlier learning phase. Likewise, a high degree of alertness, avoidance of both electrocautery and aggressive blunt dissection reduce the risk on rectal injury [49, 50]. Sharp dissection also can cause rectal lesions; however, these have typically smooth, well-vascularized edges that can be sewn safer than larger lacerations occurring with blunt dissection, or thermal necrosis that can be unrecognized. Diagnosis during surgery is done with the bubble test, which consists of passing a 22 Fr. catheter through the rectum and injecting 60 cc of air, while observing the pelvis filled with saline. If bubbling occurs, air is passing through the rectum to the pelvic cavity. The lesion should be closed in two-layers. In non-nerve-sparing surgery, the lateral tissue can be moved to the midline as an additional layer of safety. The rectal repair should be moved away from the anastomosis to reduce the risk of fistula formation.

After repairing the injury, repeat the bubble test. Generous irrigation of the operative field dilutes bacterial contamination. Even if normally no drain is placed after rectal injury, this should be done. Additional days of hospitalization, 3–7 days of antibiotic therapy with anaerobe coverage, and prolonged catheter placement is recommended. A cystourethrogram is mandatory prior to catheter removal.

Early symptoms of rectal injury are lower abdominal pain, fever, abnormal white blood count, and sepsis. If unrecognized, a larger rectal lesion may progress to septic peritonitis. Late presentation occurs as recurrent or persistent urinary tract infection, rectourethral fistula, pneumaturia, or urine loss per rectum. Such fistulae are diagnosed by retrograde urethrogram, urethrocystoscopy, colonoscopy, or CT-scan with rectal contrast.

Ureteric Injuries The incidence of ureteral injuries is <1% [44, 51, 52] and more than 70% of ureteral injuries are diagnosed postoperatively. Its incidence during urologic laparoscopy surgery is 0.8% and 0.1–0.3% during RALP.

The ureter may be injured in several typical locations:

- *Intertrigonal injuries*: After the anterior bladder neck is separated, dissection continues downward, along the plane between prostate and bladder. If this plane is harder to identify, or in patients with median lobes, it is possible to "button-hole" the bladder neck. This typically happens in the trigonal area. In larger dorsal intertrigonal defects, the ureteral orifices can also be injured. To prevent this, it is recommended to repeatedly inspect the bladder via the orifice and delineate the full thickness of the detrusor with an inside and an outside view. If such defects occur, they must be closed; however, the ureteral orifices must be visualized for their location and urine efflux after each stitch with a Vicyl 4–0 suture. The catheter must not be removed without cystography. In predictably challenging cases (post-TURP, salvage) cystoscopy with ureteral catheter insertion at the beginning of the case may be prudent and should be considered in select cases.
- *The distal ureter* is prone to injury when using the Montsouris approach [53, 54]. On too lateral a dissection, the ureter can be mistaken for the vas, thereby transected, thermally injured, or ligated. If a Montsouris approach is used, a tubular structure should never be divided without being completely sure it is the vas. Vas and ureters have different trajectories, where the vas converges in the midline from lateral to medial.
- *Medial ureteral injury* occurs during extended lymph node in the vicinity of the iliac vessels. Again, visualization of the ureter at all times eliminates the risk of injury. The use of the third robotic arm to pull the ureter away from the lymph node template increases safety distance.
- *Special considerations after TUR-P*: In patients with previous TURP, the ureteral orifices might be displaced from their typical location. Here, the anterior opening results in the bladder being wider open than usual.

This permits visualization of the orifices. When the dorsal dissection is done, it is of utmost importance to continuously focus both orifices and check for urine efflux. Great care has to be taken to avoid cutting close to the ureteral orifice. In the early phase of the learning curve, post TURP patients should be avoided. Intravenous indigo carmine may be helpful in select cases.

Treatment of Intraoperatively Detected Ureteral Injuries As a rule of thumb, all ureteral injuries can be corrected robotically. Cauterized, nontransecting ureteral injuries should be stented in a retrograde fashion. Partially or fully transected ureters can be repaired after stent placement with a 5–0 monocryl suture. Longitudinal defects should be closed transversally to prevent narrowing of the ureter. For trigonal lesions, the extent of the repair depends on the size of the injury. As mostly the distal end of the orifice is affected, the roof of the orifice can be incised after stent placement. If the ureter or orifice is widely injured, a ureteral reimplantation is recommended.

Technical Errors and Malfunction

Injuries Caused by Electrocautery or Thermal Energy Electrical arcs can arise from monopolar instruments. Insulation failure is the typical cause for this type of injury [55]. Surgeons should avoid excessive instrument collision to maintain integrity of the insulation, and ensure insulation sleeves are placed properly and without defects. Electrosurgical arcs can cause immediate injuries to blood vessels. Thermal intestinal injury can lead to delayed necrosis and perforation several days after the procedure.

Great care must be taken when a monopolar instrument is in proximity of metallic tips of instruments of the bedside surgeon, such as a grasper or suction. Electronic arcs may jump over from the tip of the scissor to the nonisolated parts of the instrument, leading to bowel or visceral injury. As a safety measure, cautery should be minimized or avoided particularly on the rectal wall during posterior dissection.

Instrument Malfunction The most common event of instrument malfunction is a break of the wires controlling the endowrist and instrument jaws. If this happens, the instrument can be removed easily. Events such as a break of an instrument tip or a disintegration of an instrument can be dangerous as the loose part might get lost intraabdominally [56, 57].

Needle Loss A critical issue is needle loss during surgery [58, 59]. Preferably, only one needle at a time should be in situ, except when double-armed sutures are used. When needles are inserted or removed, a needle holder must be used (no grasper due to less grip), needles should be grasped directly but not on the thread and the bedside surgeon should verbally confirm successful needle retrieval each time.

In case of needle loss, it is extremely important not to move any robotic or laparoscopic instrument in a hurry [58]. Typically, the needle stays below to where it escaped, and careful, but easy search with the robotic camera will be successful. Too early movement with instruments will move intestines and potentially hide a needle. Magnetic search devices have been described [60]. In the process of searching, the lumen of the trocar should be inspected, and if in doubt, the trocar should be removed and X-rayed. Finally, the needle might be lost outside the abdominal cavity, between the surgical drapes.

End of Case Considerations

When finishing the case, the scrotum should be empty of gas, since this can distend it, causing skin lesions and breakdown. It is also crucial to assess for subcutaneous emphysema as this can easily be confused with other conditions such as generalized edema. Reduce insufflation pressure to 5 mm Hg to check for bleeders masked by higher pneumoperitoneal pressures.

Postoperative Complications

The incidence of postoperative complications is reported to be 1.9–9.0% [44, 61, 62]. The most common complications occur early after the procedure, thus it is crucial to evaluate the patient thoroughly in the first 2 or 3 h postoperatively. Assessment includes speed of regaining consciousness, vital signs, skin coloration, drainage type and volume, and abdominal tenderness.

Postoperative Hemorrhage, Blood Transfusion, and Reintervention As in open surgery, this is the most relevant immediate to early complication. The incidence of blood transfusion is low (<1.5%) [44, 61, 62]. The transperitoneal approach allows larger blood loss before detection, as the space for the hematoma to spread is large and hematomas may not irritate intraabdominal structures, which is a unique difference to the open approach. The indication for transfusion and intervention is based on clinical findings [63, 64]. Particularly in rapidly worsening patients (tachycardia, hypotension, abdominal distension) immediate reintervention is preferable, as compared to waiting for a CT-scan, which may delay a necessary intervention. Drainage output is not a reliable sign of bleeding, as the blood clots in the drain, obscuring bleeding. More often than not, open exploration is advisable, as a larger hematoma, with its associated poor vision, slower chance of hematoma evacuation via suction, and vital instability, which worsens when the patients goes back to Trendelenburg position, requires a swifter, safer, and more predictable control.

In clinically stable patients, who experience postoperative bleeding, as determined by a drop in hemoglobin, a CT-scan with IV-contrast helps to assess the urgency to intervene: If an active bleeder is seen, reintervention is necessary. In the more common situation without active bleeding, the need to intervene is determined by size and position of the hematoma: smaller hematomas in the prostate fossa that do not expand will resolve over time. Hematomas affecting the anastomosis – evidenced by bloody catheter output – indicate anastomotic rupture, pelvic urinoma, ultimately longer catheterization time and increased risk of strictures. Here, a laparoscopic evacuation of the hematoma – albeit requiring reintervention – is more beneficial for the patient in the long-term perspective.

Urinary Anastomotic Leakage The most common sign of massive urinary leakage is increased drain output, the type of fluid determined by drain fluid creatinine levels. The presence of urine is confirmed when drainage creatinine is higher than serum creatinine. To determine the origin of the leakage (anastomosis or ureteral injury), a cystography is the easiest form of assessment. A cystography shows either a partial or a total disruption of the anastomosis. To differentiate urine from a ureteric lesion from urine from an anastomotic insufficiency, the method of choice is a CT-scan with IV-contrast and urographic phase combined with 3D reconstruction: If ureter is partially or fully transected, an increased drain output with elevated creatinine can be expected. In particular after transperitoneal approach, abdominal pain and distension due to urine peritonitis is a common symptom.

Retrograde ureteropyelography has the advantage of both identifying and possibly treating ureteral lesions. If the defect is small and guidewire passage is possible, stent placement for 4–6 weeks typically resolves minor lesions. If retrograde ureteropyelography shows a larger defect, or when passage of a guidewire is not possible, reintervention, combined with percutaneous renal drainage is inevitable.

Fully obstructed ureters due to sutures or clips cause hydronephrosis and flank pain. Ultrasonography raises the suspicion, and a CT-scan with IV-contrast will identify the level and degree of obstruction.

Port Site Hernia The incidence of port site hernia ranges from 0.04% to 0.477% [64, 65]. They generally occur at larger trocars and are more frequent in sites of multiple incisions. For prevention, closure of all >10 mm ports is recommended. Port site hernias have also been described at 5 and 8 mm

port sites, and occur because the size of incision of the port differs between the internal abdominal wall and the external incision, as the movement of the trocar causes a cone effect in the abdominal wall incision. Blunt obturators reduce the incidence of trocar hernias [35, 66].

Signs of trocar hernia are abdominal pain, (sub)-ileus, nausea, and vomiting. Diagnosis is made by CT-scan with oral contrast media. Laparoscopic exploration, hernia reduction and, if needed, resection of necrotic intestine and enteroanastomosis is the treatment.

Stricture and Bladder Neck Contracture These contractures have a low incidence of 0.7–1.4%, occur at a median of 5 months after surgery [67–69], and may present as acute urinary retention. Patients usually report being previously incontinent or that their urine stream has changed and that the stream now fans out. The standard precautions of anastomotic suturing (mucosa-to-mucosa, tension-free, initial watertightness) reduce the incidence of strictures.

Lymphoceles With an incidence of up to 50% – mostly asymptomatic, though – lymphoceles are the most common long-term sequelae of RALP [70]. They are more common in patients who underwent pelvic lymphadenectomy and present with pelvic pressure or pain, abdominal distension, thrombosis formation, and/or leg edema [71]. Ultrasound confirms the diagnosis, and US- or CT-guided percutaneous drainage is the treatment of choice after Doppler sonography excludes a deep venous thrombosis (DVT) [72, 73]. More than 90% of drained lymphoceles subside spontaneously, and only those persisting require laparoscopic fenestration [71].

Thromboembolic Complications These events include DVT and the resultant pulmonary embolism. Sporadic cases have been reported, with a low incidence below 1% [44]. However, the development of DVT usually has predisposing factors, such as vascular injury, hypercoagulability, and venous stasis. Prophylaxis is advised, involving intermittent compressive devices or low molecular weight heparin [73].

Conclusions

For all its complexity, RALP is a remarkably safe procedure in experienced hands. Complications are inevitable, but open confidential reporting allows sharing of experience knowledge and lessons to be learned by other surgeons. Common pitfalls occur in RALP and these may be avoided by experience, knowledge of other surgeons' complications and open reporting. Low index of suspicion affords early diagnosis of sequelae, minimizing their potential impact.

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Cystectomy

26

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Introduction

Radical cystectomy with urinary diversion is considered to be the gold standard in the management of muscle invasive bladder cancer as well as high-risk nonmuscle invasive bladder cancer. Despite significant advances in surgical techniques and postoperative management, it continues to be one of the most morbid procedures performed in the field of urology with reported complication rates as high as 64% [1] and mortality rates as high as 2.5% [2].

Since its introduction, the da Vinci™ surgical system (Intuitive Surgical, Sunnyvale, CA) was quickly adopted by urologists as it helped overcome some of the difficulties associated with pelvic surgery. Great strides have been made in the technical aspects and the postoperative management since the publication of the first series of robotic radical cystectomy in 2003 by Menon et al. [3]. Novara et al. published a systematic review summarizing the available literature on perioperative outcomes and complications associated with robotic radical cystectomy and showed that robotic cystectomy can be performed safely with acceptable outcomes, although complications still frequently occur [4]. Interestingly, robotic radical cystectomy was associated with less blood loss, less transfusion rates, as well as a limited decrease in postoperative complication rates compared to open cystectomy.

Many of the complications related to radical cystectomy are related to the urinary diversion, which is beyond the scope of this chapter. In this chapter, we will focus the discussion on the complications that are directly related to the cystectomy portion of the operation and describe the associated risk factors, prevention methods, and how to deal with the complications when they arise.

Intraoperative Complications

- *Complications related to patient positioning*: The patient is usually placed in the lithotomy position with the arms tucked and in the steep Trendelenburg position. The duration of a robotic radical cystectomy can vary considerably, depending upon the surgeon's experience, patient's body mass index, previous surgical history, and the type of diversion used. In some reports the operative time is as long as 7 h [4]. The rate of complications has been consistently shown to be directly proportional to the operative time.

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- *Nerve injuries*: Both lower and upper extremity nerves are at risk of neuropraxia during surgery, including peroneal, femoral, ulnar, and brachial plexus injuries [5–7]. Most nerve injuries are directly related to pressure on the nerve from inappropriate positioning and are usually diagnosed in the immediate postoperative period due to the associated neurological deficits. Fortunately, most of those deficits resolve with time and conservative management.
  - *Prevention and management – Key points*:
    - Ensure all pressure points are appropriately padded.
    - Make sure no nerves are on stretch. A relatively common injury is peroneal nerve neuropraxia, which can be prevented by making sure the legs are appropriately positioned in the stirrups and that the posterior aspect of the knee is appropriately padded.
    - A neurology or physical therapy consultation can be considered on an individual basis.
- *Joint and musculoskeletal injuries*:
  - *Joint and bone injuries* are usually directly related to positioning. Predisposing factors include old age, previous orthopedic surgery, osteoporosis, as well as preexisting musculoskeletal conditions.
  - *Rhabdomyolisis* is a potentially catastrophic complication of surgery and it can represent a significant source of morbidity and mortality in robotic cystectomy patients due to long operative times, as described earlier. The key in successful management of rhabdomyolisis is early recognition. Warning signs such as brown urine, decline of renal function, and pain in a large muscle group especially at a location that was subjected to pressure during surgery should immediately raise concerns of rhabdomyolisis. The most sensitive and reliable test for diagnosis is measurement of serum creatine kinase (CK). It is easily performed and serum levels rise within 12 h of muscle injury. Serum myoglobin measurement is not as reliable as it has a half-life of less than 3 h and is cleared from plasma within 6 h. The cornerstone in management and avoiding serious complications is to initiate treatment as early as possible consisting of alkalization and hydration. Mortality from rhabdomyolisis has been reported to be as high as 5% [8–13].
  - *Compartment syndrome*: Compartment syndrome is another feared complication. The pathognomonic sign is pain out of proportion to physical exam findings. Patients may present with decreased capillary refill and diminished peripheral pulses, although in acute compartment syndrome both may be absent. Early recognition and prompt surgical consultation for decompression are key to prevent limb loss and decrease mortality.
  - *Prevention and management – Key points*:
    - Ensure adequate positioning of the patient with joints being in a neutral position. The surgeon should always be aware of any previous musculoskeletal history and incorporate that into positioning, such as in patients with previous joint replacement surgery.
    - Adequate padding of all pressure points and making sure that all limbs are in a normal ergonomic position.
    - Careful placement of IVs and lines away from pressure points and checking for IV infiltration.
    - Early identification of rhabdomyolysis and compartment syndrome with appropriate treatment and appropriate consultation.
    - Keeping operative time as short as possible.
    - Avoiding lithotomy position if possible (the new Xi robot allows robotic cystectomy to be performed without lithotomy position).

- *Ocular complications*: Relatively rare but potentially devastating. Ocular complications have been reported with robotic pelvic surgery including increased intraocular pressure, ischemic optic neuropathy, corneal abrasions, and postoperative loss of vision [14].
  - *Prevention and management – Key points*:
    - Restriction of intravenous fluids, eyelid taping, ocular dressings, and careful preoperative ophthalmological assessment.

- *Complications during surgery*:
  - *Vascular injuries*: Vascular injury, albeit rare, can occur at any surgical step, such as while gaining access into the peritoneal cavity, trocar placement, during surgical dissection, and with specimen extraction. The most common vessels injured with Veress needle placement are the right common iliac artery as it branches off the aorta right under the umbilicus, and the aorta [15]. The inferior epigastric vessels can also be injured with trocar placement and specimen extraction, whereas intraperitoneal and retroperitoneal arteries and veins can be injured during the robotic portion of the surgery and mainly include the obturator, common iliac, internal iliac, and external iliac vessels.
    - *Prevention and management – Key points*:
      - Trocars are best placed under direct vision. The pneumoperitoneum pressure can be raised during port placement to increase the distance between the abdominal wall and the intraabdominal structures.
      - In cases of injury to the inferior epigastric vessels, ligation of the vessel with a figure of eight suture or clipping is preferred to avoid bleeding and rectus sheath hematoma. This is preferably done with a cut down to the vessel to allow for adequate control. A temporizing figure of eight suture can be placed robotically until the case is completed prior to definitive control.
      - Continuous attention to the surrounding vasculature is of paramount importance. The bedside assistant should be cognizant of the vasculature and preferably exchange instruments and assist under vision. The surgeon should handle the vessels with care to avoid avulsion and be careful while using electrocautery and remain constantly vigilant of the contact surface of the instruments to the nearby vascular structures. The insulation on the robotic monopolar scissors should be inspected not only by the scrub tech prior to inserting the instrument but also periodically by the surgeon during its use.
      - In cases of intraabdominal vein injuries, management depends on the vein injured and the size of the injury. Measures that can be taken include raising the pneumoperitoneum to 20 mmHg to tamponade bleeding, using various hemostatic agents if the injury is small, and using a vascular suture as appropriate. If the injury is large, the surgeon can consider proximal and distal control with bulldog clamps prior to the definitive repair.
      - In cases of small arterial injuries and avulsion, suture ligation or clipping is appropriate. At our institution, we always have a 6 in. 2–0 vicryl suture with a hem-o-lok clip tied to the end ready to be used in cases of large vascular injures (Fig. 26.1). If visibility is poor, using this tamponading suture can slow down the bleeding enough such that a definitive repair can be performed.
      - Open conversion should not be delayed if bleeding is excessive, and this should not be considered a failure. Occasionally, a consultation to a vascular surgeon may be necessary.

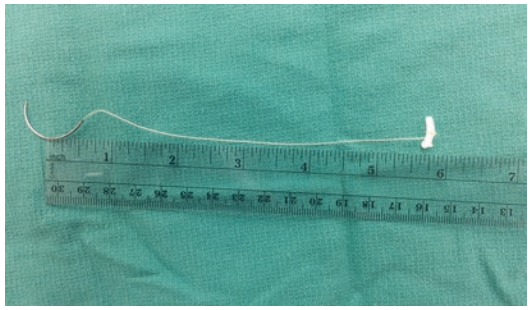

Fig. 26.1 The "rescue stitch" is a 6 in. long 2–0 vicryl suture on a CT-1 needle with a Hem-o-lok clip tied into the end of the suture. The CT-1 needle is readily visible in a pool of blood where a smaller needle such as an RB-1 or an SH needle might not be visible. The Hem-o-lok clip at the end of the suture will serve to tamponade a bleeding point in the vessel and help decrease the hemorrhage, thereby allowing definitive repair to be performed

  - *Nerve injuries*: Nerve injuries are relatively rare. In a robotic cystectomy, the two nerves that are mainly at risk are the genital branch of the genitofemoral nerve, which can be injured during lymph node dissection, and the obturator nerve, which can be injured either during control of the bladder pedicle or the lymph node dissection.
    Genitofemoral nerve injury results in altered sensation to the upper anterior thigh, as well as the skin of the anterior scrotum in males and mons pubis in females. Those injuries do not need repair.
    Obturator nerve injuries result in loss of sensation in the medial aspect of the ipsilateral thigh as well as loss of lower limb adduction.
- *Prevention and management – Key points*:
  - Prior to any clipping, stapling, or electrocautery in the vicinity of the nerves, it is advisable to visualize the nerve and be aware of its location at all times.
  - In cases of obturator nerve injury, repair can be done with an end-to-end anastomosis using 6–0 polypropylene sutures. If a primary anastomosis cannot be performed, then nerve grafting should be considered, such as with an autologous sural nerve graft or a cadaveric nerve graft and occasionally a neurosurgical consultation may be required [16, 17].
  - *Bowel injuries*: Incidence of bowel injury during minimally invasive pelvic surgery has been reported to be between 0.02% and 0.14% [18]. During a robotic cystectomy, bowel injuries can occur during Veress needle and port placement, lysis of adhesions, surgical dissection, and even specimen extraction and closure. When recognized intraoperatively, these injuries are repaired primarily. The gravest consequences arise when the injury is not recognized intraoperatively. For example, injuries occurring outside the field of view of the surgeon can be difficult to identify intraoperatively. These injuries most commonly are caused by the blind passage of the assistant's instruments and can result in serious postoperative complications including an acute abdomen and sepsis with a high morbidity and mortality.
  - The most common bowel segment to be injured is the rectum, especially in male patients with incidence of about 0.2–0.4% of cases. Rectal injuries are more common in patients who had previously received radiation therapy or hormonal therapy, previous infections, advanced cancer stage, and a history of previous pelvic surgery. The risk is also higher earlier in the learning curve of the surgeon as experience plays a pivotal role in preventing rectal injuries.
  - At our institution, when there is any concern of a possible rectal injury and in all case of difficult rectal dissection, we have an assistant perform a digital rectal exam intraoperatively and also blow air through a rectal tube after filling the pelvis with irrigation fluid to check for any air bubbles and make sure no small injuries are present. This is also performed after a rectal injury repair to check for a watertight closure. If there is gross fecal spillage from a large injury, or an injury in the irradiated rectum, a diverting colostomy might be necessary.

- *Prevention and management – Key points*:
  - Checking integrity of all instruments and proper insulation is crucial to avoid unintentional electrosurgical transmission to bowel.
  - Passing of instruments by assistants should be done carefully and under direct vision, and all movements of instruments should be done deliberately and in a controlled fashion.
  - All small injuries should be repaired primarily as soon as they are recognized.
  - For large injuries with gross spillage, a bowel resection and occasionally a diverting colostomy may be needed.
  - In cases of suspected missed bowel injuries in the postoperative period, a CT scan of the abdomen and pelvis with oral and rectal contrast should be obtained, and a stat colorectal consult may be necessary.
- *Complications in the postoperative period*:
  - *Lymph leak and symptomatic lymphocele formation*: This is a known complication of pelvic procedures especially when a lymph node dissection is performed, with a reported incidence of 2–9% [19]. This complication is usually delayed in presentation and presents with lower extremity swelling due to direct compression of the pelvic vessels, which could be painful or painless. Occasionally, lymphoceles can get infected and the patient can present with signs of localized pain and fever. Lymphoceles are easily diagnosed by obtaining a CT scan.
    - *Prevention and Management – Key points*:
      - Using of surgical clips plays a very important role in decreasing lymphatic leaks and lymphocele formation. Nutritional optimization of patients is also important.
      - Asymptomatic or minimally symptomatic lymphoceles can be managed with observation as most resolve spontaneously.
      - In cases of symptomatic lymphoceles, initial management is usually by placement of a percutaneous drain under ultrasound or CT guidance. In recalcitrant cases, intraperitonealization by fenestration can be performed robotically.
  - *Thromboembolic complications*: Symptomatic venous thromboembolism (VTE) affects approximately 1–5% of patients undergoing major urologic surgery, with pulmonary embolism accounting for most cases of postoperative death [20]. In radical cystectomy patients, symptomatic VTE has been reported to be as high as 3.7% [21]. Risk factors include old age, cancer diagnosis, smoking, comorbidities, extensive pelvic lymphadenectomy, central venous catheter placement, prolonged immobility, and use of adjuvant and neoadjuvant chemotherapy.

    The surgeon should be aware of the symptoms and signs of deep venous thrombosis such as calf swelling and tenderness.
    - *Prevention and management – Key points*:
      - Early ambulation is the cornerstone in preventing deep venous thrombosis. Patients should be encouraged to ambulate as soon as possible.
      - Pneumatic compression devices should be placed in the perioperative period and continued until the patient is ambulatory.
      - Prophylactic anticoagulation is recommended for patients undergoing major pelvic surgery [21].
      - Management is by systemic anticoagulation for 6 months or placement of an inferior vena cava filter if anticoagulation is contraindicated [22].
  - *Postoperative ileus*: Defined as a delay of bowel function return lasting more than 4 days [23]. Although seldom a serious complication, postoperative ileus can result in significant patient discomfort, pain, abdominal distension, vomiting, and increased hospital stay [24]. Implementation

of the Enhanced Recovery After Surgery Protocol (ERAS) has resulted in a decreased incidence of postoperative ileus as well as a decrease in hospital stay [25, 26]. This protocol includes reduced usage of bowel preparation, standardized feeding schedule, standardized analgesic use avoiding opioids, and omitting the use of nasogastric tube or early removal combined with metoclopramide usage [27]. The addition of Alvimopan has been found to safely accelerate return of bowel function and decrease hospital stay [28].

- *Prevention and Management – Key points*:
  - Implementation of the ERAS protocol, elimination of bowel prep, early ambulation, decreased narcotic use, Alvimopan usage, and careful electrolyte monitoring are key in decreasing the incidence of postoperative ileus.
  - If postoperative ileus is prolonged, imaging with oral contrast is required to rule out partial or complete bowel obstruction.
  - Nasogastric tube can be considered in cases of prolonged ileus associated with nausea and vomiting
  - In the absence of a timely resolution, evaluation of an intraabdominal process should be done, such as a urine leak, lymphocele, or an abscess with appropriate management consisting of percutaneous drain placement, surgical intervention as appropriate, and antibiotic use.

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Orthotopic Neobladder Formation

27

Christian Andreas Bach and Anthony Koupparis

General Considerations

Radical cystectomy is the gold standard of treatment for localized muscle-invasive and selected high-risk non-muscle-invasive bladder cancer. Robot-assisted radical cystectomy (RARC) was first described over two decades ago [1] and is provided in high-volume complex cancer centres [2].

After removal of the urinary bladder, the urinary stream requires reconstruction. Broadly speaking, the options include the formation of an ileal conduit [3], continent cutaneous reservoirs [4] and orthotopic bladder reconstruction [5]. Each has its own advantages and disadvantages, and all of which can be performed intra-corporealy.

In many centres, radical cystectomy and reconstruction are still performed as a 'hybrid' procedure, in which the extirpative sectioned proceeds robotically, while the reconstructive part is performed in an extra-corporeal fashion [6]. This hybrid procedure constitutes a transition point for surgeons during the early learning curve for this complex operation. Although an extra-corporeal approach still provides many of the benefits of minimally invasive surgery, it is the authors' belief that the ultimate goal should be a fully robotic procedure. The extra ureteric length and dissection required, together with the extra bowel handling with this approach leads to similar rates of post-operative ileus and ureteric stricture to open surgery (Koupparis et al. unpublished results). Additional benefits with an intra-corporeal reconstruction include faster operative times, less post-operative ileus and far better visualization of the anastomoses. Early published series have demonstrated these observation as well as equivalent oncological outcomes [7].

The most common urinary diversion to be performed robotically is the ileal conduit, with approximately 10% of patients receiving an orthotopic neobladder [8]. Patient choice and co-morbidities remain significant drivers for this observation. Conservation of the patient's body image and the ability to maintain quasi-normal voiding pattern are important. However, it remains debatable whether quality of life with an orthotopic reconstruction is better than with an ileal conduit [9–11]. What is certain is that in carefully selected patients, robotic-assisted orthotopic reconstruction is extremely successful [9, 12].

It is important to note that these procedures are complex and require a high level of surgical

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expertise. They can be associated with a prolonged operating time during which the patient is placed in steep Trendelenburg position. We would suggest a two-surgeon approach for these procedures, especially during the early learning curve to minimize any risk. A recent review found that the median operating time for the reconstructive part of the surgery was 180 min (144–300 min) [13], with another study presenting a refined technique, and a median time of 124 min (97–327 min) [14]. Our median console-operative time is currently 182 min, and we would suggest that even with teaching and training, the total procedure should be no longer than 4 h for an ileal conduit and 5 h for an orthotopic neobladder [7].

As a general rule, the high morbidity and mortality of radical cystectomy (regardless of the surgical approach and the urinary diversion chosen) are reduced when performed in high-volume centres, and there is a clear volume-outcome relationship [15, 16]. A complication is defined as a deviation from the normal post-operative course, and it can generally be categorized as intra-operative, early, or late. Early complications are directly linked to the intervention, and arise by definition during the first 30 days after surgery. The prevalent ones are gastrointestinal, urinary leak and infection. Other early complications are pelvic collections, thrombo-embolic events and wound-related complications.

This chapter will focus on the steps in patient selection, preparation, technical details and post-operative care that are needed, in order to minimize complications due to robotic orthotopic neobladder formation.

Prevention

Patient Selection and Pre-operative Preparation

There are two key aspects to patient selection; firstly, informed patient choice, and secondly, appropriate assessment of patient co-morbidities. An orthotopic neobladder requires special lifelong post-operative care and attention, and only patients who are willing and able to do so should be chosen for this type of diversion. Patients should have an honest discussion regarding the long-term functional outcome, and it is essential that this should include previous patients and specialist nurses, continence and enhanced recovery staff. One of the rate-limiting steps is the ability to perform intermittent self-catheterization. This is an important skill enabling a patient to manage continence issues, mucus, minimize infection and metabolic complications. It should be central to the initial patient counselling process.

Patients for radical cystectomy are usually older and have comorbidities, which partially explains the high complication rates of this procedure [17]. Chronological age is less of a consideration than biological age and mental and physical fitness [18]. Patients at our institution undergo a specific pre-operative assessment focusing on anaesthetic aspects, enhanced recovery and stoma/neobladder care. We routinely use cardiopulmonary exercise testing for cystectomy patients. Some authors recommend using a cardiopulmonary exercise anaerobic threshold (CPEX-AT) of <8 mL/kg/min as a contraindication. We would suggest care needs to be taken with any patient with an AT <11 mL/kg/min.

Good respiratory, hepatic and renal functions are essential in order to manage the metabolic and acid-base disturbances. Hepatic impairment is a contraindication for an orthotopic reconstruction, as these patients may not be able to metabolize the ammonium that is reabsorbed from the urine, potentially leading to hepatic encephalopathy [19]. Continent urinary diversion leads to prolonged contact of urine with highly absorptive bowel mucosa, and patients with impaired renal function are not able to excrete absorbed hydrogen ions, often leading to hyperchloremic metabolic acidosis. Clinical signs are dehydration, nausea, lack of energy, vomiting and seizures [20]. Hence, patients with an eGFR of less than 50 mL/min/1.73^2 should not be offered a continent reconstruction [21].

Prior surgery can make minimally invasive access to the abdomen difficult. However, in our experience, this is only a relative contraindication to robotic surgery. Crohn's disease and ulcerative

colitis, previous pelvic surgery and radiation are further contraindications. Patients with a history of bowel resection, urethral stricture and radical prostatectomy should not be operated on during the early learning curve, but remain potential candidates for an orthotopic reconstruction.

There are several aspects of pre-operative preparation, which can translate into improved outcomes. Firstly, poor pre-operative nutrition is associated with co-morbidities and underlying disease processes, such as cancer [22]. In patients undergoing cystectomy, it is an independent risk factor for complications, increased hospital stay and costs [23]. We routinely use the Malnutrition Universal Screening Tool (MUST) produced by The British Association of Parenteral and Enteral Nutrition. A dietician reviews patients identified as high-risk pre-operatively.

Secondly, the routine practice of mechanical bowel preparation (MBP) has been challenged for over 30 years. Not only does MBP cause metabolic and electrolyte imbalance, dehydration, abdominal pain/bloating and fatigue, but it may actually have detrimental effects on surgical outcome. Multiple RCTs and meta-analyses have been published over the last decade suggesting that it is safe to omit MBP [24], and as a result, it has long been abandoned in our centre.

Finally, the practice of fasting patients from midnight is used to avoid pulmonary aspiration has no evidence base. In fact, it increases the metabolic stress, hyperglycaemia and insulin resistance, which the body is already prone to during the surgical process [24]. We routinely use clear carbohydrate-loading drinks 2 h prior to surgery. In addition to the improved metabolic effects, it facilitates accelerated recovery through early return of bowel function and shorter hospital stay, ultimately leading to an improved perioperative well-being [25].

Patient Positioning

Patient positioning is an essential part of any operation but particularly for robotic-assisted procedures due to the steep Trendelenburg position required. Various complications have been described in association with patient positioning. These include compartment syndrome, perioperative deep venous thrombosis (DVT), neurological damage due to pressure areas and traction and damage to skin. A significant predictive factor is the duration of surgery.

There are a variety of methods to position the patient and support them. Vacuum or egg-box mattresses, or gel-pads have been used to support the patient's body. Options for leg support include hydraulic lithotomy boots or a split leg table. With either approach attention to pressure points is essential. In addition, we would routinely use graduated compression stockings and pneumatic compression devices to reduce the risk of thrombo-embolic events.

The arms are wrapped by the patient's side with attention given to the anaesthetic lines and monitoring to prevent direct pressure to the skin. An NG tube should be used, to ensure decompression of the stomach, and to prevent acidic stomach contents refluxing, leading to aspiration and potentially damaging the cornea. We routinely use eye masks and eye cream to protect the eyes.

The most significant predictor of a positioning-related complication in robotic-assisted surgery is the duration of the procedure. Attention to all of the points raised above is important; however, individual surgical teams should be mindful of operative times with the primary focus being patient's safety. Particularly early in the learning curve, we would suggest surgical teams have pre-agreed limits on operative time and progression through the operative steps (see Fig. 27.1). Difficulty in achieving these should then result in a positive and safe decision to either level the patient for a short period or convert to an open procedure.

Bowel Isolation and Urethral Anastomosis

Several techniques of orthotopic neobladder formation have been described which will be discussed in more detail later in the chapter. All techniques use a segment of ileum of about 50 to

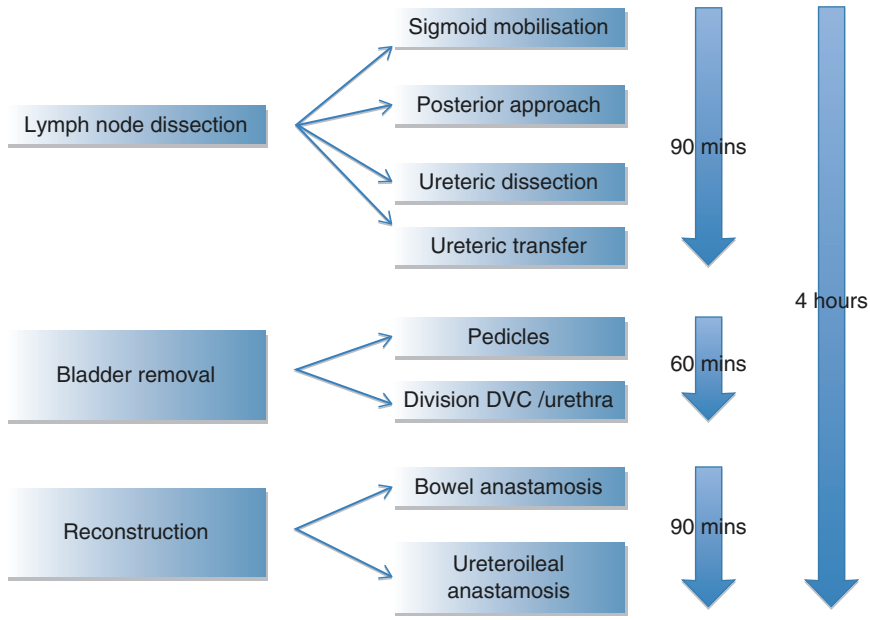

Fig. 27.1 Bristol Urological Institute modular training scheme for robotic-assisted radical cystectomy and intracorporeal ileal conduit, including console times. (Training orthotopic neobladder requires an additional 60 min)

65 cm length, which is disconnected with an Endo GIA. We use a 60-mm laparoscopic tissue load (3.5-mm thickness) stapler (Echelon Flex 60, Ethicon Inc., Cincinnati, OH). For bowel handling, we use atraumatic Cardiere forceps (Intuitive Surgical Inc., Sunnyvale, CA, USA) as they are more versatile than the atraumatic double-fenestrated bowel graspers. The Cardiere forceps have the added benefit of allowing more precise tissue handling and suturing; however, they have a slightly increased risk of tissue trauma when compared to the bowel graspers.

The port placement shown in Fig. 27.2 optimizes the work space for efficient bowel handling. The robotic port railroaded into the 15-mm assistant port on the left side is removed allowing access with the bowel stapler into the peritoneal cavity. In our experience, there is no need to selective identify the small bowel vascularization by illumination, or to use cyano green, as proposed by some authors [26]. Leakage of the ileal anastomosis has been reported in 1% of cases, and most surgeons perform a side-to-side anastomosis using an Endo GIA stapler [13]. We do not routinely re-enforce the anastomosis with sutures, but prefer to perform the so-called trouser stitch, as the heel is the weakest point of the anastomosis and is prone to tearing. The key step to avoid inadvertently compromising the bowel vascular supply is to apply the stapling device in parallel with the mesenteric arcades (see Fig. 27.3). We do not use stay sutures, but instead mark the distal end of the ileal conduit with a 2–0 polyglactin 910 suture (Vicryl) (Ethicon Inc., Somerville, NJ, USA) to help guide our orientation and prevent the incorrect bowel segments being re-anastomosed. As with open surgery, the terminal portion of ileum needs to be preserved, in order to prevent malabsorption with subsequent diarrhoea and Vitamin B12 deficiency.

When performing an orthotopic neobladder, we adopt the technique described by M. Annerstedt et al. We will often examine the small bowel for mobility early on in the procedure enabling the theatre staff to prepare for the ultimate reconstructive choice. Our preferred approach is to perform the initial and most distal staple line before starting the urethral-enteric anastomosis. Performing this step first minimizes traction on the delicate urethral-enteric anastomosis after its completion. The remaining steps to form the neobladder are performed following

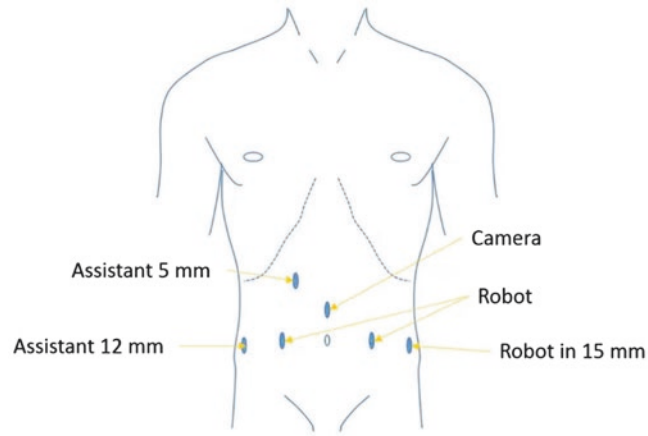

Fig. 27.2 Port Placement, the 15-mm port is used for the laparoscopic stapler. During Cystectomy, a Pro-Grasp forceps is introduced through the port in a standard robotic cannula

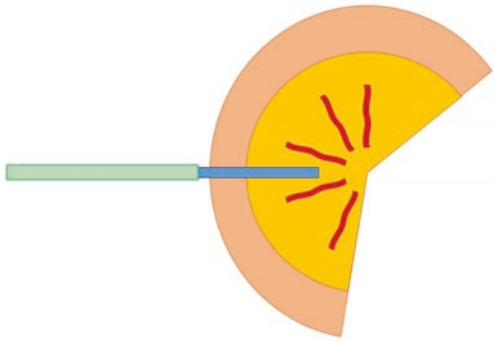

Fig. 27.3 The laparoscopic Endo GIA introduced through the left 15-mm port is used to isolate ileum for neobladder formation

the anastomosis, which essentially fixes the bowel in position enabling efficient progression through the subsequent steps.

The bowel segment chosen should have a sufficiently long mesentery that can reach the urethra easily, allowing a tension-free anastomosis. As with open surgery, incision of the mesenteric serosa can be made to gain additional length. However, proceeding with orthotopic reconstruction should be carefully considered if such methods are employed, as the ultimate aim must be a true tension-free anastomosis. Preservation of post-operative continence requires steps described extensively from radical prostatectomy. These include careful apical dissection, preservation of urethral length and nerve-sparing. We use a double-armed 3–0 poliglecaprone (Monocryl) suture with an RB-1 needle (Ethicon Inc., Somerville, NJ, USA) to perform the anastomosis in a running fashion (although some surgeons prefer a 3–0 barbed, locking suture). In addition, using a bowel grasper or Cardiere forceps in the fourth arm allows the bowel to be held and stabilised deep within the pelvis, whilst needle drivers are used in the two main working arms to complete the anastomosis. This step has a similar effect as performing a Rocco-suture prior to the anastomosis in radical prostatectomy.

Ureteric Anastomosis

Stricture of the ureteric-intestinal anastomosis occurs in 2.4%[4] to 5.4%[13] of cases (3% from our data). Thus, its incidence is rather low and comparable to that seen with open surgery. Leakage due to an insufficient ureteric-ileal anastomosis is reported in up to 4.3% of cases [27]. As anti-reflux ureteric implantation seems to offer little benefit in terms of preservation of renal function and prevention of urinary tract infections, refluxing techniques have become the standard for both open and robotic surgery [8]. Nevertheless, as a mechanism to reduce reflux, we would suggest routinely using an isoperistaltic afferent limb for ureteric implantation, as first described by Studer [28].

Many surgeons prefer the Wallace implantation technique over the Bricker technique [13] as it was traditionally reported to have lower

stricture rates; however, this is still under debate [29]. With the Wallace technique, retrograde access to the kidneys is certainly easier, but the disadvantage is that a potential stricture frequently blocks both kidneys. In essence, the type of anastomosis should be chosen according to the surgeon's preference and experience. Implantation follows the principles of open surgery: the ureter should be tension-free and kinks should be avoided. We recommend careful handling of the tissue during ureteric anastomosis, and we avoid any stripping of the adventitial tissue around the ureter in order to maintain good blood supply.

After the cystectomy, we transpose the left ureter under the sigmoid, though a generous window. The key to this sometimes-daunting step is to have completed an adequate pelvic lymph node dissection. This clearly demonstrates the retroperitoneal and pelvic blood supply and allows safe passage of the ureter avoiding damage to the large vessels but also the inferior mesenteric artery. The patient's own anatomy will frequently guide the surgeon, with the window through being deeper than initially though. The ureters are closed off with a purple clip (Weck Hem-o-lok; Teleflex; Limerick, PA), onto which a 2–0 polyglactin 910 (Vicryl") (Ethicon Inc., Somerville, NJ, USA) suture is tied, to aid ureteric handling. To keep the ureters safe and to correctly identify them at a later stage, they are then clipped to the right lower quadrant of the abdominal wall. This essential step protects the ureters from accidentally getting caught within the staple-line during bowel isolation. The ureters are shortened as far as possible to remove redundant tissue and optimize blood supply, which is easily achievable with an intra-corporeal approach.

Stenting of the ureteric anastomosis has been shown to prevent urinary leakage, upper tract dilatation and associated complications [30]. We use two 7.0F single J stents (Bander Ureteral Diversion Stent Set, Cook Medical, Spencer, IN), which are fixed to the neobladder with a fast resolving 3–0 polyglactin 910 suture (Vicryl rapid) (Ethicon Inc., Somerville, NJ, USA) to prevent accidental removal. We externalize the stents through the neobladder wall and the abdominal wall, while some others tie them to the catheter for easy extraction when the catheter is removed [26].

Neobladder Formation

The majority of post-op complications following radical cystectomy are linked to the reconstructive part of the procedure [31]. A recent review found a complication rate of 17.2%. There were 31.4% Clavien I, 1% Clavien II, 62.9% Clavien III and 0% Clavien IV and V [13]. This seems to be comparable to the rates reported in a large open series [31]. Another study by the International Robotic Cystectomy Consortium, which did not distinguish between neobladder and conduit construction, found a major complication rate of 20% for RARC in patients with intra-corporeal diversion. In the group with extra-corporeal diversion, a 32% complication rate was seen [6]. Our own data demonstrate a reduction in overall complications from 48 to 31% in favour of robotic-assisted surgery, with a 5% significant (Grade 3/4) complication rate [7].

The first case of an RARC with intra-abdominal formation of an orthotopic ileal neobladder – a Hautmann neobladder – was described in 2003 [5]. Since then, several different techniques have been described; the most commonly used technique being a modified Studer Pouch [13]. A U-shaped without cross folding [32], a Y-shaped pouch [33] and a pyramid-shaped neobladder [34] have been described as well. Our preferred approach has previously been described by M. Annerstedt et al. Post-operative urodynamic evaluation has proven this technique provides a safe low-pressure system which is achievable without prolonged operative times.

Stone formation in the reservoir is rare, and it has been described in 1.4–2.8% of cases [13, 27]. It is associated with infection, residual urine and foreign bodies in contact with urine. To prevent later stone formation (for example, on staples), nearly all authors use absorbable sutures in a running fashion [13]. To prevent slipping and to guarantee water tightness, we would suggest a barbed

suture (V-lock 2–0; Covidien Inc.; New Haven, CT) [35]. However, it is interesting to note that there is no clear proof that staples act as nucleus, around which stones may form [36], and a partially stapled neobladder has been described, which yielded few problems with stone formation and had the advantage of a reduced surgical time [37]. Furthermore, it is routine practice to use stapling techniques to close the proximal end of the ileal conduit and yet this does not translate into problems with stone formation. The most challenging part of the neobladder closure involves the posterior and anterior walls close to the urethral-enteric anastomoses. It requires a careful sero-submuscosal closure around this particularly fragile portion of the neobladder. Another helpful approach is to use a few interrupted sutures to oppose the edges along the neobladder walls; this aids with the inevitable movement of the neobladder as closure proceeds.

After neobladder formation, a leak test is mandatory, and residual openings can be closed off with extra interrupted sutures. We routinely place a Robinson drain in the pelvis, located close to the anastomosis.

Post-operative Care

Post-operative care of these patients is dictated by our enhanced-recovery after surgery (ERAS) protocol. Our protocol focuses on pre-operative counselling, nutrition, standard analgesic and anaesthetic regimens and early mobilization, and has continued to develop over several years. ERAS protocols modify the physiological and psychological responses to major surgery; however, limiting the initial surgical insult, for example, with a robotic-assisted approach has become one of the key principles [7].

Our ward-staff and ERAS team ensure the neobladder is flushed every 4–6 h with 50 mls saline, to prevent blockage of the catheter by build-up of mucus. The patients are instructed to have a high fluid intake, and the catheter bag must be emptied regularly. The drain is removed as soon as the output drops to less than 150 mL/day and creatinine in the drain fluid is equal to serum levels. The exteriorized ureteric stents are removed at day 8 post-operatively and the patients return at 3 weeks for a cystogram and subsequent urethral catheter removal.

Our ERAS programme also includes a standard anaesthetic protocol. This includes the use of a low-dose heavy bupivocaine spinal anaesthetic. This reduces the use of perioperative opioids thereby avoiding many of their disadvantages. This approach, in addition to early mobilization and the use of chewing gum, reduces the incidence of post-operative ileus.

Another significant aspect of the ERAS protocol is pre-operative patient counselling. Our patients attend an enhanced recovery and pre-operative assessment afternoon. It is during these consultations that patients receive their post-operative diaries. These identify the significant post-operative milestones and also the daily goals expected of the patients (Fig. 27.4). This simple aspect improves patient satisfaction and recovery times, empowering patients to take charge of their recovery.

Urinary tract infection is a frequent complication in patients with an orthotopic bladder reconstruction. A contributing factor is certainly the high rate of bacterial colonization of the bowel segments. Reflux into the kidney and build-up of mucus and residual urine can also be contributing factors. The majority of urine cultures of these patients are positive, and while leucozyturia occurs frequent, most patients are not symptomatic. It is recommended that only symptomatic patients be given treatment.

Follow-Up

After radical cystectomy, patients need thorough follow-up, as complications can occur at any point after the surgery. Complications include deterioration of renal function, infection, stones, acid-base disturbance and functional deterioration with incontinence and disease recurrence.

We would suggest a regular check of the patient's renal and liver function, in addition to an assessment of acid-base balance and a full blood count. Continence is assessed clinically

Fig. 27.4 Bristol Urological Institute robotic cystectomy patient diary

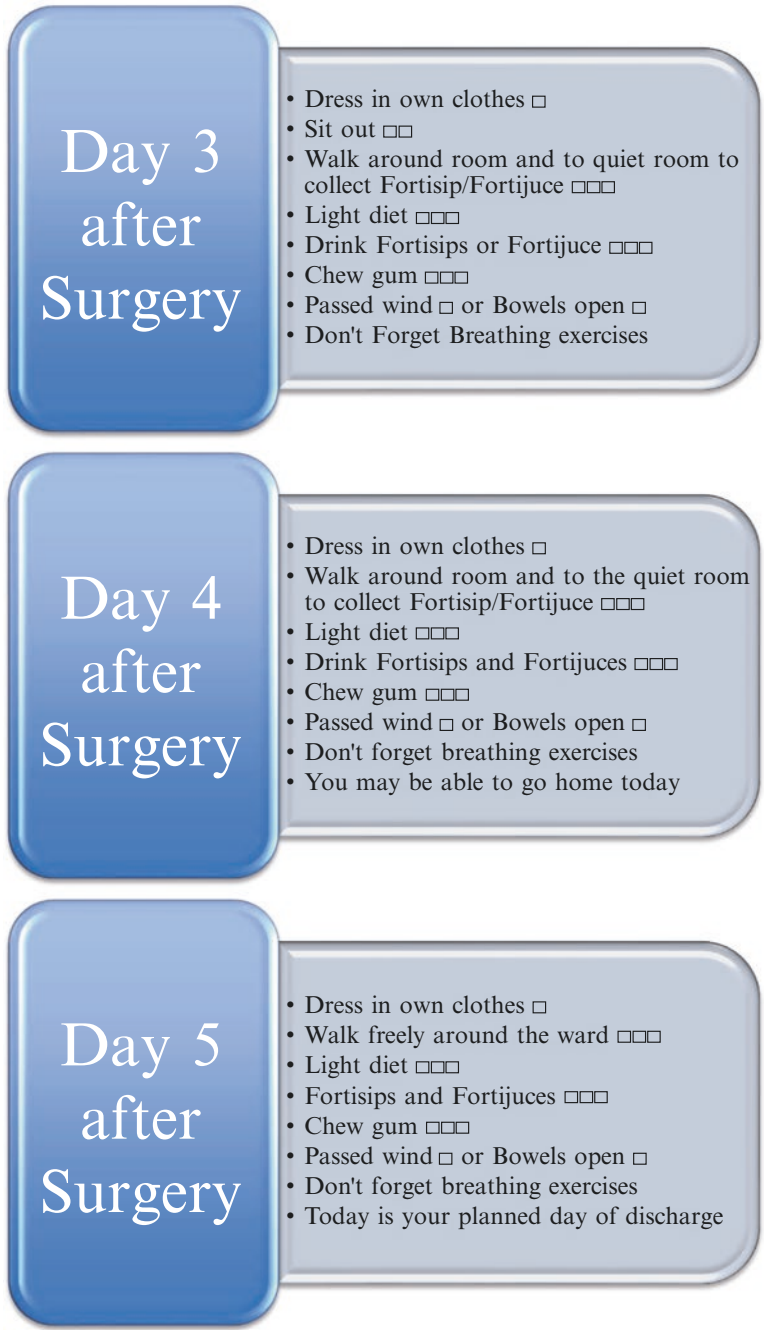

Fig. 27.4 (continued)

and with the use of voided volumes and intermittent self-catheterization volumes. Some authors recommend measuring continence no sooner than 12 months post-operatively, as the neobladder needs time to mature and to reach full capacity. Several series have achieved day- and night-time continence rates of up to 80–90% in men and 70% in women [27].

We would suggest a stage – dependant approach to the detection of disease recurrence. A protocol based on ultrasound is adequate for T2 patients. Cross-sectional imaging should be used 6 months and 12 months post-operatively in patients with T3 or more or any nodal involvement. The final group is patients with high-grade superficial disease who should receive annual assessment of their upper tracts with excretion-phase cross-sectional imaging.

Conclusion

Robotic orthotopic neobladder formation is feasible and safe. Data on specific complications of RARC are sparse; however, the rates seem similar to those that have been published for open series. Following of sound surgical principles, optimization of the minimally invasive approach and proper patient selection are the keys to success.

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Radical Cystectomy and Urinary Diversion

28

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Introduction

Radical cystectomy (RC) with pelvic lymph node dissection (pLND) represents the standard of care for muscle-invasive and refractory nonmuscle-invasive bladder cancer. Growing interest in minimally invasive approaches, especially robot-assisted radical cystectomy (RARC), has been spurred aiming to decrease perioperative morbidity. RARC has been shown to be equivalent to the open approach in terms of oncologic and functional outcomes but superior in terms of blood loss, transfusion, hospital stay, and convalescence [1].

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However, irrespective of the surgical approach, RC remains a morbid procedure with significant complications [2, 3]. It remains a complex and demanding procedure that involves simultaneous procedures performed in the urinary and gastrointestinal tracts, in addition to the retroperitoneum. Adding to this, bladder cancer is a disease of the elderly, and given that smoking is the main contributor to bladder cancer, patients usually suffer other comorbid conditions, especially cardiac and pulmonary, that pose additional anesthetic and surgical risks [4]. All of the aforementioned factors contribute to the high morbidity associated with RC.

Complications can be broadly divided into two main categories: general complications that may occur with any major surgery, e.g., thromboembolic events, cardiac and pulmonary complications; and procedure-specific (those related to RC, pLND, and urinary diversion). Perhaps, most of the latter groups are diversion-related [5]. Such complications vary according to the type (ileal conduit vs continent diversion) and technique of diversion (intracorporeal vs extracorporeal). They may respond to conservative, endoscopic, and percutaneous measures, but many will require reoperations during convalescence or even years later [5, 6].

While complications following RARC have been reported using standardized approaches, mainly within 30 or 90 days after RARC, there have been paucity of data on management of

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complications and their outcomes, especially those requiring surgical intervention. In this chapter, we describe postoperative complications related to RC and urinary diversion that may require reoperations, their causes, means of prevention, and treatment including operative management.

Uretero-Enteric Complications

Uretero-enteric anastomotic complications represent the main cause of renal dysfunction after urinary diversion. They include obstruction, reflux, and urinary leakage. Obstruction may occur as a result of malignancy (local recurrence or pelvic adenopathy), or due to edema or hematomas in the early postoperative period, or from inadvertent twisting of the ureters when replacing the new reservoir in the abdomen after extracorporeal diversion during RARC [7]. Strictures may result from ischemia due to previous radiation or compromised ureteral vascularity during dissection or due to technical errors during anastomosis [8]. It is controversial if the type of uretero-enteric anastomosis (Bricker vs Wallace) affects the stricture rates [6, 9, 10]. Antireflux (tunneling) techniques have been associated with higher rates of strictures [11]. There is wide discrepancy in reporting the incidence of uretero-enteric complications, which may be attributed to the variability in reporting (in terms of patients or renal units), the frequency and type of imaging used, surgical technique and the follow up durations [12, 13]. Strictures were reported in 12% of patients after RARC after a median of 5 months. The cumulative incidence was at a rate of 12%, 16%, and 19% at 1, 3, and 5 years following RARC, respectively [6]. After open RC and neobladders, strictures occurred in 11% of patients at a rate of 8%, 11%, and 14% of renal units at 5, 10, and 15 years, respectively [5].

Usually patients are asymptomatic and there is often a long latency period before diagnosis (5–18 months) [14]. Therefore, follow-up is crucial especially during the first 2 years after surgery for early detection and prompt management [14–16]. Delayed management of urinary obstruction may compromise renal function and adversely impact long-term outcomes [14]. Any findings suggestive of obstruction, infection, or deterioration of kidney function should prompt further investigation.

In our experience, few technical points can prevent such complications: (1) Avoidance of excessive dissection and skeletonization of the ureters and therefore, having a good vascularity of the distal ureteric end; (2) Placing the ureters in a retroperitoneal position; (3) Wide spatulation of the ureter, and anastomosing it to a wide enterotomy in the conduit or a new bladder. We recommend removing a "button-hole" part of the bowel mucosa to serve this purpose; (4) Choosing the proper length of the ureter avoiding short ureters that will put the anastomosis under tension, or longer redundant ureters that may hinder drainage.

Initial management of uretero-enteric complications usually involves early endoscopic or percutaneous techniques, which provide initial relief of obstruction without exposing patients to significant risks. However, they lack durable long-term patency rates [17]. When conservative management fails, the gold standard is open revision with a success rate of up to 92% [17]. Despite the higher success rate, the associated morbidity and technical complexity may render the procedure challenging. We have recently reported our initial experience with robot-assisted revision of uretero-enteric anastomosis. We found that the initial results are promising and are comparable to the open approach [6]. Few other small case series reported similar outcomes and concluded that with increased comfort with the robotic platform, satisfactory outcomes can be achieved [18, 19].

Paralytic Ileus and Bowel Obstruction

Paralytic ileus and bowel obstruction can occur in up to 11% of patients undergoing RC [6, 20, 21]. Type of preoperative bowel preparation, prolonged fasting before surgery, pain control, long-term nasogastric intubation, excessive fluid

administration, and delaying oral feeding after surgery are well established risk factors for paralytic ileus [22]. Bowel obstruction may occur as soon as few days following surgery or many years after. Possible causes include excessive bowel manipulation during surgery, presence of retroperitoneal collections resulting from urinary leakage or infections, electrolyte imbalance (e.g., hypokalemia), stenosis of the ileo-ileal anastomosis, and intraperitoneal adhesions. Nevertheless, most patients usually respond to conservative measures (Drip and Suck—IV fluids and nasogastric tube drainage). Less commonly internal bowel herniation and peritoneal carcinomatosis (<5%) may also cause bowel obstruction [6, 23].

Bowel-related complications may be avoided by gentle bowel handling during surgery, electrolyte replacement, adequate anastomosis, and adopting the fast-track principles (avoid prolonged fasting preoperative, carbohydrate loading few hours prior to surgery, early removal of the nasogastric tube, early institution of oral diet postoperative, early mobilization, and gum chewing) [24]. Some medications may also be helpful as Alvimopan [24].

The intervention rate after failure of conservative measures has been less than 3%, in both open and robotic series [5, 6, 25]. Intervention usually involves adhesiolysis and evaluation of bowel integrity. If bowel viability is a concern, bowel resection and diversion or primary anastomosis may be required. We have recently reported our experience in the robot-assisted management of bowel-related complication and found comparable results with open exploration [6].

Fistula

Fistulae following RARC and open RC occur in less than 4% of cases [5, 25]. Fistulae may develop between the intestine and the reconstructed urinary tract or from any of these to the skin or even the other organs. Symptoms vary with type and size of the fistulous tract. Patients can present with total incontinence (neobladder-vagina), pneumaturia or fecaluria (neobladder-bowel) or with recurrent urinary tract infections.

Technical modifications may decrease the incidence of fistula, including preservation of female genital organs (when oncologically feasible), closing the vaginal stump meticulously with embedding of the mucosa, covering the vaginal stump with peritoneum in front of the anterior rectal wall and interposing a generously pedicled omental flap between the closed vaginal stump and the urethra-enteric anastomosis, or placing it in front of neobladders [26].

We reported our initial experience with robot-assisted repair of different types of fistula following RARC. Although the operative time was significantly longer, none of the patients required reoperation [6]. Similar results have been reported by a recent study, that described successful RA repair of 10 iatrogenic vesico-vaginal fistulas after gynecologic procedures [27].

Stones

Stones may occur because of urine stagnation which may result from improper emptying of reservoirs and accumulation of mucus. They may also occur as a result of urine contact with staplers, or as a consequence of recurrent urinary tract infections with urease producing bacteria [3, 28]. Inadequate hydration of patients, hyperosmolar supersaturated urine that may further contribute in stone formation are additional risk factors [3].

Adequate hydration of patients and proper emptying of reservoirs are the main means of prevention. This can be achieved by timed voiding (voiding by the "clock"), where patients regularly empty their reservoirs either by straining and performing pressure on the lower abdomen (Crede method) or by the use of intermittent self-catheterization (ISC), or indwelling catheterization especially at night. Another key point is to avoid the use of excessive bowel length, as reservoirs distend with time, which may be complicated by high residual urine, increased absorptive and metabolic complications, renal dysfunction, and overflow incontinence [3]. The use of Vicryl staplers may reduce stone formation but on the expense of reduced volume [29].

Treatment of asymptomatic bacteruria until the urine is sterile is controversial because as many as 40% of neobladder patients will have persistent bacteruria [3].

Stones can be managed according to their size and composition. In most of the cases, endoscopic dusting, or disintegration and extraction can be safely performed. For larger and harder stones, open or robot-assisted removal can be ensued [6].

Stomal Complications and Parastomal Hernia

Stomal complications range from skin excoriations, stomal stenosis requiring only dilatation, to complete stomal failure requiring stomal revision. These may be attributed to compromised blood supply to the conduit, as a result of narrow base of the mesentery supplying the conduit, or inadvertently twisting it, or patients with compromised bowel function as a result of inflammatory bowel disease, or prior irradiation. It may also occur as a result of narrowing at the skin level [3].

These can be avoided by ensuring adequate vascularity and breadth of the mesentery supplying the conduit. In cases of prior pelvic irradiation and possible bowel dysfunction, the transverse colon may provide a better alternative [3]. Mesh can be used to reinforce the weakened fascial planes around the stoma [30]. However, this may be associated with recurrent stenosis, and stomal relocation to the other side may be necessary [3].

Parastomal hernia is a common complication following ileal conduit urinary diversion. They are usually asymptomatic and diagnosed on routine imaging as part of cancer surveillance. Some authors suggested prophylactic insertion of a mesh while constructing the ileal conduit [31]. Less than 1% of patients will require repair for parastomal hernias after RARC and open RC [6]. Most parastomal hernias can be safely managed conservatively. Repair includes dissection of the hernia sac and contents and lysis of any adhesions. The contents should be carefully inspected and viability assured. If viability is of any concern, omentum and or bowel resection should be considered. A mesh is then fashioned around the conduit and sutured to the anterior abdominal wall. Recently, robot-assisted adhesiolysis and mesh hernioplasty have been shown feasible and of durable response [6].

Neobladder-Associated Retention and Rupture

The neobladder lacks the nervous innervation and therefore, patients usually do not get the desire to void but rather a sense of abdominal distension. Therefore, patients are instructed to void by the "clock" and to regularly empty their neobladders. In cases of large residual urine, patients may also be asked to perform intermittent self-catheterization (ISC). Bladder irrigation to wash any accumulated mucus is also essential [3]. Otherwise, over distension of the neobladder may result in overflow (incontinence, especially nocturnal), increased metabolic complications (as hyperkalemia, acidosis, etc.) from increased absorption of urine constituents, stone formation or rarely, neobladder rupture with minor trauma [5]. Abdominal exploration will usually be required with neobladder repair and/or urinary diversion.

Subneovesical obstruction may occur in approximately 2% of cases because of local tumor recurrence infiltrating the pelvic floor and neobladder neck, neovesicourethral anastomotic stricture and urethral stricture [5]. Malignant obstruction is managed by systemic chemotherapy with undiversion to other forms of urinary diversion [5]. Neovesicourethral anastomotic stricture can be successfully managed endoscopically.

Lymphocele

There is growing body of evidence highlighting the importance of pLND. Despite controversy about the extent and the template, there is increased utilization of extended pLND with minimal additional morbidity [32–35]. Lymphoceles may be related to inadequate control of lymph vessels

during pLND. The incidence also increases with salvage RC [36]. Lymphoceles may be asymptomatic and require observation only. Larger lymphoceles may compress the ureters and cause hydronephrosis and therefore, usually require percutaneous drainage [3]. Adequate sealing (bipolar coagulation, ligating, or clipping) of lymphatic vessels may help prevent this complication [3].

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Incontinence and Pelvic Organ Prolapse Surgery

29

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Introduction

Since 2005, the Food and Drug Administration (FDA) granted its approval to use the da Vinci Robotic Surgical System for gynecological practice. The da Vinci robot (Intuitive Surgical, Inc., Sunnyvale, CA, USA) was developed to overcome the tough learning curve of laparoscopic surgery in different reconstructive surgical procedures. The robotic instrument's three-dimensional vision, stereotaxy and more precise and controlled movements allow surgeons to perform minimally invasive complex procedures in a safe and comfortable environment. Currently, robotic procedures are being used to treat urinary incontinence and to treat pelvic organ prolapse with good results around the world [1]. Ulubay (2015) reported similar results in a 6-month follow-up when curing urinary incontinence with both conventional Burch and robotic laparoscopy [2]. Constant progress in robot surgery has also warned of possible complications. Wechter et al., report that intraoperative complications occur between 1.6% and 3.5% of all gynecologic surgeries: damage to the intestine, 0.7–2.8%; damage to the urinary tract from 1.2% to 3.5% and conversion to laparotomy from 0% to 26.3% [3]. Other reported complications include de novo detrusor instability, acute urinary retention, failure in the procedure requiring another operation and a possible increase in posterior compartment prolapse.

In spite of the ever more generalized use of the robot, there is still limited experience in the prevention of complications. Since a detailed review of the different techniques goes beyond the objectives of this chapter, we will focus on analyzing the major complications reported in robotic surgery for stress urinary incontinence and pelvic organ prolapse.

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General Complications

Measures to prevent complications start with the selection of the patient. The surgeon should be aware of the fact that a variety of factors, such as advanced age, hormonal status, obesity, and associated illnesses will greatly influence whether a patient is eligible for urogynecologic robotic surgery, in order to counterbalance the risk of complications [1].

As concerning the positioning of the patient, the Trendelenburg extreme position has been reported as not necessary in benign gynecological disorders. Thus, increased morbidity in ventilatory and anesthetic mechanics is greatly lessened [4]. Prolonged time in surgery [5], in addition to significantly raising costs, may favor nerve damage by prolonged lithotomy position. The most commonly affected nerve bundles are the posterior tibial in the lower extremities and the brachial plexus in the upper limbs [1]. Once surgeons gain experience and dominate surgical anatomy, such surgical times and the appearance of complications are significantly reduced [6].

Robot laparoscopy has some risk factors inherent to it, such as loss of tactile sensitivity, the surgeon's position being far from the surgical field; use of the robot's fixed rigid arms, and potential electrothermal damage because often the arm carrying the electric instrument escapes from the visual field of the surgeon [3].

Chen (2015) reports 5% robotic surgery complications in urogynecology benign pathologies and 8.6% in oncological gynecological surgery. The resulting complications were intestine and ureter lacerations and bladder injury [7], although we must consider that oncology gynecologic surgery per se bears more risk of complications than those in benign procedures such as Burch and Sacrocolpopexy [8].

Surgery for Urinary Incontinence

Burch Procedure

Retropubic cystourethropexy or Burch colposuspension is considered the golden standard for the management of stress urinary incontinence. It currently shares this place with the use of tights and straps [9]. The advantage of using the robot in this procedure has been demonstrated since the articulated movements make dissection and suture easier [10]. The most commonly reported complication is damage to urinary organs, up to 4%. This is similar to the open procedure technique, which can have greater incidence when there are concomitant procedures such as hysterectomy or oophorectomy [11].

Damage to Urinary Organs

Bladder Injury

Bladder injuries can occur in the bladder dome during initial dissection, or in the neck of the bladder during suturing, and they can be repaired intraoperatively if noticed in the moment. Inadvertent bladder lesions can cause urinary leakage and chemical peritonitis if they communicate with the abdominal cavity, or urinomas and abscesses of the pelvic cavity if located in the Retzius space, which will trigger systemic inflammatory response and sepsis, the reasons of suspicion.

How Can It Be Prevented?

The empty bladder is less susceptible to intraoperative injury because it takes up less space in the surgical field and thus contact is avoided. To accomplish this, the proper functioning of the urinary catheter has to be verified, as well as making sure that the device is not pinched and there is no kink in its path. Bladder neck injury can be prevented by separating the side walls of the vagina from the bladder neck and the urethra, aided by the thimble of an assistant, who can also countertract the urinary catheter for better differentiation of tissues.

Diagnosis

Bladder injury can cause macroscopic hematuria, evident in the urine collection bag, so its presence must rule out urinary injury. Intraoperative cystoscopy is mandatory in all major urogynecological procedures, its use can confirm suspected or unseen bladder injuries. It may also show bladder suture entrapment or displacement of the trine to one side and bleeding through the ureteral

meatus, which gives way to suspicion of ipsilateral ureteral injury. The instillation of dyes such as methylene blue through the urinary catheter can help identify bladder lesions in the operative field. Those injuries that are not initially suspicious require a cystogram and pelvic tomography for later diagnosis.

Treatment

A singular, short, and linear bladder injury can be repaired intraoperatively ideally with two suture planes, ensuring the proper functioning of the urinary catheter that will remain for 7–10 days. Extensive, multiple, or complex stroke injuries, aside from the closing, may require cystostomy tube to reduce intraluminal pressure, and placing a drain outside to avoid collection and evaluate their output. Intestinal or vascular injuries require the inclusion of other specialists and the possibility of conversion to the open technique.

Ureteral Injury

It can happen due to entrapment of the ureter with the suture, which is more common in the intramural portion, or due to its complete or incomplete section during dissection of tissues; it is more commonly reported on the right side. Risk factors for these injuries are: history of previous pelvic surgery or radiotherapy.

How Can It Be Prevented?

Knowledge of surgical anatomy is required. The ureter can be confused with the gonadal vein; in order to distinguish them, one must first differentiate their path. Moreover, the robot's camera can be approached to see, after a moment, the peristalsis movement of the ureter, which can sometimes be seen even without dissection; this structure must be handled extremely carefully, since if it were actually the gonadal vein, it could cause a tear and severe bleeding.

Preoperative placement of ureteral catheters in patients with risk factors reduces the incidence of injury and promotes rapid diagnosis and treatment. In laparoscopic surgery, it has been suggested that when the surgeon stands on the left side of the patient to operate, the placement of the suture tends to go from lateral to medial in the right side structures, which increases the risk of trapping the bladder and the intramural ureter with the suture. This does not happen on the left side because the surgeon places medial to lateral stitches; therefore, it is always recommended to suture from medial to lateral. In open surgery, the surgeon could traditionally feel the assistant's thimble and locate the correct placement of stitches; however, in robotic technology, the ability to distinguish the hardness of the instruments depends on the surgeon's experience.

Diagnosis

Early injury is suspected in the surgical field, and there may sometimes be hematuria in the urine collection bag. Inadvertent ureter injury usually causes fever and flank pain on the affected side in the first few days. Later on, there may be ileus and peritonitis if there is leakage of urine to the abdominal cavity; in late cases, ureterovaginal or skin fistula may arise. Intraoperative cystoscopy and retrograde pyelography should be performed at the slightest suspicion of ureteral injury; in late cases, the contrasted abdominopelvic tomography is also required.

Treatment

It will depend on the time of diagnosis and the degree of ureteral trauma. The best chance for successful repair is in the operating room when the lesion is recent. Lower-grade injuries may be solved during the procedure with primary closure and placement of double-J stent; late and higher-grade injuries may require one or more surgical steps, including surgical cleaning and closure, ureterovesical reimplantation, use of tubular bladder flap (Boari Flap), or whatever is necessary in order to preserve renal unity.

Vascular Injuries

Vascular complication is the most devastating. It may occur when addressing the Retzius space, damaging the neurovascular obturator bundle. Typical damage occurs when the needle is handled carelessly, and it causes vessel injury. When this happens, the area must immediately be irrigated to allow visualization of the damaged vessel and occlude it, the use of 10-mm hemoclips is

recommended for this. Electrocauterization is not recommended due to the risk of causing more damage and injuring the obturator nerve; if the blood vessel retracts, hemostasis becomes very difficult, and the support of a vascular surgeon will be required [12].

Obturator Nerve Injury

When the Retzius space is dissected, it is essential to know the anatomy and locate the neurovascular obturator bundle immediately to avoid injuring it. The injury can be seen in the operative field. It may be partial or complete, and intraoperative neurorrhaphy should be performed. This injury may have temporary effects that require medical handling and physical therapy, but it may also have irreversible consequences affecting the patient's life quality.

Urinary Retention

It is more common in elderly patients with long evolution of urinary incontinence and associated comorbidities. The immediate step is to evacuate the urine by placing a Foley catheter; however, if the problem recurs, the placement of a cystostomy catheter is probably necessary while the patient is again suited to transurethral urination.

Failure Procedure

Should re-evaluate fully the overall clinical context of the patient, draw on such paraclinical studies and urodynamic to confirm incontinence and together with the patient to decide if again new procedure Burch colposuspension or is decided by the management with straps or mesh.

Surgery for Vaginal Vault Prolapse

Sacrocolpopexy

Sacrocolpopexy has been performed with proven success when handling vaginal vault prolapse since its introduction by Lane in 1962. Prolapse treatment aims at restoring anatomy and function. It is indicated when conservative measures fail [13, 14]. The challenging difficulties of sacrocolpopexy surgical technique make it the ideal urogynecological procedure with robotic surgery.

It is important to consider that, often during sacrocolpopexy, the anterior vaginal wall is repaired, as well as the possibility of associated Burch, in order to prevent urinary incontinence masked by the prolapse. Therefore, it is important to plan surgical time and technical details to make these procedures simultaneously, since this constitutes significant increase in costs and risks [1, 13, 15–19].

Robotic laparoscopic surgery offers good results and fast recovery to patients who undergo sacrocolpopexy [19]. Level III studies suggest similar results to those obtained with open sacrocolpopexy. Laparotomy, laparoscopy, and robotics share the same efficacy and safety. Some advantages have been reported with the use of the robot, such as less blood loss and better visualization, especially in the dissection of the presacral space. Moreover, the robot facilitates maneuvers, such as intracorporeal knots. As for operating time, Ayay et al. reported an average of 170 min in sacrocolpopexy, without any complication. Surgical time will depend a lot on the surgical team's experience hours [20, 21].

Vascular Injuries

During presacral dissection, bleeding from injury to the iliac vessels or medial sacral vessels in the sacral promontory may occur; although not frequent (4.4%), it can be very disturbing when it does happen. Routine maneuvers must be carried out: raising the pneumoperitoneum, clearing the surgical field as far as possible to assess the extent of the damage and determine treatment.

Complications Related to Use of Mesh

Choosing the type of mesh to reduce the risk of erosion is very important when sacrocolpopexy is performed. Parkes (2014) recommends

polypropylene mesh as the best option. If the Y-preformed mesh is used, surgical time is reduced. To avoid the risk of inflammation of the L5-S1 disc, it must be identified and avoided; the suture must be placed below, between S1 and S2, and place the longitudinal suture for better grip. It is also important to cover the mesh with peritoneum to reduce the risk of erosion [1].

How to Prevent?

Parkes et al. (2014) propose the following measures to make robot sacrocolpopexy safer [1]:

(a) The prolypropilene Y-Preformed mesh is the one that yields the best results, and it reduces surgical times.
(b) The fixation of the mesh to the vagina should not be too low, and sacral fixation must be done with horizontal suture at S1-S2 level.
(c) Surgeon's experience in hours of surgery is important.

Treatment and Control

In case of damage to the bladder or intestine, the surgeon must decide whether to repair the damage and then continue placing the mesh, or to only repair the damage and not place the mesh, knowing that the patient will continue with prolapse. It must be taken into consideration that placing mesh on a repaired bladder or intestine increases the risk of infection and damage to adjacent organ and/or fistula [1, 22]. There are no reports or experience in literature regulating the behavior to be followed in similar case, decisions must be made very carefully based on the surgeon's experience.

Other Complications

Other complications such as injuries to the urinary tract (3.1%), intestinal lesions (5.9%), inflammation of intervertebral disc at L5-S1 (a rare but worrisome complication that can reach osteomyelitis), damage to the posterior tibial nerve due to the Trendelenburg position have been reported [1], and their treatment should be following the recommendations above and based on the experience of the surgical team.

Conclusions

The proper choice and preparation of the patient, the knowledge of the case, the appropriate use of technology, and the experience of the surgeon and his team, in conjunct, be able to reduce the incidence of complications and treat them adequately if they occur. Formal training of new robotic surgeons and the unstoppable development of technology will make Netzath's words a reality: "There is no doubt that the era of big incisions will soon come to the end… it is a burning desire not to have to wait long until large incisions are finally a memory in history" [23].

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Urinary Fistulas

30

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Introduction

The term fistula indicates an abnormal communication between two epithelial surfaces or the skin. Urological fistulas have a communication between a segment of the urinary tract and another body cavity. These include vesicovaginal, urethrovaginal, ureterovaginal, rectourinary (rectourethral and rectovesical), and vesicouterine fistulas. Urological fistulas are usually acquired and a consequence of an unrelated medical or surgically treatment. Most are delayed complications from inadvertent injuries to the bladder, rectus, uterus, or ureter. One must also rule out a malignant etiology. It has been estimated that there are currently 2–3 million women with untreated fistulas worldwide. 30,000–130,000 new cases develop annually of which >95% are in the developing world [1]. In the developing world, most fistulas are obstetric in etiology, resulting from prolonged obstructed labor [2]. Fistulas in the developed world, however, are usually from nonobstetric causes and are much less common. Among men, these may be a consequence of prostate surgery. Hilton reported his personal experience over 25 years in the United Kingdom and found 73.6% of fistulas were vesicovaginal, 10.9% urethrovaginal, and 6% ureterovaginal. Most were a consequence of surgical treatment [1].

Once the diagnosis is made, the principles of urinary fistula repair include adequate nutrition, elimination of sources of infection, unobstructed urinary drainage, tension-free closure, and interposition of healthy tissue. Conservative management of urinary fistulas has been described, but definitive treatment with surgical repair is often necessary.

Vesicovaginal Fistulas

Vesicovaginal fistulas (VVF) are the most common acquired fistulas of the urinary tract. VVF is an abnormal opening between the bladder and vagina, which may result in urinary incontinence and cause emotional and psychological distress in the patient Fig. 30.1. In the developed world, injury to the bladder, either during a vaginal or transabdominal hysterectomy, may result in the

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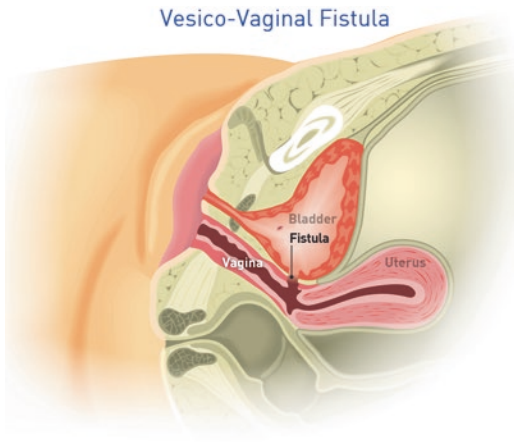

Fig. 30.1 Vesicovaginal fistula

development of a VVF [3]. Hilton reported 37.9% of VVFs occurred after an abdominal hysterectomy, 9.7% after radiation therapy, and 10.3% due to miscellaneous causes [1]. One important consideration for fistulas occurring after radiation for malignancy is whether the fistula is a recurrence of the primary malignancy. In this scenario, a biopsy of the fistulous tract is mandatory. In developing countries, the primary cause is prolonged labor, due to pressure on the anterior vaginal wall and base of the bladder, resulting in tissue ischemia [3].

VVFs occur 1–6 weeks after gynecological or obstetric surgery. Recurrent fistulas may develop within the first 3 months after primary repair [1]. Cronwell found the success rate was 88.1% after one operation, 81.9% after reoperation, and 68.9% after a second reoperation. The relative risk of needing an additional procedure after a second repair compared with after a first repair was 1.52 (95% CI 0.95–2.41; $P = 0.086$) [2]. Clinically, the patient presents with urinary incontinence, especially in the standing position. Pelvic exam with speculum has to be performed if there is suspicion of a VVF. Cystoscopy is imperative to assess the characteristics of the fistula and its relationship with the bladder and the ureteral orifices. The presence of a VVF can be confirmed with the instillation of methylene blue into the bladder, which will be present in the vagina. CT urography must be performed to rule out concomitant fistulas [3, 4]. Traditionally, surgical repair is delayed 3–6 months to decrease tissue inflammation and edema and increase the likelihood of success. Conversely, others advocate only waiting long enough to ensure reasonable tissue quality, with repair performed 2–4 weeks after the initial operation [5].

Traditionally, surgical approaches for VVF repair are vaginal or abdominal. Many urologists are relatively unfamiliar with vaginal cuff anatomy, making the transvaginal approach more challenging. For this reason, most urologists prefer the abdominal approach [6]. The selected approach depends on several factors including fistula size, number and location of fistulas, history of repair, and concomitant pathological conditions. An abdominal approach is usually preferred in patients with a large (>3 cm) fistula, supra-trigonal fistula, fistulas in close proximity to ureteric orifices, and especially in patients with complex fistulas or recurrent fistulas after failed transvaginal repair [7]. Fulguration of very small fistulas has been reported with good results [8, 9].

Nowadays, minimally invasive approaches to reconstructive surgery are commonplace. Nezhat et al. first reported retrovesical laparoscopic VVF repair in 1994 [10]. Since then, laparoscopic VVF repair has reported success rates of 86–100% [7]; however, the laparoscopic approach is technically difficult with a steep learning curve [4, 5, 9, 10].

Utilizing the technological advantages of the robotic platform, robotic VVF repair has shown excellent results, while following the basic surgical principles of fistula reconstruction [7, 11]. Robotic-assisted laparoscopic VVF repair was initially described by Melamud et al. in 2005 [11]. Later, Sundaram et al. described their technique in five cases [12]. Hemal et al. also described their technique for repair of recurrent supratrigonal VVFs [13]. All authors concluded that even recurrent supratrigonal fistulas could be repaired successfully with the robotic approach. Robotic surgery often mimics the open transperitoneal approach with creation of a cystotomy and the use of an interposition graft [7, 12–16]. Sotelo et al. [17] and Nunez et al. [18] described a transvesical approach that reaches the fistulous

tract without the need for additional vaginal incisions or extensive dissection of the vesicovaginal space. This may potentially reduce the recurrence rate and irritative voiding symptoms. The critical step is the cystotomy to localize the tract. Once the fistula is reached, the vesicovaginal space is dissected, separating both structures.

Robotic Transperitoneal Transvesical Approach

Step 1: Patient positioning
After general anesthesia is administered, the patient is placed in a low lithotomy position.

Step 2: Cystoscopy and catheterization of the ureters and fistula
Cystoscopy is performed, and both ureters are cannulated with 5F ureteral catheters. This facilitates identification of the ureteral orifices and the course of the ureters. A differently colored ureteral catheter is introduced through the bladder, passed through the fistulous tract into the vagina, and retrieved at the introitus. For large fistulas, a Foley catheter can be used instead of a ureteral catheter. Fig. 30.2.

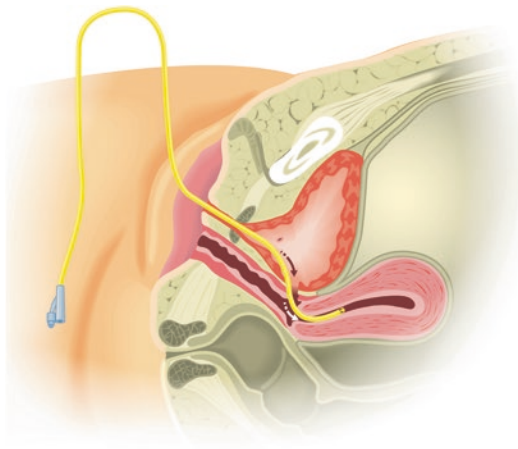

Fig. 30.2 Foley catheter can be used instead of a ureteral catheter to identified fistulous tract

Step 3: Port placement
Access is obtained with the Hasson technique at the umbilicus with a cosmetic incision. A 10–12-mm port is inserted with a 30° down lens, offering improved visualization/angles, although a 0° lens can also be used. Two robotic 8-mm ports are placed symmetrically on the left and right pararectal lines. A fourth robotic port can be omitted, with the intention of minimizing scars. If it is necessary, a fourth port can placed cephalad to the iliac crest on the left side. A 5-mm assistant port is placed cephalad to the iliac crest on the right side between the lens and the 8-mm port. Puppet maneuvers can be applied for inner retraction.

Step 4: Creation of an omental flap, cystotomy, and dissection of the fistulous tract
A sponge retractor is inserted into the vagina via the introitus. This is then used to retract the vagina posteriorly. Once abdominal access has been achieved, the first step is lysis of adhesions. Next, an omental flap is created based on the right gastroepiploic artery. Dissection of the posterior bladder wall is then performed. A vertical bladder incision is made, creating a small cystotomy, in the direction of the fistula Fig. 30.3a. A cystoscope can be inserted into the vagina and used to provide endoscopic light guidance to the fistula. However, once the bladder is opened, the tract is usually easily visualized because it has been catheterized. The bladder incision is carried deep until the posterior aspect of the catheter and vaginal sponge retractor are exposed. The bladder walls can be retracted laterally to assist with exposure. Stiches are placed on either side of the cystotomy with a Keith needle or a Carter-Thomason device. The two ends of the stitch are anchored outside of the anterior abdominal wall, providing exposure of the fistula tract Fig. 30.3b. Once the communication between the vagina and bladder is apparent, the sponge retractor is withdrawn, and a Foley catheter is placed in the vagina. The balloon is inflated with 70 cc to prevent loss of pneumoperitoneum. Dissection is continued until the fistula is

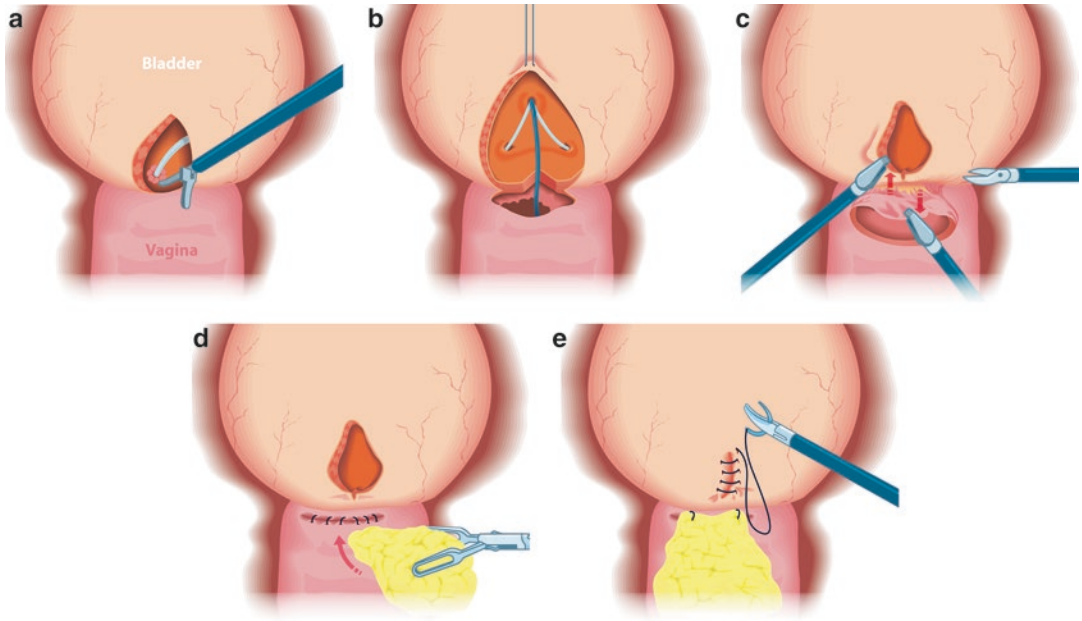

Fig. 30.3 (**a**) Vertical bladder incision is made, creating a small cystotomy, in the direction of the fistula. (**b**) Exposure of the fistula tract. (**c**) Fibrous tissue edges of the fistula are carefully excised with scissors. (**d**) Interposition of omentum. (**e**) The bladder is then closed vertically

completely separated from the vagina. The fibrous tissue edges of the fistula are carefully excised with scissors Fig. 30.3c. Further dissection is performed to create flaps for adequate tension-free closure of the vagina and the bladder.

Step 5: Closure of the vagina and bladder and tissue interposition.
The vagina is closed horizontally with a running 2–0 monocryl or barbed suture on a CT-1 needle. A suture is then placed in the anterior wall of the vagina, distal to the closure. This is used to anchor the tissue that has been harvested for interposition – omentum, if available, or an epiploic appendix can be used Fig. 30.3d. The bladder is then closed vertically, beginning at the distal apex, with a running 2–0 monocryl or barbed suture on a CT-1 needle. A second layer closure incorporating the bladder serosa is performed with an absorbable suture Fig. 30.3e.

Step 6: Catheter placement.
The ureteral catheters are removed. A 20F urethral catheter is then inserted to maintain bladder drainage. The bladder is then filled with solution colored with methylene blue to confirm a watertight closure. A suprapubic cystostomy tube is not utilized. A drain is placed in the pelvis.

Postoperative Management

Immediate Care

- Two or three additional doses of appropriate intravenous antibiotic
- Prevention of urethral catheter obstruction
- Irrigation of the bladder only if necessary

Outpatient Care

- Drain removal in 2 to 3 days, depending on fluid characteristics
- Urethral catheter removal 10 days postoperatively
- Oral antibiotic of choice for 10 days
- Sexual abstinence for 2 months
- Patients are advised to not use tampons

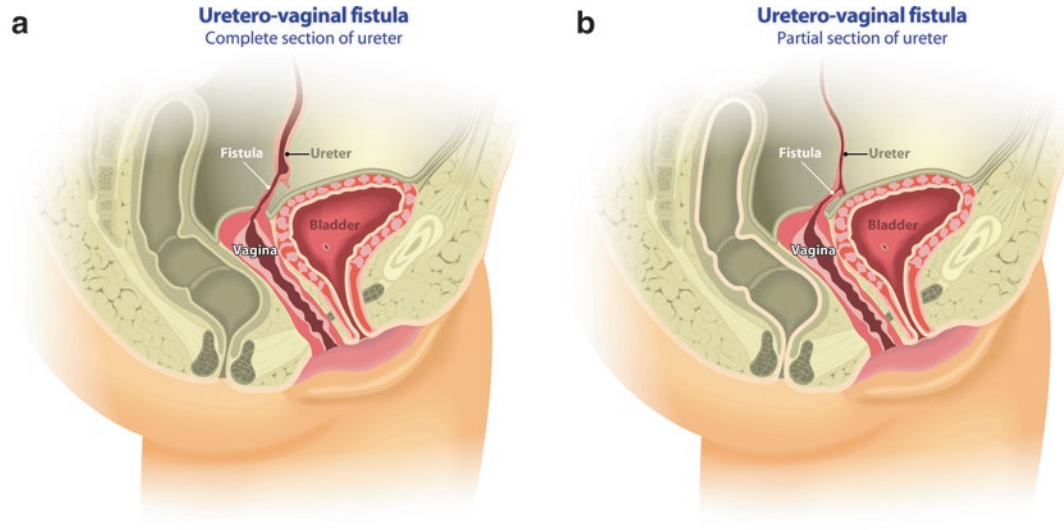

Fig. 30.4 (**a**) Complete obstruction of the ureter presents with incontinence. (**b**) Partial obstruction of the ureter, urine follows the fistula tract and also partially fills the bladder

Of note, this operation is often performed after a hysterectomy. VVF with a uterus present is rare and usually occurs after a c-section. The principles of repair are the same; however, it is critical that the bladder be opened first, without attempting to find the plane amid the bladder and the uterus, because of the risk of inadvertently opening the cervix canal. It is also critically important to adequately mobilize the vagina and bladder as much as possible to allow for a tension-free closure. This often requires closing the vagina longitudinally instead of transversally.

Ureterovaginal Fistulas

The incidence of ureteral injury during pelvic surgery is between 2% and 11% and most commonly occurs to the distal ureter during gynecological surgery [19, 20], potentially resulting in ureteral fistula formation. Nonsurgical causes of ureteral injuries are uncommon and include radiation, trauma, retroperitoneal fibrosis, and infection. The incidence of ureterovaginal fistulas due to obstetric causes varies from 5% in the developed world to 68–80% in the developing world. The incidence resulting from iatrogenic injuries during gynecological surgeries is estimated to be 0.5–2.5% [1, 19–22]. The mechanisms of injury include ureteral laceration, avulsion, partial or complete ligation, and ischemia.

The most common presentation is continuous urinary incontinence 1–4 weeks after surgery, similar to VVFs. It is important to distinguish between these because there can be a concomitant fistula in up to 12% of patients [20]. Complete obstruction of the ureter presents with incontinence. If there is partial obstruction of the ureter, urine follows the fistula tract and also partially fills the bladder Fig. 30.4a, b. This can be managed conservatively with stent insertion. Evaluation and diagnosis are made with physical examination, cystoscopy, CT scan, and retrograde pyelography/excretory urogram. Initial management with a ureteral stent, in cases of a patent ureter in continuity, has reported success rates of 55% [22, 23]. With short segmental defects, the success rate with stenting alone was as high as 71% in some series [24]. If ureteral stenting fails or leakage persists, surgical intervention is indicated. Ureteral reimplantation with a psoas hitch, Boari-flap, ileal ureteral substitution, or even auto-transplantation have been used as reliable options [25]. Yohannes et al. reported the first case of robotic ureteral reimplantation for ureteral stenosis after stone disease [26].

Studies focusing exclusively on robotic ureterovaginal fistula repair have been nearly absent.

Ureteral Reimplantation

Step 1: Patient positioning and trocar placement
The patient is positioned in the dorsal lithotomy position. A 12-mm camera port is placed 5 cm above the umbilicus in the midline. Bilateral 8-mm robotic ports are placed along the midclavicular line 3 cm above the level of the umbilicus. A 5-mm assistant port is placed several centimeters above the right iliac crest. The da Vinci robotic system is brought between the patient's legs, and the robot is docked.

Step 2: Ureter dissection
The hemicolon is mobilized along the line of Toldt until the psoas muscle is identified. The ureter is dissected in a caudal and cranial direction, with maintenance of its blood supply. The dissection is continued distally until the region of the ureteral lesion is located. The ureter is transected proximal to this fistulous segment.

Step 3: Bladder mobilization
The bladder is filled with 200 mL of saline. The lateral umbilical ligaments are ligated and transected, and the bladder is freed laterally. The urachus is cut with bipolar coagulation. The peritoneum is wiped off, and the dome of the bladder is mobilized until it can reach the psoas muscle without tension.

Step 4: Psoas hitch (optional: in case the ureter cannot reach the bladder)
The psoas muscle is exposed to create enough space for bladder suspension. The genitofemoral nerve is identified and preserved. The psoas hitch is performed with two sutures of 2–0 Vicryl to fix the detrusor to the psoas muscle without tension. These two sutures are placed 2 cm apart. The bladder dome is then incised. Two stay sutures are placed to keep the bladder dome open and anchored outside the abdominal wall.

Step 5: Submucosal tunnel preparation
A submucosal bladder tunnel is created by gently opening and closing the robotic scissors, starting from the level of the fixed bladder dome on the psoas muscle. Because the psoas hitch sutures are already tied, the bladder mucosa is stretched, which facilitates tunnel preparation. A mucosal patch is excised. Next, the pull-through maneuver is performed, in which the ureter is pulled through the submucosal tunnel with a 2–0 Vicryl suture tied at its end.

Step 6: Ureteroneocystostomy
The ureter is spatulated and anchored deep in the detrusor muscle with two sutures at the 5 and 7 o'clock positions. A nonrefluxing ureteroneocystostomy is created using 4–0 monocryl on a 3/8 needle. Four interrupted sutures are placed at the 6, 3, 9, and 12 o'clock positions. Once the anastomosis is completed, a 7F double-pigtail ureteral stent is placed. The bladder is closed in a T-shaped fashion to prevent leakage of urine at the bladder dome. The mucosa is closed with running 4–0 monocryl, and the detrusor is closed with running 2–0 Vicryl sutures. A 21F catheter and a drain are placed.

Postoperative Management

Immediate Care

- Two or three additional doses of appropriate intravenous antibiotic
- Prevention of urethral catheter obstruction

Outpatient Care

- Drain removal in 2–3 days, depending on fluid characteristics
- Urethral catheter removal 10 days postoperatively
- Double-J stent removal 30 days postoperatively
- Oral antibiotic of choice for 10 days

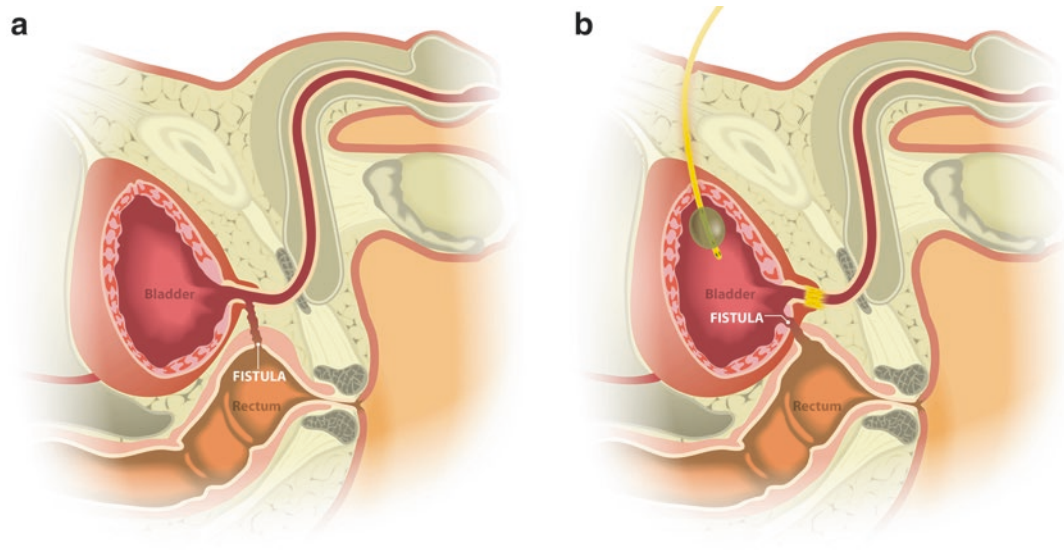

Fig. 30.5 (**a**) Rectourethral fistula, the communication is distal to the bladder neck. (**b**) Rectovesical fistula, the communication is proximal to the bladder neck

Rectourinary Fistulas

Rectourinary fistulas (RUF) include rectourethral, rectovesical, and enterourinary fistulas. These are rare and occur in men under several circumstances. Rectourethral fistulas are typically a consequence of prostate treatment for benign or malignant disease. Radical prostatectomy for the management of prostate cancer is the most common cause in modern series, with rates as high as 1% of RUF. The risk is increased in patients with a history of previous rectal surgery, pelvic radiation, or TURP (thransurethral resection of the prostate) [27, 28]. Rectourethral fistulas have been reported in approximately 0.3–3% of patients after brachytherapy [29] and 0–0.6% of patients after external bean radiation therapy [30]. The incidence of rectourethral fistulas after HIFU (High intensity focused ultrasound) is 2.2%, most commonly after salvage or repeated sessions of HIFU [31].

Rectovesical and enterovesical fistulas are less common. Etiologies include diverticular disease, colon cancer, extirpative or ablative procedures of the prostate, inflammatory bowel disease, and perirectal abscesses [31–35].

The bladder neck is an important anatomical landmark for correct denomination of a RUF after a radical prostatectomy. When the communication is distal to the bladder neck, it is a rectourethral fistula Fig. 30.5a, and when the communication is proximal to the bladder neck, which is more common, it is a rectovesical fistula Fig. 30.5b. The former is approached through the perineum, and the latter is approached through the abdomen.

Signs and symptoms depend on the type of fistula and may include UTIs (urinary tract infections), pneumaturia, fecaluria, and urine leaking per rectum. Work up includes physical examination, cystoscopy, colonoscopy, barium enema, and CT scan.

Conservative management with urinary diversion in patients without signs of sepsis or fecaluria can be attempted with a rate of success of 25% [36]. Fecal diversion should be performed in any patient with a previously failed repair, signs of pelvic infection, or irradiated tissue [25, 33, 36].

The surgical approach is dictated by the clinical situation. Several key principles to successful RUF repair include aggressive debridement of the fistula tract, ensuring that the urethral and rectal repairs are not in direct apposition, and

interposition of healthy tissue [33, 35, 36]. Perineal or abdominal approaches are both possible with excellent success rates and high patient satisfaction [32]. The use of the robotic platform was first described in a small case series by Sotelo et al. [37] with shorter operative time and hospitalization without recurrence.

Robotic Transperitoneal Transvesical Approach

Step 1: Patient positioning
The patient is placed in a low lithotomy position in stirrups with steep Trendelenburg. Sequential compression stockings are applied to the lower extremities.

Step 2: Cystoscopy and catheterization of the ureters and fistula
Cystoscopy is performed, and both ureters are catheterized. This facilitates ureteral identification and protection during excision and closure of the fistula. A differently colored ureteral catheter is then advanced through the fistula into the rectum and retrieved out the anus, to facilitate identification of the fistula.

Step 3: Port placement
A transperitoneal approach with five ports, similar to that for a robotic-assisted radical prostatectomy, is used. The port configuration can be shifted to the right or left, as needed, to avoid injuring the colostomy, if one is present. After establishing pneumoperitoneum and placing trocars, lysis of adhesions is carefully performed. An omental flap, based on the right gastroepiploic artery, is created.

Step 4: Cystotomy and dissection of the fistulous tract
A vertical midline cystotomy is created and carried distally toward the fistulous tract. This incision is continued in the direction of the catheter that defines the fistula, until the posterior aspect of the catheter is exposed. This incision can be retracted laterally with stay-sutures placed on either side. Fibrous and necrotic tissue is excised with scissors. Once the communication between the bladder and the rectum is reached, meticulous dissection between the bladder and rectum is performed with scissors.

Step 5: Closure of the rectum
The rectum is closed with a 2–0 monocryl or barbed suture in an interrupted one-layer technique, with the initial knot on the outer surface of the rectum.

Step 6: Tissue interposition
If there is adequate length, the omental flap can be brought down to serve as a tissue interposition to bolster the repair. The initial suture of the rectum closure is used to anchor the tissue interposition. In robotic surgery, the omental flap is mobilized laparoscopically at the start of the procedure.

Step 7: Closure of the bladder
The bladder closure is subsequently performed in one layer, using a 2–0 monocryl or barbed suture in a running fashion. This suture is run in a superior direction. The closure is not completed until the suprapubic tube has been placed.

Step 8: Cystostomy and colostomy creation
An extraperitoneal suprapubic cystostomy tube is placed under robotic guidance. Subsequently, the closure of the bladder is completed. The bladder is filled with saline to confirm a water-tight closure. In addition, a urethral catheter and a Blake drain are placed. If necessary, a colostomy can be created. There is no need to reposition the patient.

Robotic Rectourethral Technique (Fistulas Distal to the Bladder Neck)

Rectourethral fistulas, which are communications between the prostatic urethra and rectum, may develop after urethral dilatation that accidentally perforates the prostatic urethra, TURP, prostatic focal therapy, and colorectal surgery. The general principles of repair include performing a prostatectomy, closure of the rectum, and urethrovesical anastomosis.

Step 1: Port placement and patient positioning
The patient is placed in a low lithotomy position in stirrups with steep Trendelenburg. Access can be transperitoneal or preperitoneal. Standard robotic prostatectomy port placement is used.

Step 2: Prostatectomy
The anterior and posterior bladder neck is transected with electrocautery. The ampulla of the vas and seminal vesicles is preserved. The anterior aspect of the prostatic capsule is cut longitudinally, enabling identification of the fistula. Once identified, the posterior aspect of the capsule is incised to the fistulous orifice, completing the prostatectomy.

Step 3: Rectum closure
The rectum is closed with a 2–0 monocryl suture with an interrupted one-layer technique. If a transperitoneal approach is performed, an omental flap is mobilized and placed between the rectum and the bladder. If a preperitoneal approach is performed, the preserved neurovascular bundles and periprostatic fascia are approximated toward the midline with interrupted 3–0 Vicryl sutures, acting as a second layer of repair.

Step 4: Urethrovesical anastomosis
The bladder is then mobilized proximally, and the urethrovesical anastomosis is performed in the standard running fashion.

Sometimes more complex fistulas, such as those occurring after HIFU, cryotherapy, or proton bean radiation, do not permit an adequate urethrovesical anastomosis due to tissue damage. In these instances, after the bladder and rectum are separated and closed, a flap of omentum is interposed, and a definitive suprapubic tube is placed Fig. 30.6. Alternatively, a Mitrofanoff procedure or cystectomy and creation of an ileal conduit can be performed.

Another complex situation occurs after rectal surgeries, when the posterior bladder wall is accidently incorporated when firing an end-to-end stapler in the rectum. In this situation, a prevesical approach and prostatectomy are initially performed. The posterior bladder is then mobilized in a retrograde fashion, disconnecting the bladder from the rectum. Care must be taken to avoid injury to the ureters or ureteral orifices. Double-J ureteral stents should be placed. Mobilization of the rectum is performed to allow a tension-free and adequate caliber closure. Finally, omental interposition, posterior bladder wall closure with a posterior racket technique, and urethrovesical anastomosis are performed.

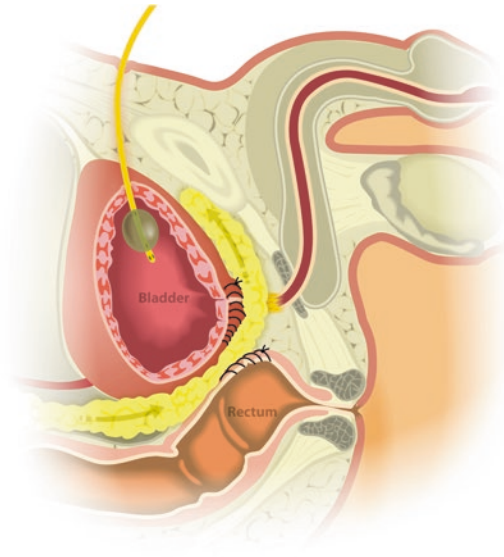

Fig. 30.6 Complex fistula, after the bladder and rectum are separated and closed, a flap of omentum is interposed, and a definitive suprapubic tube is placed

Postoperative Management

- It is important to maintain the patency of the urethral catheter and suprapubic tube by preventing clot obstruction and urinary retention.
- Only irrigate the urinary catheters if there is suspicion of an obstruction.
- Prophylactic antibiotics are administered.
- The urethral catheter and surgical drain are removed on the third postoperative day.
- The suprapubic tube is removed after 1 month. Adequate healing should first be confirmed by a normal cystogram, with timing of the study

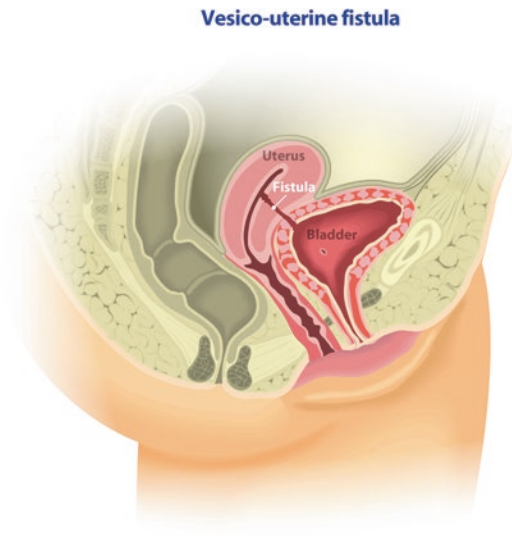

Fig. 30.7 Vesicouterine fistula, clinical presentation is urinary continence, menouria, cyclic hematuria, and amenorrhea

dependent on the technique and etiology of the fistula.

- At 4 months, bowel continuity is restored with laparoscopic assistance.

Vesicouterine Fistulas

Vesicouterine fistulas are the least common urinary fistulas, accounting for only 1–4% of all cases of urogenital fistulas Fig. 30.7 [38, 39]. The most common etiology is cesarean section, with simultaneous injury of the bladder and uterus. It could also result from prolonged obstructed labor, obstetric instrumentation, radiotherapy, and endometriosis [38, 40]. As opposed to other urinary fistulas, it can be presented with or without continuous urinary leaking. The classic presentation, known as Youssef Syndrome, includes urinary continence, menouria, cyclic hematuria, and amenorrhea. These are classified as: type I – menouria, type II – menstrual flow from both the bladder and vagina, and type III – normal vaginal menses [38].

Diagnosis is made with cystoscopy, hysterography, and/or cystography. MRI may also be helpful [38, 40–42]. Conservative management entails urinary catheterization for 4 weeks and medical induction of amenorrhea to assist with fistula healing [38, 40]. The optimal surgical approach depends upon the patient's reproductive desires. Hysterectomy followed by bladder repair is recommended for patients who do not desire fertility. For patients who desire preservation of fertility, uterine-sparing approaches can be considered. The most common technique is the transabdominal O'Connor technique [40]. Hemal et al. reported the first robotic repair of this uncommon fistula [39].

Robotic-Assisted Repair

Step 1: Both ureters are catheterized with 5F ureteral catheters, and a catheter is placed through the fistula.

Step 2: A 12-mm trocar is placed through the umbilicus. Two 8-mm robotic ports are placed 5 cm superior and 1 cm medial to each anterior superior iliac spine. A 10-mm assistant port is placed 2 cm above the umbilicus between the camera port and the right accessory port.

Step 3: Lysis of adhesions is performed, exposing the uterus and bladder. An additional 10-mm port is placed lateral to the right rectus muscle at the level of the umbilicus for retraction of the uterus.

Step 4: Cautery dissection of the peritoneum between the bladder and uterus is performed, revealing the fistula tract.

Step 5: The catheter is pulled into the peritoneal cavity, and the fistula tract is dissected until viable tissue is exposed.

Step 6: Both fistula openings are closed in opposite directions with 3–0 monocryl sutures in an interrupted fashion.

Step 7: The patient is returned to the supine position after the robot is undocked, and the omentum is mobilized over the bladder. The omental flap is interposed and anchored between the bladder and the uterus.

Step 8: A suprapubic tube and urethral catheter are placed for bladder drainage. These are removed on postoperative day 5 and 14, respectively.

Conclusion

Urological fistulas are uncommon but present a serious health problem. Surgical repair is the cornerstone of management. The first attempt at repair has highest success rate. For this reason, these patients must be referred to surgeons and centers with extensive experience in reconstructive and minimally invasive surgery. Robotic-assisted laparoscopic surgery has yielded excellent results.

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Pelvic Lymphadenectomy

31

Gerald Heulitt and James Porter

Introduction

Pelvic lymphadenectomy provides important staging and potential therapeutic benefits to patients with prostate, bladder, and penile cancer. The exact limits of pelvic lymph node dissection (PLND) have been debated with recent literature supporting a more extended dissection. As the extent of PLND increases, there is greater risk for injury to adjacent structures. With the close association of the pelvic lymph nodes to vascular, neurologic, and urologic structures in the pelvis, complications may occur. Fortunately, complications related specifically to the pelvic lymphadenectomy are rare with a reported rate of 0–5% [1]. In this review, the potential complications of pelvic lymphadenectomy in the setting of robotic-assisted laparoscopic surgery will be discussed and the methods for diagnosis, management, and prevention of complications will be highlighted.

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Lymphocele

Lymphocele formation occurs due to incomplete ligation of lymphatic channels divided during lymphadenectomy. This results in lymphatic fluid leakage which in most cases is reabsorbed by the peritoneal cavity. However, in a closed space such as the extraperitoneal space, lymphatic fluid may accumulate and create a lymphocele. A transperitoneal approach, while felt to be protective, does not eliminate the risk of lymphocele formation, and there are multiple reports of lymphocele formation after robotic prostatectomy performed transperitoneally. The mechanism of transperitoneal lymphocele formation is thought to be due to walling off of the area of dissection by the bladder. While many lymphoceles are subclinical and are of no consequence to the patient, some may become infected requiring drainage. Other manifestations of lymphoceles include lower extremity edema, urinary frequency or urgency, and deep venous thrombosis.

With a reported incidence of 0–30.9% [1, 2] symptomatic lymphocele formation is the most common complication of pelvic lymphadenectomy (Table 31.1). Traditionally, lymphostasis has been obtained with permanent surgical clips; however, bipolar and harmonic sealing devices have been evaluated in vitro with acceptable lymphatic control [3]. Grande et al. reported a randomized prospective comparison of titanium

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Table 31.1 Lymphocele incidence after robotic or laparoscopic pelvic lymph node dissection [1, 2]

Reference:	Incidence:
Yee et al.	0%
Katz et al.	0%
Modi et al.	0.13%
Kumar et al.	0.13%
Liss et al.	0.4%
Yip et al.	0.4%
Babaian et al.	0.5%
Ghazi et al.	0.6%
Lallas et al.	0.6%
Cooperberg et al.	1.1%
Ploussard et al.	1.1%
Hashimoto et al.	1.5%
Sejima et al.	2%
Stololzenburg et al.	2%
Zorn et al.	2%
Sagalovich et al.	2.4%
Galfano et al.	1–3%
Polcari et al.	3%
Silberstein et al.	3%
Waggenhoffer et al.	3%
Yuh et al.	3%
Davis et al.	4%
DiPierro et al.	4%
Feicke et al.	4%
Koo et al.	4%
Orvieto et al.	7.9%
Froehner et al.	30.9%

clips to bipolar cautery in sealing lymphatics during PLND performed at the time of robotic prostatectomy. There were 110 patients in the bipolar and titanium clip groups, respectively. They noted a lymphocele incidence of 47% in the clip group compared to 48% in the bipolar group as determined by ultrasound performed at 10 days after surgery. The rate of clinically significant lymphoceles was 5% for the clip group and 4% for the bipolar group. They concluded that there was no significant difference in the occurrence of lymphocele formation between the two methods of lymphatic control [4].

Since most lymphoceles are subclinical, the diagnosis is based on clinical suspicion and symptoms. Patients with pelvic pain localized to one side, irritative urinary symptoms, or unilateral leg swelling should prompt radiologic evaluation. CT scan or ultrasound can be used to evaluate a patient for lymphocele formation. The true rate of subclinical lymphoceles is difficult to define as they often are asymptomatic. Keskin et al. reported on 521 patients after robotic-assisted radical prostatectomy who were prospectively imaged at 1 and 3 months postoperatively with abdominal and pelvic ultrasound. They found an overall lymphocele rate of 9%, of which, 2.5% became symptomatic. Interestingly, 76% of lymphoceles discovered at 1 month postsurgery resolved by the 3-month study. If patients continued to have lymphoceles on the 3-month ultrasound, 64% of those patients went on to have symptoms related to the lymphocele [5].

Risk factors for lymphocele formation include the number of lymph nodes removed [6], presence of nodal metastases, tumor volume in the prostate, and extracapsular extension [7]. The extent of PLND has been clearly shown to correlate with the lymphocele formation. Davis reviewed his experience with limited and extended PLND performed robotically for patients with intermediate and high-risk prostate cancer. He noted a higher rate of lymphoceles with the extended PLND and noticed that there were fewer lymphoceles if care was taken to clip as many open lymphatic channels as possible. He also noted a higher rate of symptomatic lymphoceles in patients undergoing the extraperitoneal approach for PLND (3/16 or 19%) as compared to the transperitoneal approach (0/47) [8]. This has led to the practice of creation of a peritoneal fenestration in those patients undergoing extraperitoneal prostatectomy with PLND in an effort to allow the lymphatic fluid to escape into the transperitoneal space and be reabsorbed [9].

The majority of lymphoceles that occur after transperitoneal PLND are asymptomatic and resolve without complications. If an asymptomatic lymphocele is discovered, it can be observed with serial imaging to confirm resolution. Some lymphoceles may become clinically apparent by causing compression of the bladder, leading to bladder symptoms such as urgency and frequency. These symptoms are common after prostatectomy so an index of suspicion is needed to prompt radiographic investigation for the lym-

phocele. Lymphoceles that are clinically silent may become apparent if the lymphocele becomes infected. Davis noted cases of infected lymphoceles occurring greater than 6 months after PLND and speculated that an asymptomatic lymphocele could persist after PLND and later become seeded with an infection from another source [8]. In the series by Keskin, symptomatic lymphoceles developed, on average, 11.2 months after PLND with lymphoceles becoming clinically significant as long as 22 months after surgery [5]. Therefore, the surgeon needs to maintain an index of suspicion for this complication not only in the early postoperative period but also in the long-term follow-up.

Lymphoceles leading to secondary complications including lower extremity edema, infection, deep venous thrombosis, or ileus require treatment. Treatment is also indicated for symptomatic lymphoceles resulting in patient discomfort such as pelvic pressure or urinary frequency. Initial management of lymphoceles involves placement of a percutaneous drain until the drain output is minimal which can take several days to weeks. It is recommended that lymphocele fluid be sent for culture to evaluate for infection as well as fluid creatinine to rule-out urine leak. If lymphocele recurs, secondary treatment options including repeat percutaneous drainage with instillation of a sclerosing agent. A variety of sclerosing agents have been used, either alone or in combination, with success including tetracycline, doxycycline, povidone iodine, and alcohol. The initial size of the lymphocele is a risk factor for failure of sclerotherapy with larger-sized lymphoceles leading to greater failures [10]. Larger lymphoceles may be better treated with marsupilization of the lymphocele which can be performed laparoscopically, robotically or by an open approach.

Vascular Injury

Vascular injury during pelvic lymphadenectomy is rare and reported in the literature as case reports. Hemal described a case of external iliac vein dissection injury sustained during laparoscopic PLND and radical cystectomy. The vein injury was successfully repaired with laparoscopic suturing and they noted that increasing the pneumoperitoneum pressure and keeping the patient in steep Trendelenburg position were key maneuvers to provide visualization of the injury [11]. Safi et al. reported a case of complete transection of the external iliac artery encountered during laparoscopic PLND and prostatectomy. The artery was very redundant, was below the external iliac vein, and was mistaken for the lymphatic packet. They reapproximated the artery end to end with a laparoscopic running double-armed suture after gaining proximal and distal control with laparoscopic graspers. Laparoscopic prostatectomy was completed and the artery remained patent on postoperative imaging [12]. Another case study presented by Castillo details thermal injury to the external iliac artery which occurred during laparoscopic PLND and cystectomy. The injury was due to heat from an electromechanical scalpel instrument used during dissection. Vascular bulldog clamps used for open surgery were introduced through a 10-mm laparoscopic port and were applied to gain proximal and distal control. The injury was debrided and sutured laparoscopically using 5–0 monofilament suture with a successful outcome [13].

The iliac and obturator lymphatics in the pelvis surround major vascular structures including the external iliac vein artery, the internal iliac vein and artery, and the obturator vessels. The pelvic vasculature are at risk from injury during dissection, application of clips and by inadvertent thermal injury from electrocautery. When dissecting around the pelvic vasculature, it is important to maintain adequate exposure and ensure that the bedside assistant has clear access to the area of dissection so that suction may be applied if bleeding is encountered. Another potential cause of vascular injury is the uncontrolled or blind passage of robotic instruments into the body by the bedside assistant. This is especially concerning during the introduction of sharp instruments such as the robotic scissors and can be avoided by pulling the robotic camera back to watch the instrument pass through the robotic port. Vascular injury is also possible when there

is failure of insulation surrounding a monopolar instrument leading to inadvertent conduction of electrical current onto a vessel [14]. This can be prevented by ensuring the insulation on the instrument is intact and avoid resting the sheathed portion of a monopolar instrument on the vessels. Finally, when using both monopolar and bipolar instruments simultaneously around the pelvic vessels, great care must be taken to avoid pressing the wrong foot pedal during robotic dissection. This is because the instrument not applying energy is used to provide exposure and if the wrong pedal is inadvertently pressed, this could lead to serious injury. This is best prevented by conscious hesitation prior to applying any form of cautery and performing a mental check to ensure the proper pedal is being activated.

In the case studies describing laparoscopic repair of vascular injury, the common factor among all the reports was the vast experience of the laparoscopic surgeons performing the repair. Laparoscopic suturing is a complex skill and should only be attempted by experienced laparoscopic surgeons. Robotic surgery with the enhanced ease of suturing over pure laparoscopy makes repair of lacerations of the pelvic vasculature possible without the need to convert to open surgery. However, one must always be mindful that a significant vascular injury that cannot be controlled robotically necessitates conversion to open for appropriate control and repair. Consulting a vascular surgeon is also indicated if there is any question regarding the extent or management of the injury.

Principles for robotic control and repair of vascular injuries include immediate application of pressure at the bleeding site, increasing the pneumoperitoneum to 20 mmHg to decrease venous bleeding, and gaining proximal and distal control of the bleeding vessel [15]. Robotically, this can be achieved with application of laparoscopic bulldog clamps. The injury should be inspected and, particularly if from a thermal injury, debridement of edges should be performed prior to attempted repair. Repair of the injury can then be performed with polypropylene or polytetrafluoroethylene suture followed by appropriate sequential removal of the bulldog clamps and lowering of the pneumoperitoneum to assess for points of bleeding. Vessels that necessitate repair including the common and external iliacs. Unilateral ligation of the internal iliac may be performed if repair cannot be performed; however, some patients may experience gluteal muscle claudication after ligation. Smaller vessels, including the obturator vessels, can be ligated if bleeding occurs and cannot be controlled by other means. Major vascular injury with repair should be routinely included in the preoperative surgical counseling and informed consent discussion for any patient undergoing PLND.

Neurologic Injury

There are three categories of nerve injury: neurapraxia, axonotmesis, and neurotmesis. Neurapraxia is caused by compression or traction resulting in an injury that which will block the neuronal signal. However, this does not lead to axonal degeneration. Recovery occurs over several weeks. Axonotmesis results in degeneration of neural elements distal to the injury site, but the neuronal support structures remain intact. This is usually caused by prolonged compression or excessive traction. Function recovers over 6 months to 1 year. Neurotmesis is from complete transection of the nerve and recovery is not expected [16].

Obturator nerve injury is the most common nerve injury during pelvic lymphadenectomy, but is still rare occurring in 0.1% of pelvic lymph node dissections [17]. The obturator nerve arises from L2 to L4 segments of the lumbar plexus. It exits the psoas and travels through the pelvis in the obturator fossa. It runs parallel to the pelvic sidewall and above the obturator artery and vein. It leaves the pelvis with the obturator vessels through the obturator foramen. It innervates the medial adductor muscles of the thigh and receives sensory input from the medial aspects of the thigh. Injury to the obturator nerve leads to weakness of hip adduction and decreased sensation or pain along the medial aspect of the thigh. This can lead to variable gait disturbances. Keys to avoid injury include having a sound anatomic understanding of the obturator nerve's course

through the pelvis and identification of the nerve proximally and distally before dividing the lymph node packet. The proximal portion of the nerve is at the highest risk of injury, representing 77.8% of cases [17]. Bleeding may temporarily obscure the obturator nerve and care must be taken when applying clips or thermal energy in the obturator fossa. The obturator nerve can be injured if mistaken for the obturator artery with the intent to either cauterize or divide the artery. If transection of the obturator nerve occurs, a tension-free end-to-end epineural repair should be made with interrupted permanent suture (6–0 to 8–0 polypropylene) [18]. If a segment of the nerve is removed or after debridement of the cut edges from a thermal injury, it is not possible to perform a tension-free repair, a neurosurgical consult for nerve grafting is indicated. The sural nerve is most commonly used for grafting as its removal only causes a sensory defect [19]. If obturator nerve injury is known or suspected, it is recommended to consult physical therapy for prompt intervention.

The genitofemoral nerve originates from L1 to L2. Of clinical importance, it travels through the pelvis lateral to the external iliac vessels. Proximally, the nerve runs between the iliac vessels and the psoas muscle and may be obscured by nodal tissue. It has mixed motor and sensory functions. It divides distally into the genital and femoral branches. The genital branch receives sensory input from the ventral scrotal skin or mons and provides innervation of the cremasteric muscle. The femoral branch receives sensory input from the upper, anterior thigh. During PLND, the genitofemoral nerve is most commonly encountered just lateral to the external iliac artery and many surgeons use the external iliac artery as the lateral boundary of dissection to avoid injury to the nerve. Again, it is important to know the expected anatomic location of the nerve and identify the nerve early to avoid injury. Injury to the genitofemoral nerve may result in numbness or pain along the anterior scrotum and absence of a cremastric reflex on the injured side. Genitofemoral neuralgia has been successfully treated with antiepileptic drugs such as gabapentin or pregabalin [20].

Ureteral Injury

Ureteral injury during pelvic lymphadenectomy is reported to have an incidence of <1% [1, 21]. The ureter crosses the common iliac artery to enter the pelvis and then courses along the inferior lateral pelvis before entering the bladder. Early identification of the ureter during lymphadenectomy is key to prevent injury. With the bladder retracted medially, the ureter will course under the medial umbilical ligament near its junction with the internal iliac artery. Staying superficial to the medial umbilical ligament will therefore avoid inadvertent injury to the ureter. If a ureteral injury is noted intraoperatively, a ureteroureterostomy or ureteral reimplantation with ureteral stent placement is recommended. This can be performed as a refluxing or nonrefluxing anastomosis [22]. A missed ureteral injury manifests 48–72 h postoperatively with fever, flank pain, gross or microscopic hematuria, peritonitis, and/or leukocytosis. A CT urogram or cystoscopy with retrograde pyelogram may be performed to identify the location and extent of injury which will guide further management [23].

Small Bowel Obstruction

Small bowel obstruction due to internal herniation has been reported after robotic assisted PLND. Two separate case reports have identified patients presenting 3–12 months postoperatively for small bowel herniation behind the common iliac or external iliac artery after extended pelvic lymphadenectomy performed during robotic prostatectomy [24, 25]. Some surgeons approach the iliac lymph nodes cephalad to the external iliac artery in the so-called “triangle of Marseille” which creates a space between the psoas muscle and the iliac vessels. Small bowel can find its way into this space and become trapped, leading to obstruction. Considerations for prevention include retroperitonealization or plugging any potential sites of herniation with a collagen or cellulose patch; however, these have not been well studied.

One reported cause of small bowel obstruction was from a Hem-o-lok clip that either had opened

up after surgery or was a failed deployment and never removed from the abdomen. The hook end of Hem-o-lok clip was tethered to the small bowel mesentery, and the other end was embedded in the abdominal wall, leading to a small bowel obstruction [26]. As this case illustrates, it is important to identify and remove any improperly deployed Hem-o-lok clips.

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Inguinal Lymphadenectomy

32

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Background

Complications Associated to Open Inguinal Lymph Node Dissection (ILND)

Since the first cases of inguinal lymphadenectomy for penile cancer, many potential complications have been illustrated justifying the number of different techniques described for that approach to purpose better outcomes, low the morbidity, and minimize the complications of that procedure. The nodal dissection experience is an important factor to prevent complications [1].

The majority of high volume experiences reported with open ILND shows that the morbidity associated was more than 50% (Table 32.1).

Ravi et al. in 231 inguinal and 174 ilioinguinal lymphadenectomies on 234 patients with penile carcinoma described 18% of wound infections, 61% of wound necrosis, seroma in 5%, and lymphedema in 27%. Preoperative radiation to the groin significantly increased the healing complications [2].

Ornellas et al. made an analysis of 200 lymphadenectomies performed in 112 patients from 1972 to 1987 and illustrate 5% flap necrosis, 15% wound infection, 16% lymphedema, and 9% lymphocele [1].

Ten years after, Ayyappan et al. described 78 patients submitted to inguinal lymphadenectomy with 36% skin necrosis, 70% wound infections, 87% of lymphocele, and 57% lymphedema [3].

Bevan-Thomas et al. reported 106 lymphadenectomy procedures in 53 patients with complications (major or minor) in 58% of all cases [4].

Two years after, Nelson et al. reported a retrospective analysis of 40 inguinal lymphadenectomies and demonstrate lymphedema in 4 of 40 cases (10%), minor wound infection in 3(7.5%), and minor wound separation in 3(7.5%); 5 of 40 patients (12.5%) had lymphocele, which spontaneously resolved. Late complications were lymphedema in 2 of 40 patients (5%), flap necrosis in 1(2.5%), and lymphocele in 1(2.5%), requiring percutaneous drainage [5].

Bouchot et al. reported data from 176 lymphadenectomies from 88 patients between 1989 and 2000 with 74 complications including 12% skin necrosis, 7% wound infections, 19% seroma, and 22% lymphedema. He conclude that the procedure morbidity still significant especially in patients with multiple or bilateral inguinal lymph nodes [6].

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Table 32.1 Open inguinal lymphadenectomy series

Author	Patients	Skin necrosis (%)	Skin infections (%)	Seroma (%)	Lymphocele (%)	Lymphedema (%)
Ravi (1962–1990)	112	62	17	7	–	27
Ornellas et al. (1972–1987)	200	45	15	6	–	23
Ayyappan et al.	78	36	70	–	87	57
Lopes et al. (1953–1985)	145	15	22	60	–	30
Bevan-Thomas et al. (2003)	53	8	10	10	–	23
Bouchot et al. (1989–2000)	88	12	7	19	–	22
Koon et al. (1994–2003)	129	15	27	9	12	31
Pandey et al. (1987–1998)	128	20	17	16	–	19
Pompeo (1984–1997)	50	6	12	6	–	18
Spiess et al. (2008)	43	11	9	–	2	17

Pandey et al. analyzed 128 patients underwent groin dissection for penis carcinoma and reported a 5-year survival of 51.5% after the procedure. Although they presented 20% skin necrosis, 17% wound infections, 16% seroma, and 19% lymphedema [7].

Pompeo et al. reported 50 patients that underwent inguinal lymphadenectomy from 1984 to 1997. The complication rates were 6% of skin necrosis, 12% of wound infections, 6% of seroma, and 18% of lymphedema [8].

Koifman et al. performed bilateral inguinal lymphadenectomy in 170 patients with penile cancer (340 procedures). They described 35 complications (10.3%). They noted lymphedema in 14 patients (4.1%), seroma in 4(1.2%), scrotal edema in 3(0.9%), skin edge necrosis in 3(0.9%), lymphocele in 3(0.9%), wound infection in 2(0.6%), flap necrosis in 2(0.6%), wound abscess in 2(0.6%), and deep venous thrombosis in 2(0.6%) [9].

Other authors reported complications as seroma or lymphocele in 0–26%, lymphorrhea in 9–10%, and wound infections or skin necrosis in 0–15% [10–13].

Morbidity Associated to Laparoscopic and Robotic ILND

The idea for development of video endoscopic inguinal lymphadenectomy (VEIL) was to allow a radical removal of inguinal lymph nodes in the same limits of conventional surgery with lower surgical morbidity reduction and similar oncological outcomes.

Tobias-Machado et al. in 2009 reported 20 patients underwent 30 inguinal lymphadenectomies (VEIL) and established 5% of cutaneous event, 10% of lymphatic event, and 15% of morbidity [14]. Three years after, Sudhir et al. illustrate 22 patients with 39 VEIL surgeries from 2007 to 2011 with 1 subcutaneous emphysema, 1 skin flap necrosis, and 4 lymphocele cases. None of the patients developed local recurrence on the period [14].

Sotelo et al. described 8 patients clinical stage T [2] N(0–3)M(0) penile carcinoma who underwent inguinal lymphadenectomy with an median operative time of 91 min(range 50–150). Lymphocele developed in three patients (23%) with no wound related complications [15].

In their initial report of 16 patients, Master et al. reported 25 procedures in 12 months with 147 min average operating time. They notice one patient with seroma and two with wound infection [16].

From 2006 to 2010, Romanelli et al. operated 33 VEIL in 20 patients with penis carcinoma. The average operative time was 119 min and the mean resected lymph node was 8 per lymphadenectomy with an overall complication rate of 33.2%. No skin necrosis was reported. Lymphatic complication rate was 27.2% and 80% survival rate in 20 months follow-up [17].

In 1992, Clavien et al. proposed a surgery complication classification in a review published series of cholecystectomies from 1960 to 1990. That classification should be applicable to most surgical procedures that do not correspond with the ideal course. After its routine use for 12 years, that classification system has been modified. In 2004, with a cohort of 6336 patients undergoing elective surgery between 1988 and 1977 prospectively collected, Clavien et al. proposed a morbidity scale based on the therapeutic consequences of complications [18].

With more accumulated experience Maters et al. publish the first report of endoscopic ILND with immediate and long-term complication using the Clavien scale. Video endoscopic ILND was associated to a total of 11(27%) minor and 6(14.6%) major complications [19].

Carlos et al. [20] and Romanelli et al. [10] reported two cases that have not been described in the literature on VEIL: one case of myocutaneous necrosis [21] and one case of local recurrence with multiple implants [10]. Myocutaneous necrosis and multiple implants occurred isolated, only 1 case in more than 350 procedures performed around the world, this means less than 0.3% of the procedures reported in the literature.

Unfortunately, there is no prospective large study comparing complications of open X endoscopic ILND.

If we consider VEIL results compared to the contemporary open series, we observe at least a half of reduction in overall surgical morbidity (23 × 53%).

The compilation of VEIL series reported a total of 355 limbs with 14.4% of lymphatic complications and 6.9% of cutaneous events (Table 32.2). The open series with more than 100 cases reported a total of 1033 inguinal lymphadenectomies with 30% of cutaneous events and 23% lymphatic complications (Table 32.1).

Robotic VEIL is a new procedure described in 2009 [21] and now standardized [22]. Preliminary experiences with robotic ILND showed results compared to VEIL. The advantages of robotic include better surgeon ergonomy, movement instruments in a limited working space, and potential to improve localization of lymphatic channels. The disadvantage is the procedure higher cost.

Preventive Maneuvers to Reduction of Complications

An important initial step is to perform the dissection of the initial incision deeper than Scarpa's fascia, allowing the gas to expand through the plane that preserves the skin vascular supply.

A critical point to avoid complications refers to the correct placement and fixation of the entry ports. The lack of symmetry or excessive port proximity can greatly hinder the surgical steps. It is important to close the initial incision tightly with a continuous suture to allow a good visualization and avoid gas leakage. Suturing the ports at no more than 1 cm inside the cavity to be created also helps. To accelerate the subcutaneous dissection, initial insufflation may be performed with 15 mmHg, the camera will be compressed distally so the dissection by the gas itself progresses upwardly until above the inguinal ligament. During the setting up of the working cavity, skin transillumination helps to establish the dissection limits and is also useful for checking the thickness of the skin layer.

To avoid vascular injury, it is necessary to carefully dissect the floor of the femoral triangle. The correct identification of the boundaries of the triangle prior to the dissection in a deep plane and the location of the saphenous vein with the tributaries control at the fossa ovalis greatly

Table 32.2 Complications associated to VEIL

Author	Year	Country	N	Limbs	Morbidity (skin) (%)	Morbidity (global) (%)	Morbidity (lymphatic) (%)
Tobias-Machado et al.	2013	Brasil	40	57	5.2	22.8	18
Romanelli et al.	2013	Brasil/Uruguay	20	33	6	27	33.3
Canter et al.	2012	EUA	10	19	10.5	10.5	36.8
Zhou et al.	2012	China	7	11	0	9	27.3
Schwentner et al.	2012	Germany	–	28	–	3.5	7.1
Master et al.	2012	EUA	29	41	12.2	29.2	41.4
Sudhir et al.	2012	India	22	39	5.1	10.2	18
Huber et al.	2012	Sweden	1	2	–	–	–
Xu et al.	2011	China	17	34	5.8	2.9	8.8
Delman et al.	2011	EUA	32	45	15.5	2.5	18
Dogra et al.	2011	India	2	4	–	–	–
Josephson et al.	2009	EUA	1	2	–	–	–
Thyavihaly et al.	2009	India	16	16	6	19	25
Sotelo et al.	2007	Venezuela	8	14	0	23	23
Total			213	355	6.9	14.4	23.3

facilitate the location of the femoral vein. In some situations, especially in older patients, the femoral vein can be collapsed so it can be inadvertently damaged during the dissection of the lymph node packet.

Saphenous vein ligation should be carried out preferably with polymer clips because of the security they offer. After removal of the surgical specimen by the initial incision, the indicator finger is introduced into the incision which functions as a laparolift-type device (used in surgery without gas) and by the same orifice, an optical makes an inspection of the cavity without insufflation looking for any uncontrolled bleeding.

In cases of intraoperative vascular injury, the initial management depends on the amount of bleeding and the surgeon's ability to control it endoscopically. Bleeding of smaller vessels can be repaired with clips, bipolar or ultrasonic scalpel, or by buffering with hemostatic agents. Femoral vessel injury may initially be controlled by external pressure and buffered with assembled gauze by the nondominant hand of the surgeon. The endoscopic prolene suturing can be performed by a highly skilled laparoscopic surgeon, regarding the small space and therefore a low amount of blood difficult the anatomical view.

When the endoscopic control is not possible, conversion to an open procedure with a skin incision above the femoral vessels is used for vascular control and repair.

We have observed during open procedures that the lymphatic complications are directly proportional to the number of ligations performed during the operation. When we identify lymphatics during dissection, we applied at least one proximal clip to reduce the chance of postoperative lymphorrhea. If a lymphocele occurred, postoperative external drainage with a suction drain is preferred. We do not routinely use heparin or derivatives preoperatively, which can contribute to reduce the volume of lymph drainage. Moreover, contrary to what is recommended in conventional open surgery, we encourage early ambulation of the patient. Dietary measures such as restricting excessive fluid intake and starting a low fat diet can be helpful in accelerating the closure of any lymphatic fistula. If that strategy fails and when chylous output is higher than 500 mL/d, it can be offered no oral intake, parenteral nutrition, and octreotide for 1 week. The reoperation to ligate lymphatics after inguinal lymphadenectomy is rarely required.

In cases where the saphenous vein may be important for the drainage, its endoscopic preservation has recently proven to be feasible without resection impairing of the inguinal lymph nodes [10].

The dissection using an energy source close to the epidermis can damage the viability of the skin layer. In order to avoid skin necrosis, the dissection is performed with scissors without thermal energy with eventual clipping of vessels if necessary when the superficial lymph nodes are attached to the skin. The treatment of any skin lesions follows the same principles of its occurrence after conventional surgery.

Conclusions

Recent reports have now confirmed that VEIL is a feasible alternative to open lymphadenectomy.

New frontiers need to be explored in the near future to improve results including artifacts to better intraoperative identification of nodes, alternative techniques to reduce lymphatic events, robotic approaches, and single-site surgery.

Based on the available data, VEIL acceptance is growing and has the potential to become the minimally invasive procedure of choice when inguinal lymphadenectomy for low volume disease is required.

The robotic technology improves the surgeon ergonomics and facilitated the procedure. More robust experience and a larger oncological follow-up will be necessary to validate the present data.

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Part V

Complications in Pediatric Robotic Urologic Surgery

Complications in Pediatric Robotic Urologic Surgery

33

Rodolfo A. Elizondo, Gene O. Huang, and Chester J. Koh

General Considerations

Minimally invasive laparoscopic procedures for urological diseases in children have proven to be safe and effective, with outcomes comparable to open procedures. Technical advances, including smaller instruments and high-definition cameras, have contributed to the expanded role of minimally invasive surgery in children. The major drawback to conventional laparoscopy has been the relatively steep learning curve due to the technical difficulties of suturing and the limitations of instrument dexterity and range of motion. Since its approval by the Food and Drug Administration (FDA) in 2000, the use of the Da Vinci® surgical system (Intuitive Surgical, Sunnyvale, California) has grown dramatically in both the adult and pediatric populations. Over the years, there have been modifications to improve visualization (3D high definition), provide fine control of instruments (EndoWrist ®) and needles, and fine-tune arm movement to maximize the working field without instrument collision. All of these features have been upgraded over time to enhance surgical performance, facilitate learning curves, and decrease complications [1–3].

Laparoscopic procedures for urological diseases in children have also been proven to be safe and effective. However, the availability of laparoscopic procedures is still often limited to experienced high-volume centers because the procedures can be technically demanding. The da Vinci robot system is being used for an increasing variety of complex reconstructive procedures because of the advantages of this approach, such as motion scaling, greater optical magnification, stereoscopic vision, increased instrument tip dexterity, and tremor filtration. Particularly in pediatric urologic surgery, where the surgical field is limited owing to the small abdominal cavities of children, robotic surgical technology has developed its own breakthroughs. Currently, robots are used to perform many surgeries in children that were previously performed laparoscopically. In this review, we aimed to provide a comprehensive overview of the current role of robotic-assisted laparoscopic surgery in pediatric

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urology by analyzing the published data in this field. A growing body of evidence supports the view that robotic technology is technically feasible and safe in pediatric urological surgery. Robotic technology provides additional benefits for performing reconstructive urologic surgery, such as in pyeloplasty, ureteral reimplantation, and enterocystoplasty procedures. One of the main limitations to robotic surgery is its high initial capital costs for the purchase of the robot and its maintenance costs, and the cost-effectiveness of this technology remains to be validated [3].

Robotic surgery allows surgeons to perform refined surgical movements that exceed the natural range of motion of the human hand that are combined with high-definition three-dimensional visualization and superior magnification. While open surgery has long been the standard of care in the pediatric population, robotic surgery has gained increasing acceptance among pediatric urologists, by bridging the gap between conventional laparoscopy and open surgery. Pyeloplasty for ureteropelvic junction obstruction remains the most commonly performed robotic procedure in pediatric urology; however, utilization of robotic surgery has expanded to include nearly all upper and lower urinary tract surgeries commonly performed by pediatric urologists. Ongoing innovation has led to improved methods and instrumentation that continue to expedite the patient recovery experience and lead to improved quality of life outcomes [3].

Robotic surgery in pediatric urology is used for a wide variety of procedures ranging from simple excision to complex reconstruction. When considering robotic surgery for a pediatric patient, the surgeon must account for the small working space in children in addition to the technical principles that apply to adult robotic surgery. The prevention of complications requires a team-based approach, which includes the surgeon, anesthesiologist, and operating room team members. In this chapter, we will highlight complications, their management, and potential preventative measures related to pediatric robotic urologic surgery (Table 33.1).

Prevention (Preoperative)

Patient Positioning

The first step to preventing complications in pediatric robotic surgery is proper patient positioning with adequate padding. Although positioning varies between surgeons and procedures, several universal measures for the prevention of nerve injury are noted below. In the supine position, maintaining upper extremity abduction to less than 90° reduces the risk of brachial plexus injury. Furthermore, ensuring a supinated or neutral position of the forearm prevents ulnar nerve compression [4]. The use of Trendelenburg position should be avoided for prolonged periods as this can place the pediatric patient at risk for both positional migration and cardiopulmonary changes. After a patient is secured to the operating room table, communication with the anesthesiologist is vital to ensure that respiratory excursion is not compromised. Rehearsal positioning of the bed prior to docking of the robot can confirm proper secure positioning since the patient position should not migrate once the robotic is docked. With lithotomy positioning, care must be taken to limit pressure of the fibular head on the peroneal nerve. And during flank positioning, an axillary roll placed between the chest walls caudal to the dependent axilla and the bed prevents compression of the brachial plexus.

Although limited data exists regarding peripheral nerve injury during robotic procedures in the pediatric population, the adult experience has shown that upper extremity ulnar and brachial plexus injuries are the most common [4]. Review of a multicenter database of 880 pediatric robotic urologic surgeries identified one patient with knee numbness and another with facial swelling that resulted from positioning [5]. These complications were self-limited and resolved spontaneously similar to the majority of positioning-related injuries. However, if prolonged sensory or motor deficits are persistent, referral to pediatric neurologic specialists for further evaluation may be indicated.

Table 33.1 Complications and management options for pediatric robotic urologic procedures

Robotic procedure	Presentation (time)	Signs and symptoms	Evaluation	Treatment	Follow-up
Ureteral reimplantation					
Urinary retention	Immediate	Lower abdominal pain, inability to void	Abdominal examination, possible bladder scan	Straight catheterization or indwelling catheter	If indwelling catheter, remove in 2 to 14 days
Ureteral obstruction	Immediate to 7 days	Decreased urine output, worsening hydronephrosis	Ultrasound	Retrograde ureteral stent or if unable, antegrade	Stent removal in 1 month, follow-up ultrasound afterward
Ureteral injury/urine leak	4–7 days	Lower abdominal pain, nausea, emesis, fever	Ultrasound, possible CT urogram	Retrograde pyelography with ureteral stent, indwelling catheter	Indwelling catheter removal in 5 days, stent removal in 1 month, follow-up ultrasound after
Pyeloplasty					
Anastomotic leak	4–7 days	Abdominal pain, nausea, emesis, fever	Ultrasound	If stent is present, indwelling catheter and anticholinergics, if not, retrograde pyelography with ureteral stent versus nephrostomy	Indwelling catheter removal in 1 week, stent removal in 1 month, if nephrostomy, antegrade nephrostogram prior to removal, follow-up ultrasound after
Stent migration	Variable	Abdominal pain, nausea, emesis, urinary symptoms	KUB	Cystoscopy with possible ureteroscopy and stent placement	Stent removal in 1 month, follow-up ultrasound after
Complex reconstruction (appendicovesicostomy and/or augmentation cystoplasty, bladder neck reconstruction)					
Stomal incontinence	Variable	Leaking at stoma site	Urodynamics, possible video urodynamics	Depending on severity and etiology, anticholinergics, endoscopic bulking agent injection, or surgical revision of channel	Clinical follow-up after procedure
Stomal stenosis	Variable	Difficulty catheterizing	Endoscopic evaluation of channel	Dilation versus surgical revision	Clinical follow-up after procedure
False passage	Variable	Difficulty catheterizing, hematuria with catheterization	Endoscopic evaluation of channel	Conservative management with indwelling catheter versus surgical revision of channel	If indwelling catheter remove in 1–4 weeks, if surgical revision remove catheter in 1 month, clinical follow-up after procedure
Small-bowel obstruction	Variable	Abdominal distention, nausea, vomiting	Acute abdominal series, possible CT scan with oral and IV contrast	Conservative management with NGT and parental nutrition versus surgical exploration	Clinical follow-up
Bladder stones	12 months or more	Hematuria, malodorous urine	Bladder ultrasound, possible KUB	Endoscopic versus percutaneous lithotripsy, open cystolithotomy	Ensure adequate drainage with possible need to irrigate bladder, clinical follow-up
Nephrectomy or heminephrectomy					
Urine leak	4–7 days	Abdominal pain, nausea, emesis, fevers	Ultrasound	Retrograde pyelography with ureteral stent, possible indwelling catheter and anticholinergics	If indwelling catheter, removal in 1 week, stent removal in 1 month, ultrasound

Intraoperative

Intra-abdominal Access

There are two classic techniques for intra-abdominal access: Veress (closed) and Hasson (open). The closed technique consists of a Veress needle (blunt-tipped, spring-loaded, inner stylet surrounded by a sharp needle) that is inserted into the abdominal cavity without visualization. The blunt tip extends forward to protect the abdominal viscera and vasculature from the sharp needle after lower resistance is encountered upon entry into the peritoneal cavity. The needle is often passed at a 45 ° angle in nonobese patients and adjusted to 90 ° in obese patients to avoid visceral and vascular injuries. Once the needle is placed, aspiration and/or injection of fluid prior to insufflation is recommended to confirm proper placement [6, 7].

The open Hasson technique can be used in all patients and is especially preferable for patients with obesity, prior abdominal surgery (with possible intra-abdominal adhesions), or failed Veress needle access. After the initial skin incision, a pair of stay sutures at the fascia level can assist with the fascial opening and allow for peritoneal entry under direct vision and therefore without the need for confirmation of intraperitoneal placement as with the closed technique [6]. Once the trocar is placed, the stay sutures can be used to secure the port in place.

Regarding the prevention of access complications, the open technique is often utilized since the anteroposterior diameter of the pediatric abdomen is relatively narrow. Other recommendations include decompression of the stomach with a nasogastric tube and of the bladder with Foley drainage to avoid injury to a distended intra-abdominal organ. Subsequent port placement should always be performed under direct visualization and with blunt-tipped trocars and especially for accessory ports that may be placed outside of the visual field (behind the camera). In patients with previous abdominal surgeries, ventriculoperitoneal shunts, and/or previous bladder reconstruction surgery, access superior to the umbilicus may facilitate safe entry.

Intra-abdominal access injuries are often recognized immediately and can involve vasculature, intestine, or nerves, with an incidence as high as 5.4% with the Veress technique [7]. Passerotti et al. and others noted that the best predictor for avoiding complications was the surgeon's previous experience with laparoscopic procedures [8–10]. The treatment of access complications will be addressed below.

Vessel Injury

Vessel injury is the most common type of intraoperative complication with minimally invasive surgery. A large multi-institutional analysis showed a complication rate for vascular injury of 0.4% in 880 pediatric robotic urologic procedures [5]. Vascular injuries can occur during intra-abdominal access, port placement, instrument insertion, cauterization of surrounding structures, excessive traction, and careless handling of needles. Common preventive measures include the introduction of ports and instruments with care under direct visualization, dissection with caution to surrounding tissues and vessels, and the avoidance of excessive traction. A set of vascular open instruments should always be available in case rapid conversion to an open procedure is needed. Any vessel injury should be identified and addressed immediately to avoid major blood loss and deterioration of hemodynamic status. If the bleeding source is venous, direct pressure or cauterization can often help to control this bleeding [9, 10]. If a major vessel is injured, the trocar should be left in place and rapid conversion to open exploration is warranted. For minor vessels, if the bleeding cannot be controlled laparoscopically, conversion to open surgery is also recommended [5, 11, 12]. If vascular entry of CO2 during insufflation is suspected, the patient should be placed in the left lateral decubitus position to trap the embolus in the right atrium. Treatment of this potentially catastrophic complication can often be accomplished with central line aspiration and transesophageal ultrasonography [6].

Bowel Injury

Intestinal injury can occur during intra-abdominal access, port placement, and instrument insertion, as well as with electrocautery. The extent of these injuries can vary from simple serosal tears to full-thickness enterotomies. Often, the careful handling of instruments and needles in the abdominal cavity can help to prevent these injuries. In addition, the appropriate placement of insulation tip covers can prevent unintentional cauterization of adjacent tissues. However, for patients with a history of previous abdominal surgeries and/or ventriculoperitoneal shunt placements, a higher risk of bowel injury may be present due to the presence of intra-abdominal adhesions.

For serosal tears, the repair should include imbricating seromuscular sutures. If a full-thickness enterotomy is seen, repair with one or two layers of braided absorbable suture is needed. If multiple tears are present in a bowel segment, bowel resection and primary anastomosis, or intestinal diversion, may be required. If a bowel injury is not immediately identified at the time of surgery, patients can present a few days later with signs and symptoms of peritonitis (i.e., abdominal pain, ileus, leukocytosis, fever with tachycardia, and hypotension) that can progress to sepsis and shock in some cases. Early identification of these injuries in the postoperative period is critical and usually leads to immediate surgical intervention. Laparotomy with intestinal repair or diversion as well as evacuation of debris, secretions, and pus is necessary along with copious irrigation of the peritoneal cavity with antibiotics and saline. An intra-abdominal drain is left in place to prevent re-accumulation of a closed fluid collection [5, 6, 12]. Consultation with the general surgery service is usually recommended for these cases.

Needles

Lost needles during a robotic procedure should be avoided at all costs as they can lead to potential injury as well as additional operative time during the search for the lost needle. Maintaining strict and accurate needle counts during surgery is essential to prevent misplacement of a needle. In addition, the use of a single needle at a time and the verbal reporting by the bedside assistant of the introduction and removal of needles are critical for maintaining accurate counts. If a needle is lost during surgery, it is recommended to avoid movement of the instruments or intestines since movement can alter the original position of the needle and lead to increased difficulty of the search. Undocking of the camera as well as an intraoperative X-ray can assist with locating the needle if initial visual inspection is not successful. Once a lost needle is found, assessment of the bowel and surrounding structures should be performed to evaluate for injury and assess whether repair is warranted [12].

Postoperative Complications

Ureteral Reimplantation

Urinary Retention

Urinary retention rates have been reported as low as 0.5–1.5% after robotic extravesical ureteral reimplantation, which is lower than the historical rate associated with open surgery [13–15]. Patients with bilateral high-grade reflux and severe preoperative dysfunctional elimination syndrome (DES) are known to be at higher risk of developing urinary retention after surgery [15–17]. Once the postoperative urethral catheter is removed, it is important to ensure that patients are voiding on their own prior to discharge. If a patient is unable to void, clean intermittent catheterizations or an indwelling catheter can be used. Conservative management is recommended, as resolution of urinary retention usually occurs in 2–14 days, after which a voiding trial usually results in spontaneous voiding [14, 16, 18–21].

Ureteral Obstruction

Detrusorraphy (closure of the muscle flaps) during robotic reimplantation can be accomplished via several techniques, top-down or bottom-up, and with the use of interrupted sutures or running

sutures [22]. In addition, some authors recommend a ureteral advancement stitch and/or an alignment stitch at the apex to prevent excessive angulation of the ureter during reimplantation and potential obstruction, although the advancement stitch may increase the risk of obstruction as well [16, 17]. Previous studies have reported an incidence of ureteral obstruction in patients undergoing RALUR as high as 4–5%, but this may be a technical issue as this appears to be limited to a few centers [14, 16, 18–22]. Ureteral obstruction may result from aggressive handling of the ureter during surgery, cautery injury during the dissection, and severe postoperative bladder edema. These patients often present during the first postoperative week with abdominal distension and pain, decreased urine output, increased hydronephrosis, and elevated post-void residual volumes. If a ureteral obstruction has occurred, placement of a ureteral stent and possible future surgical repair to repair the obstructed segment may be needed. Serial ultrasonography is useful to monitor the status of the hydronephrosis and hydroureter.

Ureteral Injury/Urinoma

Urinoma, after ureteral reimplantation, is often due to a ureteral injury with resulting urinary leakage into the abdominal cavity. While this can also occur secondary to bladder mucosal injury during the detrusorotomy, this occurs less commonly. The incidence of urine leak after RALUR ranges between 1.7% and 5% at some centers [14, 16, 18–21]. Delicate handling of the ureter including the principle of the "no-touch" technique during distal dissection is necessary to avoid this type of injury. The use of umbilical tape as a sling around the ureter can help to reduce the incidence of ureteral injuries [17], in addition to the use of the hook cautery instrument without cautery during the dissection, since monopolar cauterization near the ureter can lead to unintentional ureteral damage and leakage [21]. Patients with a urine leak may note symptoms such as lower abdominal pain, abdominal distension, anorexia, as well as nausea/vomiting as late as postoperative day 4–7. Ultrasonography often shows the presence of a fluid collection. Computerized tomography (CT) of the abdomen and pelvis or an excretory urography can be used to confirm the ureteral leak. After the diagnosis of a urinary leak, Foley catheter drainage for 1 week and placement of bilateral ureteral stents for 1 month are often needed. Resolution of leak can be verified by ultrasonography 1 month after ureteral stent removal [14, 16, 18–21].

Pyeloplasty

Anastomotic Urinary Leak

Leakage of urine from the ureteropelvic anastomosis is the most common complication of robotic pyeloplasty with an incidence ranging from 2.9% to 10% [5, 23]. The presence of an indwelling ureteral stent for 2–6 weeks after surgery can help to prevent this complication. Excellent outcomes have been reported with a variety of closure techniques and suture materials. The most important factor to avoid urinary leaks is to place sutures evenly at the same angle to achieve a hermetic closure. Also, careful handling of the suture with the robotic instruments can avoid unintentional breakage of the suture and the replacement of previously placed suture lines. Similar to ureteral injuries during reimplantation, anastomotic urine leaks after robotic pyeloplasty can present as late as postoperative day 4–7 and usually require placement of ureteral stent or a nephrostomy tube for drainage. Closure of the leak often occurs in 4–6 weeks after which the ureteral stent or nephrostomy tube can be removed [5, 24–29].

Stent Migration

Ureteral stent placement can be performed in an antegrade or retrograde fashion and can be performed prior to or during the robotic pyeloplasty. Stent migration (distal or proximal) occurs in 0.7–2% of these procedures, and an additional procedure is often needed to retrieve the dislodged stent [24, 25, 27]. Robotic pyeloplasty without the use of a stent has been reported that can avoid this type of complication but these reports often involved the use of a flap reconstruction as opposed to the use of a dismembered

pyeloplasty [23, 30]. Confirmation of the placement of the distal end of the stent into the bladder can be achieved by visualization or with the use of methylene blue dye in the bladder. A postoperative abdominal X-ray is useful to confirm the appropriate stent position after surgery. If a stent has migrated proximally out of the bladder, a urinary leak can occur if there is inadequate drainage via the ureter into the bladder. A migrated stent can be removed either via ureteroscopy or via percutaneous removal through the kidney.

Complex Genitourinary Reconstruction Procedures (Appendicovesicostomy/Ileocystoplasty, Bladder Neck Reconstruction)

Stomal Incontinence

Adequate detrusor tunnel length is necessary for achieving continence in patients with a Mitrofanoff appendicovesicostomy. With the definition of incontinence as the inability to remain dry for more than 4 h, the incidence of urinary incontinence after appendicovesicostomy has been reported to be at least 7% to 10% [5, 31–33]. The risk of incontinence may be higher in detrusor tunnels that are less than 3.5 cm long and if the appendix length is less than 6 cm. If the appendix is not adequate in size (<6 cm), a Monti catheterizable channel may be a better option for these patients. Stomal incontinence can occur as early as within the first year of surgery, but long-term follow-up (>1 year) is needed since stomal complications in this patient population may occur beyond the first year [31, 33]. Incontinence can initially be treated with anticholinergic therapy for the bladder as well as dextranomer/hyaluronic acid injections to the bladder-channel anastomosis. If this is unsuccessful, surgical revision of the channel via an open or robotic approach is indicated.

Stomal Stenosis

Stenosis of the stoma is the most common long-term complication of robotic Mitrofanoff appendicovesicostomy with surgical revision rates as high as 10% to 23% [5, 32, 33]. Most stenosis occur at the skin level and are secondary to angulation or suturing of the stoma to the skin. Parastomal hernias have also been described as a cause of stomal stenosis [31, 34]. The diagnosis usually occurs when there is difficulty in passing the catheter for clean intermittent catheterizations. Surgical revision (usually at the skin level) is needed to achieve stoma patency and to prevent urinary retention. If a parastomal hernia is present, surgical exploration with repair is the treatment of choice [5, 31–33].

False Passage

The patient as well as family members should be trained to care for patients with a catheterizable channel. The incidence of false passage in the pediatric population for catheterizable channels has been reported as high as 18% [35]. If a false passage is suspected, evaluation and careful placement of an indwelling catheter are needed. If successful catheterization is successful, the catheter is left in place for 3–8 weeks to allow the channel to heal [5, 31–33]. If there is extensive trauma to the channel, a cystoscopy with guidewire-assisted placement of a catheter or urinary diversion (Foley or suprapubic tube) can be performed. Surgical exploration with repair may be needed if continued difficulty with catheterization is encountered. Prevention with extensive caregiver education on proper clean intermittent catheterization technique can help to avoid false passages in this patient population.

Small-Bowel Obstruction

Small-bowel obstruction (SBO) can occur secondary to post-op intra-abdominal adhesions. The incidence of small-bowel obstruction after robotic complex reconstructive surgery is estimated at 6–7% [32, 36, 37]. Patients with spina bifida have an increased risk of adhesions and small-bowel obstruction due to the presence of a ventriculoperitoneal shunt and a history of multiple abdominal surgeries. In addition, anterior dissection of the bladder to create an umbilical stoma, for a catheterizable channel, can create a window where bowel can potentially herniate and obstruct. A tacking stitch from the bladder to the anterior abdominal wall may help to pre-

vent this bowel hernia. Regardless of the cause, symptoms such as nausea, vomiting, and abdominal distention after surgery may suggest a small-bowel obstruction. Abdomen X-rays with dilated loop of bowel, air/fluid levels, and signs of coin stacking can confirm the diagnosis of SBO. Conservative management with dietary restrictions and fluid replacement will often improve the patient's symptoms. In acute cases of SBO due to extensive adhesions or herniation, urgent surgical intervention is performed to remove the adhesions and manipulate the bowel as well as close the potential hernia window [32].

Bladder Stones

Stone formation after robotic complex reconstruction with or without ileocystoplasty is a common finding due to urine stagnation, with an incidence of stone formation after robotic ileocystoplasty as high as 20% [31, 32, 34]. Adequate bladder drainage via clean intermittent catheterization (CIC) is necessary to help prevent urinary stones. The location of the appendicovesicostomy may influence urinary drainage patterns and lead to an increased risk of stones and especially in patients with an ileocystoplasty. However, this can also occur for patients with incomplete bladder emptying despite intermittent catheterizations. Patients with bladder stones often present with suprapubic pain, hematuria, or signs of a urinary tract infection. Cystoscopic lithotripsy, or open surgery for large stones, can be performed for removal of the stones [5, 31–33].

Bladder Neck Reconstruction

Robotic reconstruction of an incompetent bladder outlet has been reported with the use of a modified Leadbetter-Mitchell repair, bladder neck sling, and appendicovesicostomy diversion [38]. Conversion to an open approach was required in four patients, due to extensive intra-abdominal adhesions or inadequate appendix length. Postoperative complications included de novo vesicoureteral reflux in four patients and bladder stones in two patients.

Nephrectomy/Heminephrectomy

Contemporary series demonstrate similar rates and types of complications in laparoscopic and robotic upper urinary tract surgery [39]. In a series of 19 patients undergoing robotic heminephrectomy for nonfunctioning moieties, one patient (5%) experienced inadvertent injury to the non-diseased moiety requiring a complete nephrectomy. Previous reports estimate the risk of injury to the innocent renal moiety at 4–5% for open and laparoscopic approaches [39]. Another cohort of 16 robotic heminephrectomy patients found two patients (13%) with postoperative urinomas which were self-limited and four patients (25%) with asymptomatic cysts at the margin of resection on follow-up ultrasounds [40]. Three urine leaks (13%) were noted in a series of 22 patients with retroperitoneal laparoscopic partial nephrectomies who were successfully managed with Foley catheter placement in two patients and ureteral stent with Foley placement in another patient [41]. A multi-institutional review of pediatric urologic robotic procedures included 60 heminephrectomies and 52 nephrectomy cases [5]. In the heminephrectomy group, seven grade I, ten grade II, and two grade III Clavien complications were observed. For nephrectomy, five grade I and six grade II complications resulted. Although complete details were not available for all complications, one notable incident of postoperative pneumothorax was noted in a patient undergoing right heminephrectomy in the setting of prior renal surgery. Because of the small size of the pneumothorax, the patient was managed conservatively and did not require a tube thoracostomy.

Conclusions

Robotic-assisted laparoscopic surgery can be used for the majority of reconstructive procedures in pediatric urology, but surgeons should be aware of the potential pre-, intra-, and postoperative complications. While a learning curve is associated with all new procedures and tech-

niques, it is recommended that surgeons who are beginning to use robotic surgery start with simple straightforward procedures and then graduate to more complex reconstructive cases to help prevent both intra- and postoperative complications. This chapter addresses the most common complications that can occur before, during, and after the most commonly performed robotic-assisted laparoscopic procedures in pediatric urology.

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Part VI

Complications in Robotic Single Port Surgery

Complications in Robotic Single Port Surgery

34

Ryan J. Nelson and Robert J. Stein

Introduction

The first reported implementation of laparoendoscopic single-site (LESS) surgery was performed in 2005 by Hirano et al. in which basic laparoscopic instruments were used through a single incision site during a retroperitoneal adrenalectomy [1]. This spurred interest in this approach to laparoscopic surgery but it was not until 2008 when Rane et al. first reported a LESS nephrectomy [2]. Since then, considerable advances in single-site port instruments have made and developments progressed, including the first reported R-LESS surgery by Kaouk et al. in 2009 [3]. At that time, the da Vinci S surgical robot (Intuitive Surgical, Sunnyvale, CA, USA) was configured using standard multiport instruments through a single incisional site (Fig. 34.1). This configuration was not optimal due to the arm clashing and difficulty with triangulation. Nevertheless, it did pave the way for the development of the prototype SP1098 single-site robotic platform which exhibits three double-jointed articulating instruments which are able to work through a singe 25-mm port. These innovations will allow urologic surgeons to complete some of the most demanding surgical procedures through a single incision.

Since R-LESS surgery is still emerging and, to a certain degree, in its infancy as a surgical technique. Few studies have reported on the overall complication rates as in comparison to conventional laparoscopy (CL). Reported complication rate for R-LESS ranges from 0% in small studies [4] to 18.8% [5] postoperatively. Several studies have set out to classify and categorize these various complications, namely these are divided into intraoperative, early postoperative, and late postoperative. The Clavien-Dindo standardized grading system is commonly used to report postoperative complications. Early complications were defined as occurrence within 90 days and late complications were referred to as an occurrence after this period of time. This chapter will outline and review the reported R-LESS studies and the specific experienced complications during these procedures (Table 34.1).

Intraoperative Complications

During R-LESS cases, mechanical instrumentation and procedural movement is quite hindered and cumbersome due to the lack of operative space available in attempt to triangulate the instruments through the single port. When attempting to retract, dissect, or advance in the

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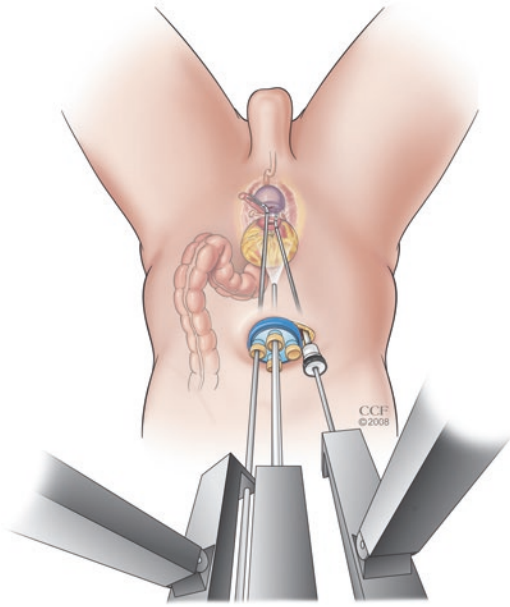

Fig. 34.1 This figure identifies one of the first modified R-LESS attempts at port placement (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2008–2017. All Rights Reserved)

surgical procedure, working under such constraints becomes the main culprit of injury as it may be difficult to continuously visualize every instrument tip during procedural dissection. To minimize the risk of injury, blind advancement and movement of instruments should be avoided.

Bowel Injury

Bowel injury can be subcategorized into injury related to insufflation, mechanical injury by instrumentation, thermal injury, and injury related to trocar/port placement. Most commonly, access and insufflation to the peritoneal cavity is carried out with a Veress needle in R-LESS in the same fashion that occurs during CL. In patients with extensive history of prior abdominal surgeries, the risk of enteric injury during a Veress needle placement is increased and therefore it has been recommended that the placement of the Veress needle should be at least three finger breaths away from an incisional scar. Early identification of bowel injury is paramount and can often be recognized by a sudden increase of insufflation pressure after the CO2 has been connected. If a bowel injury is noted, immediate desufflation and, depending on the injury, a general surgery intraoperative consultation is in order. Only a serosal bowel injury and a rectal injury have been documented in literature thus far during R-LESS urological procedures [6, 7]. Both were managed by over sewing the serosa without need for an additional port placement or management.

Thermal Injury

Thermal injury has been subcategorized into direct thermal conduction, capacitive coupling, and thermal injury due to malfunction of insulation of the instruments during CL. Despite the da Vinci monopolar instruments incorporating a silicone insulation sleeve, thermal injury can still occur. During any R-LESS case, the surgeon should always be mindful of the laparoscopic instrument as it traverses the abdominal or pelvic cavity and be aware if the instrument shaft does come into contact with any vital structure.

Vascular Injury

Additional port placement or open conversion is often required in the event that hemorrhage is encountered. First, an axillary trocar is placed to aid in either exposure or dissection by the bedside assistant. If this fails, open conversion is the next option for the surgeon. Open conversion can be followed by radical conversion in the case of attempted R-LESS partial nephrectomy. Shin et al. reported their radical conversion to be 1.3% [5], which was due to renal vein injury. Attempts should be made to achieve hemostasis intraoperatively by means of first clamping the renal artery with the robotic bulldog clamp, followed by intracorporeal suturing if possible [5].

Table 34.1 Reports of various single site procedures and complications experienced

	N	Procedure(s)	Complications	Type of complication
2009: Kaouk [4]	3	Radical prostatectomy, pyeloplasty, radical nephrectomy	None	N/A
2009: Stein [12]	4	Pyeloplasty (2), radical nephrectomy (1), partial nephrectomy (1)	Anemia (1)	Clavien 2
2010: White [13]	20	Radical prostatectomy	Single port added (2), ileus (1), PE (1), anemia (1)	Intraoperative conversion, postoperative Clavien 1–2
2010: White [14]	47	Radical nephrectomy, partial nephrectomy, nephroureterectomy, radical cystoprostatectomy, radical prostatectomy, simple prostatectomy, ureteric reimplantation, pyeloplasty, sacrocolpopexy	Conversion to standard robotics (3), single port added (3)	Intraoperative conversion
2011: Han [15]	14	Partial nephrectomy (14)	Conversion to mini open incision (2)	Intraoperative conversion
2011: Lee [16]	68	Partial nephrectomy (51), nephroureterectomy (12), radical nephrectomy(2), adrenalectomy (2), simple nephrectomy (1)	Bleeding/anemia requiring transfusion (9), conversion (3), renal vein injury (1), ureteral injury(1) serosal bowel injury (1)	Intraoperative transfusion and suturing of injured structures
2011: White [8]	10	Radical nephrectomy (10)	Skin infection (1)	Postoperative Clavien (1)
2012: White [7]	50	Renal surgery (24), pelvic surgery (26)	Converted to CL (4), single port added (6), rectal injury (1), postoperative (8)	Intraoperative (11) postoperative Clavien grade 1–4
2012: Olweny [17]	10	Pyeloplasty (10)	Urine leak(1)	Postoperative Clavien grade 3a
2012: Cestari [18]	9	Pyeloplasty (9)	Pyrexia (1)	Postoperative Clavien grade 2
2012: Fareed [19]	9	Suprapubic transvesical enucleation of the prostate (9)	Intraoperative bleeding (2), clot retention, DVT(1), UTI (1), MI(1)	Intraoperative (2), postoperative Clavien 2–4
2013: Mathieu [20]	6	Pyeloplasty (6)	None	N/A
2013: Komnios [21]	78	Partial nephrectomy (78)	Bleeding/anemia (7), radical conversion (2), urinary leak (2), retroperitoneal bleed (1)	Intraoperative bleeding, postoperative Clavien 1–3b
2014: Shin [5]	79	Partial nephrectomy (79)	Open radical conversion due to renal vein injury (1), ureteric injury (1), renal vein injury (1), hemorrhage requiring transfusion (9), pyrexia (1), clot retention (1), pneumonia (1), urine leak (1), embolization (1), hydronephrosis (1)	Intraoperative (3), postoperative Clavien 2–3(15)
2014: Kaouk [9]	19	Radical prostatectomy(11), radical nephrectomy(2), partial nephrectomy(4), simple nephrectomy(2)	Anastomotic leak(1), urinary tract infection(2), umbilical scar abscess(1), bladder neck stricture(1), bleeding(1), anemia(1), perinephric hematoma(1)	Postoperative Clavien grade 1-3b

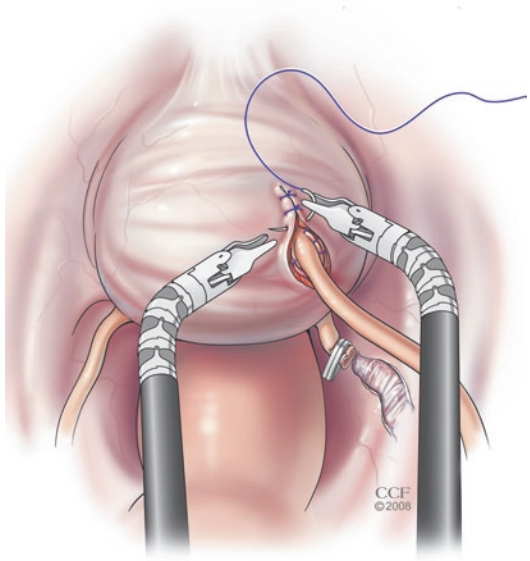

Fig. 34.2 This figure identifies the new single-site dedicated robotic platform SP1098, during a ureteral reimplant. This single site is beneficial in such cases where surgical specimen extraction is not required (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2008–2017. All Rights Reserved)

Ureteral Injury

Ureteral injury is primarily the result of thermal spread of energy as dissection takes place near the ureter with the robotic monopolar scissors. Occasionally, it can be the result of direct sharp robotic scissor dissection. Intraoperative identification is preferred and once identified can be managed with removal of any charred or devascularized tissue, suture repair, and ureteral stent placement [5]. R-LESS has been utilized for even a ureteral reimplant in such cases (Fig. 34.2). Extended duration of Foley catheter is implemented during such cases until has healed appropriately.

Postoperative Complications

Port-Site Infection

In spite of complete sterile technique and minimal contact with the skin directly during R-LESS procedures, White et al. report during a series study of 10 patients, only 1 patient developed a port-site infection [8]. In a more recent study, Kaouk et al. also report a surgical site infection at the entry site of the umbilicus [9]. These infections, like most CL surgical-site infections, were diagnosed on early follow-up in the clinic, and were treated with appropriate oral antibiotics. These infections may present as induration with blanching erythema around the port incision. If fluctuance is noted on the exam, the cutaneous sutures should be opened, any fluid drained, cultures taken, followed with wound irrigation, and allowed to heal by secondary intent.

Ileus

Postoperatively ileus is not uncommon among any laparoscopic case, and R-LESS is not an exception. Bowel manipulation, increased abdominal insufflation of CO2, general anesthetics, and postoperative narcotics are all potential instigators for the development of an ileus. Early ambulation and decreasing the narcotic threshold should be implemented on every R-LESS patient. If a patient does develop ileus, bowel rest and, if warranted, nasogastric tube placement for bowel decompression should be pursued.

Acute Blood Loss Anemia

Acute blood loss anemia requiring blood transfusion is most commonly seen in the R-LESS partial nephrectomy patient. Incomplete renorrhaphy, failure to ligate the segmental branches during repair of the partial nephrectomy defect, or suture tearing through the renal capsule once the patient is mobilized all are risk factors of postoperative bleeding. If the hemorrhage is significant, embolization may be necessary [5]. Transfusion has been reported in many of the R-LESS studies to stabilize the patient and is frequently the only treatment necessary.

Deep Vein Thrombosis and Pulmonary Embolism (DVT and PE)

Many of the R-LESS patients in reported studies are oncologic patients in combination with prolonged operating time greater than 5 h in some instances [10]. These are two of the major precipitating risk factors for vascular stasis and thrombosis, leading to embolism. A delicate balance is played during partial nephrectomy R-LESS surgery and giving prophylactic anticoagulants, and every patient should be evaluated individually. It is recommended the R-LESS surgeon be familiar with the American Urological Association guidelines on DVTs [11]. Early recognition of a thromboembolic event and appropriate management is paramount should a patient develop a complication such as this and a multidisciplinary team is often beneficial in the care.

Urine Obstruction/Leak

This complication is usually diagnosed within the first few days after the R-LESS surgery with keen clinical skills and assessment of the patient's symptoms. Increased abdominal pain with flank pain, increased drain output, and even perhaps urine drainage from the incisional site are all clues to a urine leak. Conformational diagnosis is assured with a CT with intravenous contrast identifying extravasation into the peritoneal postoperative surgical field. This leak could be the result of extravasation from a calyceal defect during a partial nephrectomy or from renal pelvis and ureteral injury. In the literature reviewed, bladder injury was not reported. Of the cases in Table 34.1, urinoma was managed by percutaneous drain, and ureteral injuries were managed with prolonged ureteric stent placement.

Conclusions

Albeit less than 200 R-LESS cases have been reported in literature, this developing technique is at the forefront of urologic surgery. With the coming new era of the dedicated single-site robotic platform of the SP1098, R-LESS might possibly become the new standard of laparoscopic surgery. Along with the incorporation of R-LESS into more centers of excellence, further studies will clearly identify other complications that have not been listed. The benefit of decreased postoperative pain and improved cosmesis must be weighed against the possible increase in overall risk and the severity of risk.

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Part VII

Simulation of Complications in the Animal Model

Simulation of Complications in the Animal Model

35

Oscar D. Martín, Jian Chen, Nathan Cheng, and Andrew J. Hung

Introduction

Since its first introduction, robotic-assisted surgery has been rapidly popularized and has now become a major surgical technique. In 2011, four of every five radical prostatectomies in the United States were done by surgical robots, and the surgical volume was increased by 25% in the year following [1]. There is a similar trend around the world over these years.

Robotic surgery initially showed similar results compared to currently existing approaches. However, over time, robotic surgery has demonstrated superiority and has even become the gold standard in some procedures, such as surgery of the upper urinary tract, partial and radical nephrectomy, pyeloplasty, and radical prostatectomy [2, 3].

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The increase in robotic surgery volume requires a solid training method for robotic surgeons, either surgical residents or surgeons willing to do robotic surgery who have not been trained before. One important aspect of the robotic surgery training is the avoidance of surgical complications. Surgical complications are related to surgeons' experience, acquisition of new skills, and the learning curve associated. All of these suggest the need of a comprehensive training system of robotic surgery to improve the learning curve initially, to subsequently transform the skills into surgery, and to ultimately decrease complications and improve results of surgery.

Training Phases

The traditional surgical training fashion is "See one, do one, teach one," meaning the novice is trained under the supervision of an experienced surgeon directly on the patient. However, this training method raises ethical concerns, and its effectiveness varies [4]. Therefore, simulation-based training allows the surgeons to acquire technical and nontechnical skills before entering to the surgical arena, promoting patient safety and surgical outcomes [5, 6].

Ideally, robotic surgical novices should go through the training process from preclinical training to clinical training. Preclinical training

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phase includes didactics, inanimate exercises, and laboratories of tissue and animal models or human cadavers. Recently, models of virtual reality (VR) have been introduced with great popularity. Clinical training phase includes observation, surgical assistance, and tutoring coming from an expert. Currently there are some proposals with great impact on robotic surgical training [7, 8].

Preclinical Training Phases

Didactic

The most efficient way to avoid complications is knowing what kinds of complications surgeons will face. Firstly, it is critical for surgeons to familiarize themselves with the robot console, robotic instruments, its working mechanism, and how to tackle common mechanical problems during a surgery. Also, surgeons should be familiar with the common complications related to robotic surgeries, such as compression injuries and thermal abrasions. After gaining the basic knowledge of the robot, surgeons may proceed to learning procedures [1, 7, 8].

Inanimate Exercises

The best introduction to the basic functions of the robotics surgical system is performing inanimate exercises. The exercises vary in difficulty, ranging from the simplest, such as gaining access to the cavity, to tasks more specific and complex, such as suturing or vascular control. After each exercise, performers will be evaluated according to the time to complete, numbers of errors, and the success of the completion of the task. A commonly used evaluation method was Fundamentals of Laparoscopic Surgery (FLS). FLS was subsequently adapted by the American Urology Association (AUA) and was modified into Basic Laparoscopic and Robotic Urological Surgery (BLUS) specific for urological surgery evaluation [7]. The utility and validity of BLUS was studied in a small cohort by the University of South California (USC), showing a good correlation between the performance of VR and that of the live robotic tasks (cross-modality validity) [9].

Wet Tissue Laboratories

Exercising in the wet tissue laboratory is considered to be the next step of training. Unfortunately, there has not been much research on such training modes. There are some proposed models for specific procedures in different specialties. Marecik et al. compared intestinal anastomosis performed by residents using robotic instruments and by hand. Result showed that the quality and time of completion significantly improved after three exercises with the use of the robot [10]. Hung et al. used swine kidney with a polystyrene foam ball built inside to develop a renal tumor model for partial nephrectomy. Feedback on the training value in this exercise from novice surgeons, intermediates, and experts demonstrated that this model had strong face, content, and construct validity [11]. Sotelo et al. [12] and Cacciamani et al. [13] reported vesicoureteral anastomosis and urethrovesical anastomosis models using chickens. Both urologist and urology residents evaluated these two models to be very similar to human urinary tract tissue and useful for training purposes.

Animal Models or Human Cadavers

Exercises on animal models or human cadavers are traditionally used for minimally invasive surgery training [14]. Unfortunately, to date, there are few studies that validated the use of the robotic platform in animals or cadavers. One study reported simulating renal vein tumor thrombi in pigs by infusing gelatin, Metamucil, and blue methylene or Kromopan hydrocolloid into renal vein [15].

Virtual Reality

Virtual reality exercises simulate various surgical skills, winning an important position in the existing training methods, revealing a positive impact on robotic surgical training through different stages of validation. The three simulators commonly used are Mimic dV-Trainer (dV-Trainer, Mimic Technologies, Inc., Seattle, WA, USA), the robotic surgical simulator (RoSS), and the da Vinci Skills Simulator (dVSS, Intuitive Surgical, Sunnyvale, CA, USA) (Table 35.1).

Table 35.1 Summary of validation studies of robotic simulators

Simulator	Face validity	Content validity	Construct validity	Learning demonstrated	Correlated with other modalities	Cost	References
dV-Trainer 2007	Yes	Yes	Yes	Yes	Yes	$100.000	[16–24]
RoSS 2009	Yes	Yes	Yes	Yes	Yes	$100.000	[30–33]
dVSS 2011	Yes	Yes	Yes	Yes	Yes	$ 85.000	[9, 34–39]

Mimic dV-Trainer

Mimic dV-Trainer is the first developed simulator and the one with the most validation studies. Its prototype was introduced in 2007. Mimic dV-Trainer is a stand-alone, portable, tabletop device with mobile foot pedals. This device has 65 unique exercises ranging from basic to advanced. Users' hand and wrist movements are tracked with three cables, which is different from the RoSS and the real da Vinci robot console. Its own evaluating system enables the learners to keep track of their performance by showing their scores and errors for both individual metrics and the whole task. The system has proven its applicability for robotic surgery training, showing the correlation between the performance of virtual reality and the performance on the real da Vinci robot console. Nine different studies have corroborated this [16–24] (Table 35.1). Training on the Mimic dV-Trainer has similar effects in basic skill improvement as the training in the setting of dry laboratory. Daily training on the dV-Trainer system has been recommended; 1 h a day for four consecutive days has shown greater improvement in skill [25].

This simulator has also been shown to be useful to acquire advanced skills in certain procedures [26]. Also, Lendvay et al. demonstrated that practicing on the mimic dV-Trainer 3–5 min prior to the surgery improves the time of surgery and the economy of the movement [27].

Robotic Surgical Simulator (RoSS)

RoSS is a portable, stand-alone system that has been available since 2009. It provides 52 unique exercises organized into five categories: module orientation, motor skills, basic surgical skills, intermediate surgical skills, and a surgical training. The RoSS has its own hardware, which differs from the current da Vinci Surgical System mainly in hand controls, having a lower range of movement resulting in a greater need for clutching.

RoSS system has been proven to be a useful training tool for developing robotic surgical skills [28]. Stegemann et al. suggested that by practicing on the RoSS system, surgeons can gain better surgical skills. Also the study advocated that the implementation of RoSS simulator practicing into a standardized training program results in significant improvement in the basic skills of robotic surgery [29]. The curriculum, formally known as the Fundamental Skills of Robotic Surgery (FSRS), consists of 16 RoSS tasks from four modules: basic console orientation, psychomotor skills training, basic surgical skills, and intermediate surgical skills [28].

RoSS has the ability to measure several performance metrics [30–33] (Table 35.1). Chowriappa et al. developed an evaluating system, Robotic Skills Assessment (RSA) Score, in an effort to delineate real-world performance metrics from others [33]. This scoring system provides the users a valid and standardized assessment tool for reality virtual simulation. A panel of robotic surgery experts developed the score by defining tasks, assigning weights, and integrating performance metrics into a hierarchical scoring system. They gave more importance to the surgical safety and critical errors but less to the time of completion of the tasks. Evaluation of RoSS system was later on based on the RSA system. It was applied to compare the scores of novice and expert surgeons to

confirm its construct validity. The RSA scoring system is potentially applicable to all robotic virtual reality simulators.

da Vinci Skills Simulator (dVSS)

dVSS is the only simulator directly connected to the console of the da Vinci Surgical System. It was first introduced in 2011 and embraces 40 exercises. There are no discrepancies in the hardware; however, the simulator cannot operate independently, requiring a console of the da Vinci Surgical System. A disadvantage of this simulator is that if the da Vinci Surgical System is in clinical use, the dVSS is then not able to be used for training purposes.

The dVSS is a useful training tool that has been widely studied, including face, content, construct, and predictive validity studies [9, 34–39] (Table 35.1). In Culligan et al. predictive validity study, surgeons performed better in robotic hysterectomy cases after training on dVSS [40]. Hung et al. demonstrated that baseline skills on the dVSS were predictive of baseline and final scores on da Vinci ex vivo tissue performance [41].

Several research groups established and validated their training programs; three research studies demonstrated proficiency-based training curriculum [40, 42, 43]. Bric et al. established an expert proficiency level: three consecutive scores at or above this level is considered to be proficient [42]. Culligan et al. also adopted the expert proficiency levels, but did not comment if consecutive attempts were required [40]. Zhang et al. used 91% composite score as the standard for proficiency [43].

Two research groups introduced their training programs, which were based on the completion within maximum number of attempts. Gomez et al. [44] and Vaccaro et al. [45] described curriculums by achieving the global score of 80% within a maximum of six and ten attempts, respectively.

University of Southern California (USC) conducted two studies. One was the concurrent and predictive validity study of the dVSS in the setting of ex vivo tissue laboratory, showing significant performance improvement from the baseline after practice [41]. The other study was the correlation study between the training on the simulator and the clinical performance of residents and fellows [29].

Clinical Exercise

After completing the preclinical training stage, the surgeon can begin the clinical phase, which involves direct contact with an actual patient.

Observation and Assistance

The clinical phase should not begin with immediate performance of a surgical operation. Instead, learning and detailing the surgical procedure with or without an instructor through observation of an operation in real time or on a video are recommended. Often, small details make big differences in the execution and results of an operation (i.e., proper angling of a needle is important in rebuilding a urethrovesical anastomosis). Thus, it is very important to recognize the correct and incorrect forms of each step in a surgical procedure and learn from errors made during operating or observing.

Following observation, the next step is to become the surgical assistant [46]. Assisting in surgeries is a necessary and logical bridge between observation and surgical autonomy. In robotic surgery, it is proposed that students start clinical training as head assistant to the surgeon's console. Presumably, this will help the training surgeon understand the functionality and limitations of the robot and the different strategies and techniques used in various procedures [46].

Operating Under the Tutorship

At this point, the surgeon in training should have broad knowledge of the operations without having mastered the tactile robotic surgical skills. The next step in learning is the last step of training: operating under tutorship. Operating under tutorship is the actual performance of surgical procedure by the training surgeon in the surgeon's console under supervision of an expert who can take charge of the surgery when necessary or during technically advanced surgical

steps [46]. A challenge in robotic surgery is the fact that many robots only have one surgeon console; therefore, the expert has no immediate operational control while the apprentice is operating [46]. A solution to this problem is the use of an additional "tutoring console" that allows the expert to operate at the same time as the apprentice. It is also important to record the procedure so the apprentice can review and improve his or her own surgical execution in this operation under tutorship phase.

Another model that has been used is telementoring, another form of tutoring in study. It allows a skilled surgeon to remotely observe the robotic surgery in real time and provide verbal advice for the apprentice's performance as needed. In the more advanced models, the expert may indicate specific areas on the display or even take control of the camera and instruments. The surgical system da Vinci has these features in research that can facilitate this mode [47]. This feature is currently facing important challenges, including latency and bandwidth of the connection and its unclear medical-legal implications.

Advantages and Disadvantages of Models

Each of the following training models facilitates the development of surgical skills.

The inanimate exercises model is one of the more economical models, thus having the advantage of being accessible and allowing for proper introduction to robotic procedures.

The tissue laboratory model is also a low-cost, easily accessible model. It allows for development of skills specific to a particular point in a surgical procedure. However, this model does not utilize newer technologies.

The animal or cadaveric model is the best model for training, allowing for low to high complexity skills development and the possibility for simulating real-time handling of intraoperative complications. The biggest disadvantage is that these models are difficult to initiate and sometimes simply banned depending on the laws in the country of use.

The virtual reality model is a costly method (40,000–100,000 USD) but can be considered as the model with the best cost-benefit ratio since it allows low to medium complexity skills development without the robotic console. The virtual reality model simulates the interface of the surgeon console and is available to the training surgeon more conveniently. There have been no studies indicating which robotic console training method represents the best option.

Proposals and Models of Training for Urologists

An expert surgeon is a person who has acquired knowledge and surgical skills through experience and instruction. There have been various mechanisms described to achieve this status: the first and very controversial is the acquisition of expert status through amount of training hours [48], as shown in some studies, including that conducted by Korets et al. [17]. It analyzed the execution of some specific surgical exercises comparing three groups: group one had incomplete training, group two had complete training, and group three was the control group without training, which demonstrated the two groups that had training had better surgical ability.

The duration of training and interval between training sessions needed to improve skills have not been stipulated; however, there have been studies trying to determine these parameters, such as that of Kang et al. [25]. The study compares three training regimens: 1 h daily for four consecutive days, 1 h weekly for four consecutive weeks, and four consecutive hours in 1 day. The group that trained for 1 h daily for four consecutive days was associated with increased performance and continuous score improvement.

Another important model in skills training is problem-based learning (PBL), an instructional method in which students learn through facilitated problem-solving. The main objectives in this model are to acquire (1) flexible knowledge, (2) problem-solving skills, (3) skills in self-directed learning, (4) effective collaboration skills, and (5) intrinsic motivation. This model

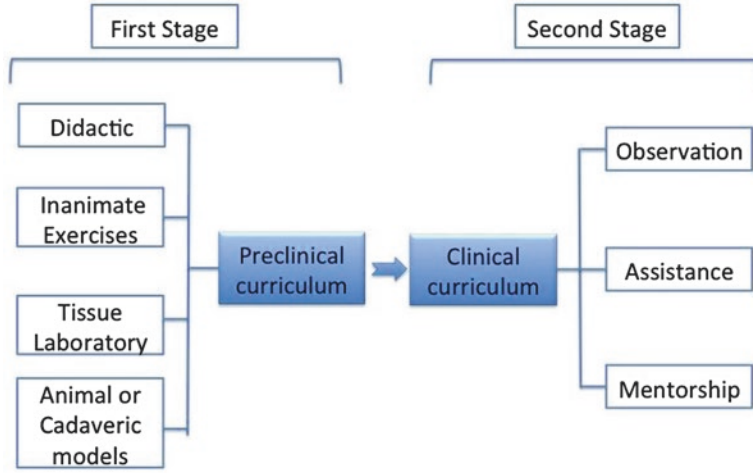

Fig. 35.1 The training phases of robotic surgery. The first stage, also known as preclinical phase, includes robotic didactic introduction, inanimate exercises, tissue laboratory exercise, and animal or cadaveric model exercise. The second stage, which is clinical phase, starts with surgical observation, assistance, and gaining surgical technique under mentorship

shows that complex problems do not have a single correct answer [49].

With the many existing models of robotic surgery training in mind, the University of Southern California proposes a model based on two phases: first, the preclinical phase, and second, the clinical phase [1] (Fig. 35.1). A similar model was developed and validated for the realization of robot-assisted radical prostatectomy (RARP) by Volpe et al. [50]. They showed that a 12-week curriculum, which included 1 week each of structured simulation-based training; e-learning or virtual reality training; synthetic, animal, and cadaveric platforms; and supervised modular training for RARP, is feasible, valid, and impactful on surgical education. The participants in the RARP training improved their basic robotic surgical skills and their capacity to carry out the preclinical training into the clinical phase of RARP. Recently, Lovegrove et al. developed and validated the Healthcare Failure Mode and Effect Analysis (HFMEA), a safety and assessment tool to measure the technical skills of surgeons performing robot-assisted radical prostatectomy. HFMEA, which supervises improvement and measures progress, can be used in the future to guide mentors to allow their training surgeons to perform procedures safely.

To date, there are few comprehensive programs validated for robotic surgery training. The efforts so far have brought us closer to achieving the goal of creating a single model that is valid and standardized to acquire specific skills and correct execution of different surgical procedures and proper avoidance of complications.

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