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SETTING THE SCENE
REVIEW

Complications in robotic urological surgeries and how to avoid them: A systematic review

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KEYWORDS

Surgical complications;
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ABBREVIATIONS

CK, creatine kinase;
DVT, deep venous thrombosis;
ICP, intracranial pressure;
MIS, minimally invasive surgery;

Abstract ***Objectives:*** To review the main complications related to the robot-assisted laparoscopic (RAL) approach in urology and to suggest measures to avoid such issues.

Methods: A systematic search for articles of the contemporary literature was performed in PubMed database for complications in RAL urological procedures focused on positioning, access, and operative technique considerations. Each complication topic is followed by recommendations about how to avoid it.

Results: In all, 40 of 253 articles were included in this analysis. Several complications in RAL procedures can be avoided if the surgical team follows some key steps. Adequate patient positioning must avoid skin, peripheral nerve, and muscles injuries, and ocular and cognitive complications mainly related to steep Trendelenburg positioning in pelvic procedures. Port-site access and closure should not be neglected during minimally invasive procedures as these complications although rare can be troublesome. Technique-related complications depend on surgeon experience and the early learning curve should be monitored.

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PN, partial nephrectomy;
RAL, robot-assisted laparoscopic;
RC, radical cystectomy;
RP, radical prostatectomy;
VTE, venous thromboembolism

Conclusions: Adequate patient selection, surgical positioning, mentorship training, and avoiding long-lasting procedures are essential to prevent RAL-related complications. The robotic surgical team must be careful and work together to avoid possible complications. This review offers several steps in surgical planning to reach this goal.

Introduction

Minimally invasive surgery (MIS), including either traditional laparoscopic and robot-assisted laparoscopic (RAL) approaches, have been promoted in a hope that their use would reduce surgical complications. Since the Intuitive da Vinci® System (Intuitive Surgical Inc., Sunnyvale, CA, USA) was approved for use in laparoscopic procedures in 2000; RAL has increasingly become the standard procedure for the management of benign and malignant urological disorders. Furthermore, it has smoothed the steep learning curve of laparoscopy, increasing the number of MIS surgeons in training around the world.

Minimising morbidities and complications is a pivotal goal of RAL. After oncological procedures, the definition of success has been based not only on oncological and functional results, but also on fewer complications. Currently, the 'pentafecta' concept has emerged as a new standard for reporting outcomes after urological surgeries, e.g. radical prostatectomy (RP), radical cystectomy (RC), and partial nephrectomy (PN) [1–3].

RAL is generally perceived as having lower perioperative complications; however, as its use has increased, numerous reports of iatrogenic complications related to positioning, trocar placement, gas insufflation, and surgical technique have been published. The risk of MIS iatrogenic complications in the USA is ~1.3%, but decreasing over time [4]. Underlying comorbidities must also be taken into account when considering a patient for MIS, as patient-related factors may impact the incidence and severity of perioperative complications [5,6].

The present review aimed to assess the main complications related specifically to the RAL approach in urology and to suggest measures of how to avoid them. Thus, we concentrate only on avoidable issues and complications associated with specific procedures will not be addressed here.

Materials and methods

A systematic search in PubMed database was performed to identify studies related to complications in RAL urological procedures. We have included only full articles in the English or Spanish language, between 2000 and 2017. The keywords comprised 'complication', 'safety', 'robot', 'robotic-assisted', 'urology', 'prostatectomy', 'nephrectomy' and 'cystectomy'. Most common RAL-related complications were also individually searched in PubMed and references, yielding a total of 253 articles. After initial screening, we excluded all case reports, editorial comments and articles clearly addressing only procedure-specific complications rather than general avoidable complications. Papers related to positioning, access, insufflation, and operative technique considerations were then selected after abstract and/or full manuscript evaluation (Fig. 1). We present an overview of avoidable RAL-related complications topics to the practicing robotic urological team.

Results

Fig. 1 shows the flowchart of this systematic search of the literature; 40 of 253 articles were included in the present review.

Patient positioning

A steep Trendelenburg position is required to allow adequate pelvic exposure in robotic pelvic procedures, e.g. RP and RC, whilst a lateral decubitus position is adopted for most retroperitoneal surgeries. The risk of perioperative complications is increased by incorrect patient positioning, inadequate fixation or even a long-time in the proper patient positioning. Positioning-related complications are even more common in obese patients, either related to weight pressure or longer operative time [5,7,8].

Skin lesions

Most skin lesions are positioning related. The combination of general anaesthesia and prolonged immobilisation is the ideal situation for decubitus pressure lesions. Inadequate fixation and patient slippage might potentiate it and lead to severe decubitus and trocar-site lesions. Fixation of the patient on the table with a gel mattress, restraints, body and shoulder straps may prevent such complications [9].

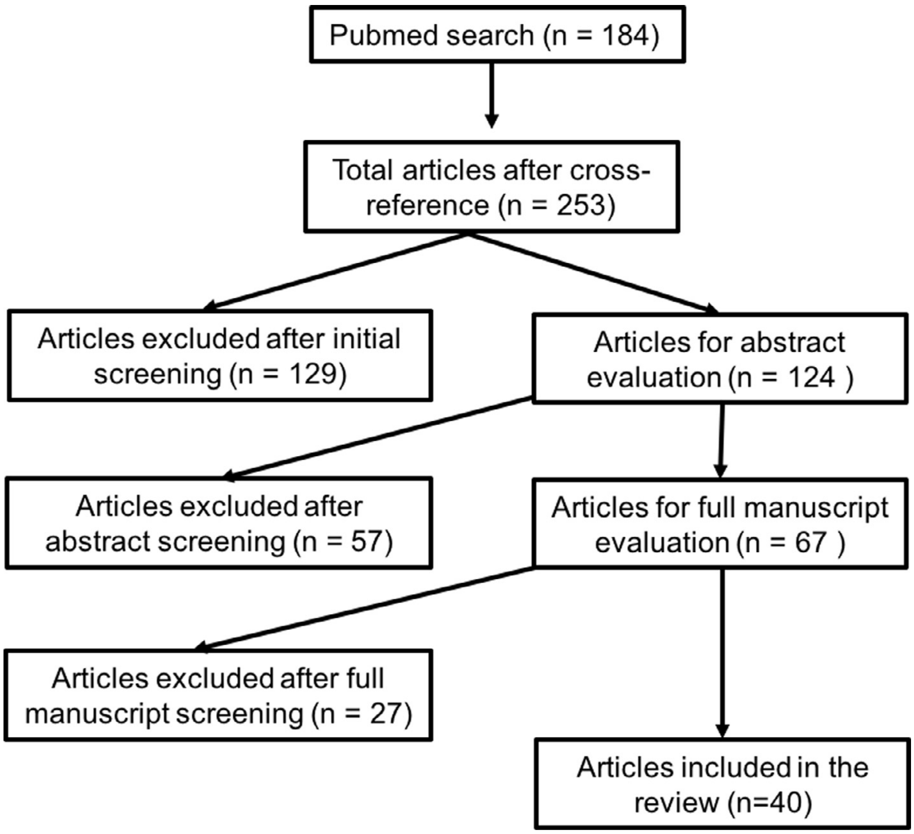

Fig. 1 Flowchart of systematic literature search.

In addition, there are other types of skin lesion that are unrelated to positioning. Improper incision length can cause skin damage during specimen retrieval. Also, scrotal skin injuries induced by scrotum gas distension are possible and it must be empty of gas at the end of the procedure. Robotic arms can also be responsible for direct injury, primarily on the face, because of the proximity of the robotic camera in the Trendelenburg position, thus the bedside assistant should be observant to prevent it [10].

Peripheral nerve injury

Patients under general anaesthesia are at risk of nerve injuries, as they are unable to protect themselves and extreme positions further increase the risk. Position-related nerve injury risk may increase as much as 100-fold for each hour of surgery for both upper and lower limbs nerves [11,12]. Arm hyperabduction can cause brachial nerve plexus injury in the Trendelenburg position, thus it must be avoided by keeping the arms close to the body. In lateral decubitus, an axillary roll should be placed to prevent contralateral brachial plexus compression and the ipsilateral arm can be positioned on the side to avoid trauma that can be caused by robotic arm collision [12]. The ulnar nerve is typically damaged next to the elbow and patients can present with sensory and/or motor deficits. It is essential to avoid such lesions by padding the elbows. Hands should be placed in a neutral position and properly fixed to prevent radial nerve injury [12]. Femoral nerve stretch injury can result from hip hyperextension, thus one must be careful during lithotomy positioning [11]. Side docking instead of standard low lithotomic position has been proposed to overcome nerve injury of the lower limbs [13].

Rhabdomyolysis

Clinically relevant rhabdomyolysis can occur in patients exposed to prolonged robotic procedures, mainly at the beginning of the learning curve. Serum creatine kinase (CK) increases after surgery peak at ~18 h after the procedure, but CK elevation in isolation should not be used to predict positioning injury [14]. Prolonged Trendelenburg position, high body mass index, peripheral vascular disease, and comorbidities increase the risk of muscle injuries [8,15]. Serum-CK dosage is indicated for these patients and for those with pain in the back, thigh or gluteals after surgery. Serum-CK levels of >1000 IU/L or myoglobinuria confirms a rhabdomyolysis diagnosis, which increases the postoperative renal failure risk. Hypervolaemic diuretic therapy and management of metabolic acidosis are required in such situations [14].

Ocular complications

A steep Trendelenburg position combined with pneumoperitoneum can cause increased intra-ocular pressure, reduced ocular perfusion, and possibly visual impairment caused by ischaemic optic neuropathy. Permanent vision loss is a rare but devastating complication [16,17].

Corneal abrasion is 6.5-fold more common in robotic than open pelvic procedures [18]. Corneal lesions are related to corneal position-related oedema, increased ocular pressure, and drying of the ocular surface.

Although one can suppose elderly and obese patients are more sensitive to ocular complications, there is no unequivocal evidence on which patients should be preoperatively evaluated. Some studies have suggested preoperative assessment in patients with ocular hypertension of past ischaemic events [16,17].

Limiting operative time, adequate intraoperative blood pressure monitoring, and transparent occlusive dressing as opposed to standard eye tape may play a role in minimising the risk of intraoperative ocular complications [16].

Cognitive dysfunction

A steep Trendelenburg position and pneumoperitoneum can result in increased intracranial pressure (ICP), reduction of cerebral oxygenation and ultimately in cognitive dysfunction, especially in elderly patients. Although ~15% of patients can present ICP at >20 mmHg, abnormal neurological signs are a rare event. Internal jugular vein valve incompetence may play a role in cognitive impairment after surgery [19]. Because monitoring ICP during robotic surgery with an invasive intracranial device is not feasible, measurement of optic nerve sheath diameter by ultrasonography appears as a novel and non-invasive technique to assess ICP [20]. Drugs, such as dexmedetomidine, have been studied in an effort to reduce the risk of cognitive dysfunction.

Raising the patient's trunk can smooth Trendelenburg positioning and potentially reduce the risk of cognitive and ocular complications; therefore, we have adopted this modification during RAL pelvic procedures.

Venous thromboembolism (VTE) complications

Deep venous thrombosis (DVT) and pulmonary embolism are postoperative complications strongly related to oncological surgeries, mainly pelvic surgery. Although there are many risk factors inherent to the patients, positioning and prolonged operative time can influence thromboembolic events [21,22]. Surgical features such as lymph node dissection can increase the incidence of DVT/pulmonary embolism up to sevenfold, whilst MIS seems to have lower risk of thromboembolism than open approaches [23].

Whilst comorbidities and most of the surgical features related to VTE are not modifiable, VTE prophylaxis management is of utmost relevance. Early ambulation, sequential compression devices, and chemoprophylaxis are helpful measures in patients at risk of VTE without contraindications [21]. A randomised study showed that 4-week anticoagulation prophylaxis has advantages in relation to 1-week administration after major abdominal surgeries [24]. Single preoperative chemoprophylaxis has also shown benefits without increasing the risk of bleeding in patients [25].

Access and insufflation complications

Transperitoneal or extraperitoneal approaches are possible, either in pelvic or retroperitoneal procedures. Access complications are related to a combination of visceral and vascular injuries during trocar placement, postoperative port-site hernias or insufflation disorders and depend on approach and technique chosen.

Access approaches and techniques

Veress needle access, Hasson open technique and optical-access trocar are the most common access techniques. A Veress needle is a sharp instrument placed blindly through the abdominal wall and should be verified if it is working properly before its introduction. In pelvic procedures patients should remain in a neutral dorsal position during first trocar placement and the needle is passed at 45 ° (90 ° in obese patients) to avoid great vessel injury. Safety checks, aspiration/injection and lifting the abdominal wall upwards help to minimise the risk of complications. As opposed to Veress needle access, the Hasson open technique allows direct view of abdominal and pelvic structures during access. However, despite what some may think, a Cochrane review of laparoscopic entry techniques found no differences between open or Veress needle access complications [26].

Trans- or extraperitoneal approaches are both safe and depend on surgeon expertise. In order to create extraperitoneal space, balloon dissection is helpful during an extraperitoneal approach [26]. A lower incidence of gastrointestinal complications and shorter hospital stay have been seen in some series of extraperitoneal approach, especially in obese patients [27–29]. Prior abdominal surgery, pregnancy, vascular aneurysms, and abdominal wall hernia require further consideration for access approach choice. In the setting of prior abdominal surgery, extra- or transperitoneal approach are both safe, but adhesiolysis is often required in the latter [30].

Vascular access injuries

Vascular complications during abdominal access occur in ~0.1% of patients [10]. Vascular injuries during trocar placement can be a life-threatening condition, and prompt evaluation and repair are essential to avoid patient death. The Trendelenburg position brings large vessels closer to the abdominal wall and these need to be avoided at first trocar insertion [26]. After Veress needle insertion, the bedside assistants should be sure it is not placed into a vessel before insufflation to avoid air embolism. In small vessel lesions, direct compression over the source of bleeding plus rising pneumoperitoneum may reduce bleeding and the structure can be safely ligated. The same procedures should be used for large vessels where suture repair may be necessary. Surrounding structures are re-inspected after bleeding control under low CO_2 pressures to certify further haemostasis is not necessary. Conversion to an open procedure after source of bleeding compression is recommended if surgeons are unable to control the blood loss robotically. In such situations, a delayed decision can be fatal.

Visceral access injuries

Bowel access injuries are even rarer than vascular ones and occur in $<0.1\%$ of laparoscopic accesses [10,26]. Prior abdominal surgery is the main risk factor for bowel lesions and closed access with Veress needle should be avoided in this situation. First trocar placement distant from the previous abdominal incision and Hasson technique access are recommended [30,31]. However, it is not possible to predict adhesion extension based on surface scars. Preoperative CT or MRI can be helpful in planning surgical access in prior surgery situations [31]. If any abdominal viscera is injured during abdominal access, the trocar should be maintained in position, thus other trocars are inserted to repair such lesions. The bowel can be repaired robotically or through a mini-laparotomy depending on surgeon expertise and lesion complexity. The worst scenario would be the lack of recognition of a bowel injury and its later consequences.

Bladder access injury is extremely uncommon, but possible if the bladder is not empty during balloon dilatation of the extraperitoneal space. Rare cases of bladder transection at the prostate–vesical junction have been reported [36].

Port-site complications

Abdominal wall vessels can be damaged during abdominal access without bleeding until trocar retrieval. Trocars should be removed one by one under direct vision to avoid postoperative bleeding complications.

Port-site hernias are a late access-related complication, which occur in $<1\%$ of RAL procedures. There is a higher incidence with $\geq$10-mm port sites, although 8-mm robotic and even 5-mm port-site hernias have been described. Cutting trocars have been associated with larger fascial defects, thus blunt-tipped obturators have been preferred. Port-site $\geq$10 mm closure is the best way to avoid hernias, although some studies have shown low incidence of hernia in non-midline port-sites of <12 mm [32].

Insufflation complications

Although rare, insufflation complications take place when the Veress needle is accidentally placed into visceral structures, after prolonged carbon dioxide (CO_2) absorption (hypercarbia, acidosis, venous gas embolism) or if the abdomen is rapidly inflated [29,33].

Long-lasting procedures and extraperitoneal approach increase the risk of CO_2 reabsorption and acidosis, but few complications have been seen in healthy patients. However, patients with pulmonary disease, such as chronic obstructive pulmonary disease, may develop severe hypercarbia after CO_2 pneumoperitoneum, therefore helium may be used as an alternative for insufflation in such cases and long-lasting procedures must be avoided [34].

Fast peritoneal insufflation can result in hypotension, bradycardia or even asystole due to vagal response, especially in patients with cardiovascular disease [6]. Thus, slow gas insufflation may reduce such complications [29].

Contrary to popular belief, a study evaluating venous gas embolism during RAL and open RP showed lower rates of venous gas embolism in the RAL group, probably related to the protective effect of higher venous pressure in the Trendelenburg position [33]. Prompt detection of gas embolism through transoesophageal echocardiography in patients with tachycardia, hypotension, desaturation, and cardiac arrhythmias and proper management are essential to avoid further complications [33].

Technique-related complications

Positioning and pneumoperitoneum complications are even more common in long-lasting procedures, whilst the procedure duration is directly related to the learning curve. In complex pelvic and retroperitoneal procedures, increasing console time has been seen as an indicator of increasing surgical and anaesthetic complications, especially when >4 h [35]. Focused training, a period of simulation, mentorship-based programmes, and well-selected patients during the early learning curve, are essential to avoid complications. Experience of ~100 procedures has been considered necessary for surgeons to master their skills in pelvic procedures, but complication rates decrease progressively even after 300 procedures [36,37]. During the training period, mentorship using a dual-console system may play a role in reducing perioperative complications [38]. Without considering the learning curve, robotic malfunction appears to be the strongest predictor of prolonged operative time, followed by blood loss, and surgery complexity [39].

Next, there are some avoidable technique-related complications that should be highlighted.

Needle loss

A lost needle in the abdominal cavity is an avoidable and troublesome complication as the operative time increases and the surgical team get stressed. The surgical team should avoid multiple needles in the cavity at the same time and be alert during needle retrieval, preferably under direct vision. A needle holder must be used to remove needles, and then the bedside assistant should verbally confirm it. When a needle gets lost, the surgeon has to keep calm and search for it carefully, avoiding large movements that can hide the needle and make the task harder. Laparoscopic magnetic devices can also be helpful in this situation. In unsuccessful cases, after confirming that the needle is not outside the patient or inside the trocar, X-ray imaging may be useful [40].

Lesions caused by instrument insertion

Initial robotic instrument insertion always has to be done under direct vision to avoid surrounding structures lesion. Instrument exchange is safe if the bedside assistant does not change robotic arm position. One should also be alert to avoid injuries during auxiliary instrument exchange, mainly in close-up view steps. The console surgeon is responsible for providing adequate view during instrument insertion, whilst the bedside surgeon should not hesitate in asking for a camera view if something goes wrong.

Thermal injury

Monopolar instruments should be electrically insulated to avoid thermal injury. The surgical team should document that the insulation sleeve is placed correctly and the surgeon has to avoid its detrition, as insulation failure can lead to severe lesions, mostly intestinal complications. Thermal energy should also be avoided in nerve-sparing RAL procedures, especially during cavernosal nerve preservation, as it appears to create a dense praxia and worse functional outcomes [41].

Polymer clip complications

Polymer clips avoid sutures and save time in minimally invasive procedures, thus they are widely used in RAL procedures. However, several complications have been reported in the literature in pelvic and retroperitoneal procedures. Since 2005, there have been many reports of severe bleeding due to surgical clip failure after renal artery clipping in living kidney donors, which led the USA Food and Drug Administration (FDA) to recall the use of Hem-o-lok polymer clips for this purpose [42]. Several surgeons have adopted stapler or sutures to manage the renal hilum during robotic nephrectomies in an attempt to avoid such a life-threatening complication.

In pelvic procedures, there have been reports of clip migration from prostate lateral pedicles to the urinary tract in $<1\%$ of RPs [43,44]. Clip migration can lead to bladder neck contracture, obstructive LUTS, haematuria, bladder spasm, stone formation, and spontaneous expulsion. Surgeons should avoid the use of polymer clips adjacent to the vesico-urethral anastomosis and loose clips must be removed.

Discussion

Published complication rates for RAL procedures are extremely variable. Surgeon experience, patient, and disease characteristics may impact the incidence and severity of perioperative complications. Moreover, classification of complications is not uniform amongst the series, which present many biases and methodological considerations. Dindo et al. [45] proposed a classification system to standardise reporting of complications. The quality of complication reporting can also be assessed by the 10 Martin criteria; however, most published studies have not accomplished them [46]. As part of quality improvement in RAL procedures, it is essential complications be well assessed and reported to develop ways to avoid them.

Most of the complications assessed in the present review are related specifically to MIS positioning, access, and insufflation, therefore are not expected in open surgery. However, with regard to overall surgical complications, RAL procedures have consistently shown better performance compared with open approaches. Large series comparing RAL and open procedures have shown earlier recovery, shorter hospital length of stay, and lower blood loss and transfusion rates in either RAL-RP, -PN and -RC, without compromising oncological outcomes [47–50].

Although there are many studies about surgical complications, few studies address complications directly related to the robot device or positioning required to perform RAL procedures. Most studies have assessed procedure-related complications and how open, laparoscopic or RAL technique can influence those issues. The present review is focused on avoidable RAL-related complications and suggests how the surgical team should work in a way to avoid them.

Conclusion

Despite MIS being expected to reduce surgical complications, RAL procedures present several specific hazards. Well-selected patients, adequate positioning, mentorship training during the learning curve, and avoiding last-longing procedures are key steps to prevent RAL-related complications. Fortunately, those specific complications are rare, but one should keep alert as they can be devastating if not recognised early, thus surgeons should have a low threshold of suspicion. A dedicated robotic team is essential to reduce perioperative complications. The present study shows several steps in surgical planning to avoid RAL-related complications.

Conflict of interest

None.

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