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Urinary System Iatrogenic Injuries: Problem Review

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Abstract
Introduction: From May to December 2019, a literature review of the urinary system iatrogenic injury problem was performed. The most cited, representative articles in PubMed, Scopus, and WoS databases dedicated to this problem were selected. Urinary system iatrogenic injuries include ureter, bladder, urethra, and kidney traumas. It is widely thought that the main causes of such injuries are urological, obstetric, gynecological, and surgical operations on the retroperitoneal space, pelvis, or perineum. ***Methods:*** The purpose of the study is to describe all aspects of the iatrogenic injure problem, under the established scheme and for each of the most damaged organs: the urethra, bladder, kidney, and ureter. The treatment of confirmed iatrogenic injuries largely depends on the period of its detection. Modern medical procedures provide conservative or minimally invasive treatment. An untimely diagnosis worsens the treatment prognosis. "Overlooked" urinary system trauma is a serious threat to society and a particular patient. Thus, incorrect or traumatic catheterization can lead to infection (RR 95%) and urethral stricture (RR ≥11–36%), and percutaneous puncture nephrostomy can cause the risk of functional renal parenchyma loss (median 5%), urinary congestion (7%), or sepsis (0.6–1.5%). ***Results:*** Lost gain, profits, long-term and expensive, possibly multistage treatment, stress and depression, and the risks of suicide put a heavy financial, moral, and ethical burden on a person and society. Also, iatrogenic injury might have legal consequences. ***Discussion/Conclusion:*** Thus, the significant problem of urinary tract iatrogenic injuries is still difficult to solve. There is a need to implement mandatory examining algorithms for patients at risk, as well as the multidisciplinary principle for all pelvic surgery.

Introduction

Intentional injury causes about half of deaths in the world [1]. Unintentional accidental injuries also lead to death or disability. A special type of unintentional traumas is an iatrogenic injury during diagnostic or medical procedures and operations.

Iatrogenic urinary system injuries include ureter, bladder, urethra, and kidney traumas. It is widely thought that such injuries appear as a result of urological, obstetric-gynecological, and surgical operations on retroperitoneal space, pelvis, or perineum [2, 3]. The purpose of the research is to evaluate the experience of solving the urinary

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system iatrogenic injury problem by a multidisciplinary approach.

Modern mini-invasive, endoscopic, laparoscopic, or robotic surgeries help to get similar or superior results compared to traditional surgical approaches; it allows doctors to follow the fast-track surgical concept but increases the frequency of urinary system iatrogenic injuries [2]. Endoscopic suture, clipping, and high-energy instruments, such as lasers, electric dissectors, and coagulators for tissue dissection, hemostasis, and other manipulations, often lead to hidden adjacent structure injuries [4]. Such injuries are extremely difficult to establish intraoperatively; their clinical manifestations can occur in the early, late, or long-term postoperative period when the patient is already out of the medical observation [3].

It is necessary to separate the direct and indirect urinary system injuries that lead to a complete or partial loss of function (due to denervation, devascularization, formation of cicatricial contractures, pathological bends, etc.) [2, 4]. The traumatic effect is a result of mechanical violation of integrity (intersection and perforation), patency (ligation, flashing, and patency violation due to pathological bending), blunt trauma, and prolonged pressure and compression (holding the organ on the clamp, holder; pressure on the organ of the instrument, retractor; prolonged drainage) [4]. The use of urothelium-aggressive chemicals for medical and diagnostic purposes is also dangerous (e.g., washing the urethra and/or bladder with antiseptic solutions, silver preparations, or contrasts for marking). Physical treatment methods (radio waves, laser, electrosurgical instruments, and radiation therapy, including brachytherapy) with their direct (direct damage to the body, including hidden) or indirect ("leakage" of electric current, denervation, devascularization, etc.) exposure also have a traumatic effect. Indirect damage can lead to interventions and incidents in the vascular system (stenting, prosthetics, occlusion, and embolism), the central and peripheral nervous system (spinal surgery, installation of neurostimulators, etc.), as well as nonobvious procedures such as acupuncture and manual therapy. A urinary tract infection associated with medical care also plays a significant role, which can be included in the urinary system iatrogenic incidents [5].

Considering given tendencies, a lot of attention is paid to measures for preventing and treatment of injuries [3]. Preventive procedures include, first of all, the identification of a typical procedural complication, a hidden procedural mistake that could cause injury [2, 4]. The most common example is incorrect urethral catheter placement tactics. The violation of asepsis and antiseptic rules leads to the infection development, and incomplete lubrication leads to urothelium damage, inflammation, and urethral stricture. Exceeding the transurethral operation duration and/or the absence of periodic lubrication increase the risk of significant leakage of electric current or mechanical damage [6]. The large diameter of the working tool or its not careful insertion also has a direct harmful effect.

The next mandatory preventive procedure is the training of specialists performing diagnostic or therapeutic interventions of the urinary tract (urologists) and surrounding organs and tissues (obstetricians, gynecologists, proctologists, surgeons, radiologists, and chemotherapists) or in their projection (radiologists). Knowing of the anatomical and histological structure features, innervation, and blood supply and understanding of the risks and signs of trauma will significantly reduce the number of patients with the urinary system trauma and the number of "overlooked" cases [7].

Preventive measures' complex includes the use of various techniques and tools reducing the injury risk [3]. Visual control is not very effective even for an experienced urologist/clinician. A classic example is intraoperative staining of urine or urinary system cavities with various dyes (oral and directly injected), X-ray control with or without out contrast (air, X-ray contrast agents, and X-ray contrast catheters), ultrasound control with dopplerography, MSCT, or MRI [2]. Light indications (luminous catheters and stents) [8], tissue-organ models for the course of the operation rehearsal, or the integrated assistance of artificial intelligence and augmented reality [9] are among more advanced methods.

The diagnosed iatrogenic injury treatment largely depends on the detection timing. Modern medical procedures are focused on conservative or minimally invasive treatment. For example, with established or suspected ureteral trauma, it is possible to apply prolonged stent drainage and to take a set of conservative measures aimed at reducing the necrosis and ischemia zone (hyperbaric oxygenation, reparants, and drugs that improve blood rheological properties, microcirculation, etc.) [10, 11]. However, this timely assistance is possible only in complex with the abovementioned preventive measures. An untimely established diagnosis worsens the treatment prognosis [2, 3].

"Overlooked" urinary system trauma is a serious threat to society and to a particular patient. Lost gain, profits, long-term and expensive, possibly multistage treatment, stress and depression, and suicide risks put a heavy finan-

cial, moral, and ethical burden on a person and the society. In the USA, the annual financial cost of treating a urinary tract infection is at least USD 300 million [12]. Moreover, iatrogenic trauma might have legal consequences [13].

Materials and Methods

From May to December 2019, a literature review of the iatrogenic injury prevention problem was performed. The most cited, representative articles with the full-text access in the PubMed, Scopus, and WoS databases were selected. The analysis includes only English and Russian texts. The search criteria were keywords and their combinations: iatrogenic, multidisciplinarity, urology, iatrogenic trauma, urinary system, genitourinary system, kidneys, ureters, urinary bladder, urethra iatrogenic injury, preventive treatment, and prevention. The cross-searching method for the issue-related texts was also used. The remoteness of the available text was not taken into consideration. The inclusion criteria were as follows: well-known cited authors, major scientific journals, article views, and relevance to the request. Works in other languages were excluded from the study, as well as works not relevant to the research topic. The previous studies, mostly, review particular aspects of iatrogenic trauma, such as diagnostic problems and treatment peculiarities. This study aims to provide a comprehensive description of the iatrogenic injury problem under the established scheme and for each of the organs. The review is as follows for each of the sections: anatomical and functional features, iatrogenic injury predictors and clinical manifestations, diagnostic techniques, and possible treatment options. The research is divided into 4 sections: urethra, kidney, ureter, and bladder injuries which present the main types and causes of damage, the existing prevention approaches, diagnosis and treatment, as well as promising areas for further studying.

Results

Urethra Injury

The urethra is particularly vulnerable to iatrogenic injuries. Assuming factors are the anatomical and functional urethra features: a physiological bending right angle, the diameter changes in the urethra lumen in different segments, and involuntarily and voluntarily (in patients in consciousness) closed external urinary sphincter. Bladder catheterization is a routine, daily procedure for all or almost all medical hospitals around the world [5]. However, this intervention carries a risk of short-term or long-term complications. Urinary tract infection in approximately 35% cases is associated with medical care and in 95% develops due to the bladder catheterization in the perioperative period or in the intensive care unit [14]. Measures to reduce the indications for catheterization and strict control of the execution algorithms have significantly reduced the risks of complications, the duration of hospitalization, and financial losses [15].

As mentioned above, the main negative effect of urethral catheters is the urinary tract infection and direct trauma in the process of staging/removing urethral drainage. The most important risk factors for bladder catheterization are prolonged (>3–6 days) drainage, the violation of aseptic rules (setting in septic conditions and opening the drainage circuit), female gender, obesity, and some concomitant diseases (diabetes mellitus, neurogenic disorders of urination, and infections in other tissues and organs). In most cases, the significance level of these predictors is extremely high ($p < 0.001$). It is also necessary to avoid washing procedures if possible [16–18].

To reduce the risk of direct urothelium injury, there are several simple rules: the smallest possible diameter of the catheter, high-quality lubrication, and control of the Foley catheter balloon location before it is inflated. It is also important to keep a small amount of fluid in the catheter balloon (about 1 mL) while removing long-standing drainage since the walls of the balloon under the influence of urine after deflation can have sharp edges and corners, which increase the risk of injury to the urothelium.

A typical complication of prolonged drainage is the inability to deflate the balloon (due to obstruction of the channel or inlaid catheter, in 50% cases), which may require its destruction under ultrasound guidance or otherwise [19]. Also, during urethra surgery, an accidental through-out suturing of the catheter is possible, which will require time either before the hydrolysis of the suture material or per catheter or surgical release [20]. Currently, there are a large number of studies indicating the risks of developing urethral strictures due to a traumatic installation (risk ratio ≥11–32%) and removal or prolonged drainage (risk ratio 36.5%) [21–23].

Iatrogenic injuries during transurethral resection can lead to the strictures. There are 2 main mechanisms of epithelium damage during such interventions: the electric current dispersion and a large diameter of the instrument [24]. At the same time, there is no significant difference between mono- and bipolar electroresection instruments; in both cases, the urethral stricture risk is approximately 3.8% [6]. The urethral epithelium trauma develops with insufficient lubrication of the urethra and, as a result, current "leakage" [25]. To prevent this condition, it is necessary to intake a lubricant. The risk of developing strictures increases with simultaneous electroreception of a large prostate (>70 mL, $p = 0.012$) due to an increase in the duration of the operation [6]. Using a laser

to vaporize the prostate can also lead to urethral strictures in 3.7% cases [26].

Iatrogenic urethral trauma is a regular consequence (with a probability of up to 5%) during an adenomectomy or a prostatectomy. Subsequent treatment may result in erectile dysfunction and/or incontinence [27]. After radical prostatectomy, the possibility of the vesicourethral anastomosis stricture or other strictures reaches 8.1% [28], significantly increasing with adjuvant radiation therapy. A stricture can form in any part of the urethra, but more often it occurs precisely in the approximation zone of the bladder neck and the distal end of the urethra [29]. A robotic, laparoscopic, or open prostatectomy method does not significantly affect the risk (RR: 1.42; $p = 0.59$) of anastomotic stricture [30].

Remote radiation and brachytherapy of prostate cancer increase the risk (3.1%) of urethral strictures, especially after the previous (67 vs. 88%, $p < 0.001$) transurethral resection of the prostate [31]. Radical radiation therapy causes severe cases of stricture formation with worse treatment outcomes, severe erectile dysfunction, and incontinence. The diagnosis of urethral injuries and their complications (urethral stricture) is a complex analysis of subjective complaints, medical history, objective examination, and additional and instrumental examination methods.

Men with narrowing of the urethral lumen due to the formation of strictures most often complain of weak urine flow pressure (49% symptom representation) and a feeling of incomplete emptying of the bladder (27%). In addition, dysuria phenomena (10%) and impaired erection or ejaculation can occur. Patients also complain of the spatter of urine stream (13%) [32]. In 10% of cases, urethral stricture may be asymptomatic. Urethral injuries are followed by pain in the genitals (100%) and/or urethrorrhagia/hematuria (86%) [33].

The main specific diagnostic procedures are uroflowmetry, urethroscopy, and urethrography [34]. Urethrosonography, MR, or MSCT can be used additionally [34]. The symptoms of urination disorders in combination with uroflowmetry and ultrasound data increase the likelihood of identifying stricture disease and performing urethrocystoscopy or urethrography (ultrasound, X-ray, magnetic resonance imaging, or computed tomography) to confirm the diagnosis [3]. A typical outcome of urethral injury is the urethral stricture [23].

Confirmed diagnosis defines the treatment method. Clearly formulated relative indications for surgical intervention for strictures of various urethra sections currently do not exist. Nevertheless, given the long period of sum compensation, patients are shown to perform dynamic observation and, possibly, undergo treatment for any detected urethral stricture, even with normal urodynamic parameters (maximum urine flow rate of >15 mL/s; no residual urine). It is possible to conduct conservative therapy using fibrinolytic dilatation and physiotherapy in the early stages of the disease development (the maximum urine flow rate of 12–15 mL/s; residual urine volume is <100 mL), as well as in severe inoperable cases [3, 4, 35].

Absolute indications for surgical treatment are the detection of the aerodynamically significant urethral stricture (maximum urine flow rate of <12 mL/s or residual urine volume of >100–150 mL) [35]. The algorithm for examining and treating urethral lesions depends on the causes of stricture [23, 31, 35]. If there is a suspicion of iatrogenic injury (e.g., during catheterization with the development of urethrorrhagia), the doctor may prescribe urethrography. If acute damage is detected, the urethra is drained by a catheter along the conductor for a period until the urethral wall heals. If there is a urethral stricture of <10 mm, an internal optical urethrectomy is performed. For longer strictures, anastomotic plastic surgery of the urethra or urethroplasty surgery using a graft is recommended [35, 36].

Kidney Injury

The main symptom of significant iatrogenic kidney injuries is hematuria (67% cases), which occurs as a result of vascular injuries during predominantly urological minimally invasive operations and manipulations [2]. Most cases of iatrogenic kidney injuries with the hematuria are not easy to detect since bleeding is insignificant and it is an admissible and even routine complication in the professional environment.

In addition, damage to the kidney parenchyma can result in the formation of arteriovenous fistula or vascular cup fistula, pseudoaneurysm of the renal vessels, or the formation of a hematoma. Damage to the structures of the collective kidney system leads to urinary leakage (7%), strictures, and stenosis (1–2%). Rarer complications are foreign bodies ("forgotten" fragments of stents, instruments, etc.).

Such complications occur when performing percutaneous puncture nephrostomy, percutaneous puncture nephrolithotomy, retrograde ureterorenoscopy (both diagnostic and therapeutic), and open and laparoscopic kidney interventions. For example, collecting system injury can occur during a ureteral stent or catheter setup. Complications of endovascular interventions (angiography, occlusion, stenting, etc.) are rare [37, 38].

Any transdermal access to the collecting system of the kidney causes parenchyma and various blood vessel injuries. The use of dilatators and nephrostomy, large-diameter nephroscope, increases the risk of significant bleeding. Also, a typical complication is a kidney infection, with the pyelonephritis and even urosepsis development (0.6–1.5% cases) [39–41].

A typical procedural complication is an incorrectly selected puncture route, outside the Braudel line [42], as well as a through wound of the kidney collecting system with a puncture needle, dilator, or instrument. An increase in the number of accesses or puncture attempts proportionally increases the risks of the complications. A vicariously enlarged kidney (due to more abundant vascularization), arterial hypertension, vascular atherosclerosis, and a violation of the blood coagulation system are the predictors of an increased risk of complications [43].

The clinical manifestation of the abovementioned complications in most cases is characterized by hematuria (micro or macro), changes in laboratory parameters (signs of blood loss or inflammation), characteristic of bleeding (weakness, palpitations, shortness of breath, etc.), and inflammation (fever, chills, pain in the lumbar region, etc.) complaints. Clinical manifestations can vary widely from minutes and hours to months from the time of intervention [39, 41, 44]. The main diagnostic methods for iatrogenic injuries are imaging methods (ultrasound with dopplerography, MRI or MSCT, urography, and angiography) and endoscopic methods (ureterorenoscopy) [2].

Most cases of the infectious or hemorrhagic complications after iatrogenic kidney injury do not require surgical intervention; conservative therapy (antimicrobial and hemostatic) is sufficient. In some cases, prolonged drainage with JJ stents can eliminate urinary leakage, secondary hydronephrosis, etc. The bleeding can be stopped intraoperatively, when performing percutaneous puncture nephrolithotomy by balloon tamponade, by changing the diameter of the instrument [40, 41].

The damage of renal artery or its branches with the development of acute hemodynamically significant blood loss will require open surgery, vessel ligation, its integrity restoration, or nephrectomy. The implementation of endovascular hemostasis methods in such an urgent situation is possible only in a limited number of cases [44].

Arteriovenous fistula or pseudoaneurysms will require conservative or endovascular treatment methods (superselective embolization of the kidney vessels – SRAE or renal artery stenting). The endovascular methods are highly effective and have a low frequency of complications [45]. However, in some cases, there is a need for the kidney resection or nephrectomy with the recurrent nature of bleeding or the ineffective treatment methods [41].

The development of purulent inflammation of the kidney or perinephric space and the formation of abscesses or multiple carbuncles will require open surgical intervention, with revision and drainage of purulent foci. In severe cases, a nephrectomy is required.

"Forgotten" foreign bodies' migration of calculus fragments outside the collective renal system will require endoscopic (percutaneous or retrograde removal) or surgical treatment. The ureteropelvic segment, the pelvis of the kidney, or calyx injuries with the development of vascular cup fistula or urinary leakage can be carried out conservatively (hemostatic and antimicrobial therapy), endovascularly (SRAE), and endoscopically (fixation of JJ stents, laser incision of stricture or laser ablation of the bleeding source, or surgery reconstruction and suturing of defects).

Ureter Injury

The ureter injury, due to its location and anatomical features, in most cases (>80%) is a result of medical interventions [46]. Any injury, even minor injury, can lead to serious consequences: infection, up to sepsis; ureteral strictures with the development of hydronephrosis and impaired renal function; ureteral fistula formation [47].

The main causes of iatrogenic ureter injuries differ according to the mechanism of occurrence: direct ligation of the ureter or the formation of a pathological inflexion during ligation of adjacent structures, crushing or squeezing with an instrument, partial or complete intersection, thermal damage during coagulation (erroneous or exposure to closely located tissues), electrical leakage, denervation, and devascularization [4, 48, 49]. The lower third of the ureter is usually more damaged than the middle and upper third [46, 48]. It should be mentioned that most injuries of the ureters are hidden, and diagnostic measures in the early postoperative period do not always make it possible to establish a diagnosis (e.g., with thermal damage, when a stricture can develop from a week to several months) [47].

Gynecological, colorectal, and urological operations prevail in the frequency of injuries. Less commonly, traumatic incidents occur during general and vascular surgery. A special role plays the complications of radiation therapy [2, 42, 50]. Over the past 20 years, there has been a decrease in the frequency of ureter injuries due to urological interventions and a change in their composition. Development and improvement of less traumatic surgical

techniques and the use of small-diameter instruments, including flexible ones, played a significant role [33, 48, 49, 51]. Moreover, laparoscopic and robotic surgical approaches do not affect the frequency of complications [49, 52]. The main "provoking" factors of ureter iatrogenic injuries are malignant formations of the pelvis, consequences of the pelvic bone injuries, massive bleeding, previous radiation therapy or surgery on the pelvis, and abdominal cavity [47, 48, 50, 53].

Endourological operations on the bladder (cystolithotripsy, resection, vaporization, or ablation of neoplasms) can cause injuries (accidently or intentionally in case of tumor removal), which lead to ureteral lumen stenosis and the development of ureterohydronephrosis [2]. Diagnostic or therapeutic ureteroscopy, catheterization, and stenting can result in urothelium injuries or perforation due to physiological bends of the ureter in the pelvis, especially with concomitant diseases (malignant diseases of the pelvic organs, pelvic prolapse, etc.) and after surgery (pathological bending ureter and "fixation" of the ureter) [2]. The main types of injuries during endourological operations are perforation (up to 1%) and urothelium injuries (up to 4%) [3].

General surgical, gynecological, and colorectal operations (as well as rarer vascular or other types of injuries) lead to ureteral injury for various reasons [47, 50, 52, 54]. Immediate damage (wall injury, crushing, dressing, or flashing) occurs during massive intraoperative bleeding (especially during cesarean section and hysterectomy), when hemostasis is performed without strictly visual control with ligation, flashing, or coagulation of wide area, large vessels, and tissue arrays. A direct ureter crossing with the iliac vessels, uterine ligaments, and vessels of the pelvic organs also contribute to the development of injury during surgery. More unpleasant is a violation of technology and anatomical orientation mistake: incorrect placement of retractors with compression of the ureter or retention of the ureter on the clamp, or confusing the ureter with the uterine ligament or vessel.

The remote irradiation and brachytherapy are the reasons for urothelium demolition, the development of post-radiation strictures (a probability of 1–2.5% with increasing frequency over time), pathological excesses, aseptic and septic inflammations, and secondary malignant processes [42]. Given the features and timing of the complication manifestation after injury, it is necessary to be especially a concern with any manipulations on the ureter or in the surrounding area. A timely diagnosis improves the prognosis [55]; otherwise, the risk of severe complications grows [46].

Clinical diagnosis is based on the patience complaints (pain in the lumbar area, nausea, etc.), typical for the development of ureterohydronephrosis or urinary infection. There can be hematuria, leakage of urine from a wound, or vagina, etc. Such complaints are nonspecific and do not allow to differentiate the diagnosis, but they should be considered [56]. Also, an objective physical examination makes it possible to suspect the ureter injury [56].

The blood creatinine level test in the perioperative period has limited effectiveness in detecting ureter injuries [57]. The golden standard for diagnosing is MSCT with urography [2], which helps to detect even hidden injury (edema or enlargement of the ureter, periarteritis, etc.) and to establish obvious (ureterohydronephrosis, extravasation of contrast, etc.).

Because of the high risks of the ureter injury, it is especially important to carry out preventive measures [58]: training surgeons in the urinary system topographic anatomy and getting acquainted with the risks of complications after any physical or mechanical manipulations. The most effective is a thorough technical operation and a good knowledge of anatomy. The prophylactic use of ureteral catheters does not reduce the risk of ureteral injuries [59]. The use of luminous catheters is better [8]; with limited use, they do not damage the urothelium [60] or cause the development of secondary urinary tract infection [8]. The use of contrasts staining urine is limitedly effective [4, 48] since most (>60%) ureter injuries are not detected intraoperatively due to hidden damage [49]. Nephrostomy is preferable in cases when it is impossible to urgently repair the damage.

Ureteral injury treatment largely depends on the mechanism of injury. Identified or suspected intraoperative damage can be resolved conservatively (by installing a ureteric JJ stent) or removed surgically (restoring ureter integrity and removing the ligature or suture) directly during surgery. It is also possible to perform a nephrostomy, but stenting is more preferable due to the sewer effect – creating a gaping lumen, which reduces the risk of stricture formation [48].

Antegrade or retrograde endoscopic bougienage, ureterotomy, or stenting have limited effectiveness (16–19%) and are not recommended in most cases, as the first stage of treatment [61]. The reconstructive surgery method depends on the level and the extent of the injury. With a small length (up to 2–3 cm), a direct anastomosis can be performed [46]. Longer damage to the upper third can be corrected by ureterocalicostomy or plastic surgery by a part of the renal pelvis [62]. It is also possible to perform transureterostomy [33] (with the opposite ureter).

The pelvic ureter injuries are very often associated with a risk of ureter devascularization and denervation; therefore, ureterocystoneostomy or urethroplasty with a bladder graft [63] (Boari method) with or without the psoas hitch technique is considered as a standard treatment procedure [13, 33]. The antireflux technique is applied individually, due to the high risk of stricture recurrence. The effectiveness of reconstructive operations in the pelvic area is very high (from 85 to 98%), but their immediate implementation is not always possible [33].

Extended defects of the ureter can be eliminated by replacing the ureter with the intestine [64] or by induction of nephroptosis, or pelvic autologous transplantation of the kidney [65]. All these methods require strict control in the postoperative period and are contraindicated in diseases of the intestine (intestinal plastics), renal vascular stenosis (induction of nephroptosis), and kidneys (all options). BMG plastic is a new direction in the ureter reconstruction with a success probability of >90%; however, this technique has not yet become widespread and is recommended to a limited extent [66].

Bladder Injuries

Bladder is the most frequently damaged organ of the urinary system during medical procedures [2, 67]. The bladder iatrogenic damage is usually divided into internal (intraluminal) and external (from the outside). The incidence varies widely and depends on the type of intervention: from 0.04% due to laparoscopic hernioplasty [68] to 4.5% due to laparoscopic and robotic operations on the pelvic organs and up to a maximum of 5.8%due to transurethral resection of the bladder [69] and 8% with men sling plastic [55].

External bladder injuries most often develop as a result of obstetric and gynecological operations, less often as a result of general surgery. Internal injuries are the result of endourological operations [56]. Malignant processes of the pelvis, injury consequences, inflammatory diseases, radiation therapy consequences, age-related changes, impaired blood supply and innervation, and obstructive urination disorders provoke traumas [67].

Typical urological features are bladder perforation during postadilon urethroplasty [70] and transurethral resections of the bladder (especially with repeated resections and large tumors) [71]. As mentioned above, resection in the projection of the ureters and their mouths is dangerous by stenosis and strictures of the ureters [45]. Such perforations usually not require surgical correction; prolonged urethral drainage can be enough. A rarer complication of endourological treatment is urinary reflux of the ureters (due to resection of the ureter or the ureterocele treatment), which is difficult to attribute only to bladder injury. Injuries due to the incorrect bladder catheterization, possibly with perforation, deserve special mention, as this damage is a typical procedural mistake.

The main clinical manifestations of iatrogenic bladder injury are hematuria and any urination disorders (dysuria, incomplete or inadequate emptying, anuria, urinary retention, etc.). Soreness, overflowing bladder, and signs of urinary peritonitis have an objective evaluation. Laboratory indicators demonstrate inflammation and an increase in uremia [56].

Intraoperative identification of bladder perforation is usually not difficult [56], especially with external damage (extravasation of the urine and visible urethral catheter) [67]. In case of internal damage, paravesical fatty tissue, abdominal cavity, or intestine are visualized [71]. It is possible to fill the bladder with a sterile solution or stain the urine to visualize the injury.

The golden standard for diagnosing bladder injury is cystography or MSCT cystography (superior imaging) [2]. It is fundamentally important not only to fill the bladder with a contrast of up to 300–350 mL with subsequent visualization but also to conduct the mixing phase. Cystography helps to determine perforation, fistula formation, and reflux in the ureters.

Cystoscopy also provides high accuracy of detecting bladder injuries [2], but its prophylactic use is not recommended (except for sling operations) [70]. The absence of bladder filling and cavity expansion indicates significant perforation.

Prevention of the bladder iatrogenic external injury includes primarily emptying of the bladder and its catheterization before surgery [49]. Endourological operations require reducing of the detrusor tone with muscle relaxation.

In most cases of the bladder, iatrogenic injury is detected intraoperatively and can be immediately eliminated [49, 56]. With significant damage, the defect is sutured, and with small perforation, in most cases, extended urethral drainage is performed, up to 5–10 or more days [56, 67]. An overlooked bladder injury during colorectal or gynecological operations (especially flashing the wall or thermal injury) can lead to the fistula formation [67].

Discussion/Conclusion

The literature review results lead to several important conclusions. First, the problem of iatrogenic injuries is well studied and analyzed. There is a set of preventive

measures for each organ of the urinary system, aimed at reducing the risk of injury. To reduce injuries, there are special techniques, consumables, and tools. However, all these measures do not exclude urinary system injuries. The human factor, the difficult surgical situation, the imperfection of the technical aspects partially offset the preventive effect.

Second, there is a lack of mandatory examination algorithms for the group of patients at risk. For example, an ultrasound examination of the kidneys in the early and late postoperative period after pelvic organ operations may possibly reduce the number of "overlooked" injuries of the ureters.

Third, in the perioperative period, all pelvic surgery – urological, gynecological, colorectal, and the others – should be evaluated by a multidisciplinary team of doctors and not just by a subject matter specialist. This will allow not only to plan the most effective treatment tactics and reduce the risks of concomitant complications but also to improve the overall effectiveness.

Thus, there is a significant problem of the urinary tract iatrogenic injuries, so far not completely resolved. There is a need to introduce mandatory algorithms for examining patients at risk, as well as the introduction of multidisciplinarity principles for all pelvic surgery.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by V.V. and I.G. The first draft of the manuscript was written by E.K., and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. Conceptualization: V.V.; methodology: V.B.; formal analysis and investigation: I.G.; writing – original draft preparation: E.K.; writing – review and editing: D.T. and T.M.; supervision: V.V.

References

1 Middleton P. The trauma epidemic. In: Smith J, Greaves I, Porter K, editors. Major trauma. Oxford: University Press; 2010. p. 604.
2 Esparaz AM, Pearl JA, Herts BR, LeBlanc J, Kapoor B. Iatrogenic urinary tract injuries: etiology, diagnosis, and management. Semin Intervent Radiol. 2015;32(2):195–208.
3 Summerton DJ, Kitrey ND, Lumen N, Serafetinidis E, Djakovic N. EAU guidelines on iatrogenic trauma. Eur Urol. 2012;62(4):628–39.
4 Delacroix SE, Winters JC. Urinary tract injures: recognition and management. Clin Colon Rectal Surg. 2010;23(2):104–12.
5 Glynn A. Hospital-acquired infection: surveillance, policies, and practice. London: Public Health Laboratory Service; 1997.
6 Komura K, Inamoto T, Takai T, Uchimoto T, Saito K, Tanda N, et al. Incidence of urethral stricture after bipolar transurethral resection of the prostate using TURis: results from a randomised trial. BJU Int. 2015;115(4):644–52.
7 Thomas AZ, Giri SK, Meagher D, Creagh T. Avoidable iatrogenic complications of urethral catheterization and inadequate intern training in a tertiary-care teaching hospital. BJU Int. 2009;104(8):1109–12.
8 Boyan WP, Lavy D, Dinallo A, Otero J, Roding A, Hanos D, et al. Lighted ureteral stents in laparoscopic colorectal surgery; a five-year experience. Ann Transl Med. 2017;5(3):44.
9 Yu F, Song E, Liu H, Li Y, Zhu J, Hung CC. An augmented reality endoscope system for ureter position detection. J Med Syst. 2018;8(42):138.
10 Capelli-Schellpfeffer M, Gerber GS. The use of hyperbaric oxygen in urology. J Urol. 1999;162(3 Pt 1):647–54.
11 Gandhi J, Seyam O, Smith NL, Joshi G, Vatsia S, Khan SA. Clinical utility of hyperbaric oxygen therapy in genitourinary medicine. Med Gas Res. 2018;1(8):29–33.
12 Zimlichman E, Henderson D, Tamir O, Franz C, Song P, Yamin CK, et al. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med. 2013;173(22):2039–46.
13 Preston JM. Iatrogenic ureteric injury: common medicolegal pitfalls. BJU Int. 2003;86(3):313–7.
14 Cassini A, Plachouras D, Eckmanns T, Abu Sin M, Blank HP, Ducomble T, et al. Burden of six healthcare-associated infections on European population health: estimating incidence-based disability-adjusted life years through a population prevalence-based modelling study. PLoS Med. 2016;13(10):e1002150.
15 Janzen J, Buurman BM, Spanjaard L, de Reijke TM, Goossens A, Geerlings SE. Reduction of unnecessary use of indwelling urinary catheters. BMJ Qual Saf. 2013;22(12):984–8.
16 Tambyah PA, Oon J. Catheter-associated urinary tract infection. Curr Opin Infect Dis. 2012;25(4):365–70.
17 Manalo M Jr, Lapitan MC, Buckley BS. Medical interns' knowledge and training regarding urethral catheter insertion and insertion-related urethral injury in male patients. BMC Med Educ. 2011;11:73.
18 Gonzalgo ML, Walsh PC. Balloon cuffing and management of the entrapped Foley catheter. Urology. 2003;61(4):825–7.
19 Davis NF, Quinlan MR, Bhatt NR, Browne C, MacCraith E, Manecksha R, et al. Incidence, cost, complications and clinical outcomes of iatrogenic urethral catheterization injuries: a prospective multi-institutional study. J Urol. 2016;5(196):1473–7.

20 Lumen N, Hoebeke P, Willemsen P, De Troyer B, Pieters R, Oosterlinck W. Etiology of urethral stricture disease in the 21st century. J Urol. 2009;182(3):983–7.
21 Vicente J, Rosales A, Montlleó M, Caffaratti J. Value of electrical dispersion as a cause of urethral stenosis after endoscopic surgery. Eur Urol. 1992;21(4):280–3.
22 Rassweiler J, Teber D, Kuntz R, Hofmann R. Complications of transurethral resection of the prostate (TURP): incidence, management, and prevention. Eur Urol. 2006;50(5):969–80.
23 Eltabey MA, Sherif H, Hussein AA. Holmium laser enucleation versus transurethral resection of the prostate. Can J Urol. 2010;17(6):5447–52.
24 Campos-Juanatey F, Portillo Martín JA, Gómez Illanes R, Velarde Ramos L. Nontraumatic posterior urethral stenosis. Actas Urol Esp. 2017;41(1):1–10.
25 Elliott SP, Meng MV, Elkin EP, McAninch JW, Duchane J, Carroll PR. Incidence of urethral stricture after primary treatment for prostate cancer: data from CaPSURE. J Urol. 2007;178(2):529–34.
26 Autorino R, Zargar H, Mariano MB, Sanchez-Salas R, Sotelo RJ, Chlosta PL, et al. Perioperative outcomes of robotic and laparoscopic simple prostatectomy: a European-American multi-institutional analysis. Eur Urol. 2015;1(68):86–94.
27 Park R, Martin S, Goldberg JD, Lepor H. Anastomotic strictures following radical prostatectomy: insights into incidence, effectiveness of intervention, effect on continence, and factors predisposing to occurrence. Urology. 2001;57(4):742–6.
28 Ficarra V, Novara G, Artibani W, Cestari A, Galfano A, Graefen M, et al. Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a systematic review and cumulative analysis of comparative studies. Eur Urol. 2009;55(5):1037–63.
29 Fonteyne V, Villeirs G, Lumen N, De Meerleer G. Urinary toxicity after high dose intensity modulated radiotherapy as primary therapy for prostate cancer. Radiother Oncol. 2009;92(1):42–7.
30 Chung PH, Esposito P, Wessells H, Voelzke BB. Incidence of stress urinary incontinence after posterior urethroplasty for radiation-induced urethral strictures. Urology. 2018;114:188–92.
31 Burks FN, Santucci RA. Management of iatrogenic ureteral injury. Ther Adv Urol. 2014;6(3):115–24.
32 Arlen AM, Kirsch AJ, Cuda SP, Little SB, Jones RA, Grattan-Smith JD, et al. Magnetic resonance urography for diagnosis of pediatric ureteral stricture. J Pediatr Urol. 2014;10(5):792–8.
33 Mundy AR, Andrich DE. Urethral trauma. Part I: introduction, history, anatomy, pathology, assessment and emergency management. BJU Int. 2011;108(3):310–27.
34 Güneyli S, Gök M, Bozkaya H, Çınar C, Tizro A, Korkmaz M, et al. Endovascular management of iatrogenic renal arterial lesions and clinical outcomes. Diagn Interv Radiol. 2015;21(3):229–34.
35 Knoll T, Daels F, Desai J, Hoznek A, Knudsen B, Montanari E, et al. Percutaneous nephrolithotomy: technique. World J Urol. 2017;35(9):1361–8.
36 Wollin DA, Preminger GM. Percutaneous nephrolithotomy: complications and how to deal with them. Urolithiasis. 2018;1(46):87–97.
37 Ierardi AM, Floridi C, Fontana F, Duka E, Pinto A, Petrillo M, et al. Transcatheter embolisation of iatrogenic renal vascular injuries. Radiol Med. 2014;119(4):261–8.
38 Venkateswarlu J, Kumar MS, Babu RP, Abkari A. Endovascular management of iatrogenic renal vascular injuries complicating percutaneous nephrolithotomy: role of renal angiography and embolization; an analysis of 159 cases. Indian J Radiol Imaging. 2017;27(3):293–7.
39 Sam K, Gahide G, Soulez G, Giroux MF, Oliva VL, Perreault P, et al. Percutaneous embolization of iatrogenic arterial kidney injuries: safety, efficacy, and impact on blood pressure and renal function. J Vasc Interv Radiol. 2011;22(11):1563–8.
40 Elliott SP, McAninch JW. Ureteral injuries: external and iatrogenic. Urol Clin North Am. 2006;33(1):55–vi.
41 Blackwell RH, Kirshenbaum EJ, Shah AS, Kuo PC, Gupta GN, Turk TMT. Complications of recognized and unrecognized iatrogenic ureteral injury at time of hysterectomy: a population based analysis. J Urol. 2018;6(199):1540–5.
42 Siddighi S, Yune JJ, Kwon NB, Hardesty JS, Kim JH, Chan PJ. Perioperative serum creatinine changes and ureteral injury. Int Urol Nephrol. 2017;49(11):1915–9.
43 Brandes S, Coburn M, Armenakas N, McAninch J. Diagnosis and management of ureteric injury: an evidence-based analysis. BJU Int. 2004;94(3):277–89.
44 Wong JMK, Bortoletto P, Tolentino J, Jung MJ, Milad MP. Urinary tract injury in gynecologic laparoscopy for benign indication: a systematic review. Obstet Gynecol. 2018;1(131):100–8.
45 Chou MT, Wang CJ, Lien RC. Prophylactic ureteral catheterization in gynecologic surgery: a 12-year randomized trial in a community hospital. Int Urogynecol J Pelvic Floor Dysfunct. 2009;20(6):689–93.
46 Lobo N, Kulkarni M, Hughes S, Nair R, Khan MS, Thurairaja R. Urologic complications following pelvic radiotherapy. Urology. 2018;122:1–9.
47 Petersen SS, Doe S, Rubinfeld I, Davydova Y, Buekers T, Sangha R. Rate of urologic injury with robotic hysterectomy. J Minim Invasive Gynecol. 2018;5(25):867–71.
48 Hesselman S, Högberg U, Jonsson M. Effect of remote cesarean delivery on complications during hysterectomy: a cohort study. Am J Obstet Gynecol. 2017;217(5):564–e8.
49 Matsumura Y, Iemura Y, Fukui S, Kagebayashi Y, Samma S. Iatrogenic injuries of urinary tract: outcomes of surgical repairs. Hinyokika Kiyo. 2018;3(64):95–9.
50 Phillips B, Holzmer S, Turco L, Mirzaie M, Mause E, Mause A, et al. Trauma to the bladder and ureter: a review of diagnosis, management, and prognosis. Eur J Trauma Emerg Surg. 2017;6(43):763–73.
51 Alabousi A, Patlas MN, Menias CO, Dreizin D, Bhalla S, Hon M, et al. Multi-modality imaging of the leaking ureter: why does detection of traumatic and iatrogenic ureteral injuries remain a challenge? Emerg Radiol. 2017;24(4):417–22.
52 Douissard J, Ris F, Morel P, Buchs NC. Current strategies to prevent iatrogenic ureteral injury during colorectal surgery. Surg Tech Int. 2018;32:119–24.
53 Hassinger TE, Mehaffey JH, Mullen MG, Michaels AD, Elwood NR, Levi ST, et al. Ureteral stents increase risk of postoperative acute kidney injury following colorectal surgery. Surg Endosc. 2018;32(7):3342–8.
54 Pedro RN, Kishore TA, Hinck BD, Akornor JW, Dickinson L, Roychowdhury M, et al. Comparative analysis of lighted ureteral stents: lumination and tissue effects. J Endourol. 2008;22(11):2555–8.
55 Alperin M, Mantia-Smaldone G, Sagan ER. Conservative management of postoperatively diagnosed cystotomy. Urology. 2009;73(5):1163–9.
56 Smith TG, Coburn M. Damage control maneuvers for urologic trauma. Urol Clin North Am. 2013;40(3):343–50.
57 El Abd AS, El-Abd SA, El-Enen MA, Tawfik AM, Soliman MG, Abo-Farha M, et al. Immediate and late management of iatrogenic ureteric injuries: 28 years of experience. Arab J Urol. 2015;13(4):250–7.
58 Wenske S, Olsson CA, Benson MC. Outcomes of distal ureteral reconstruction through reimplantation with psoas hitch, Boari flap, or ureteroneocystostomy for benign or malignant ureteral obstruction or injury. Urology. 2013;82(1):231–6.
59 Armatys SA, Mellon MJ, Beck SD, Koch MO, Foster RS, Bihrle R. Use of ileum as ureteral replacement in urological reconstruction. J Urol. 2009;181(1):177–81.
60 Zhao LC, Weinberg AC, Lee Z, Ferretti MJ, Koo HP, Metro MJ, et al. Robotic ureteral reconstruction using buccal mucosa grafts: a multi-institutional experience. Eur Urol. 2017;73(3):419–26.
61 Köckerling F, Bittner R, Jacob DA, Seidelmann L, Keller T, Adolf D, et al. TEP versus TAPP: comparison of the perioperative outcome in 17,587 patients with a primary unilateral inguinal hernia. Surg Endosc. 2015;29(12):3750–60.

62 Shazly SA, Murad MH, Dowdy SC, Gostout BS, Famuyide AO. Robotic radical hysterectomy in early stage cervical cancer: a systematic review and meta-analysis. Gynecol Oncol. 2015;138(2):457–71.
63 Nieder AM, Meinbach DS, Kim SS, Soloway MS. Transurethral bladder tumor resection: intraoperative and postoperative complications in a residency setting. J Urol. 2005; 174(6):2307–9.
64 Welk BK, Herschorn S. Are male slings for post-prostatectomy incontinence a valid option? Curr Opin Urol. 2010;20(6):465–70.
65 Ford AA, Rogerson L, Cody JD, Aluko P, Ogah JA. Mid-urethral sling operations for stress urinary incontinence in women. Cochrane Database Syst Rev. 2017;7:CD006375.
66 El Hayek OR, Coelho RF, Dall'oglio MF, Murta CB, Ribeiro Filho LA, Nunes RL, et al. Evaluation of the incidence of bladder perforation after transurethral bladder tumor resection in a residency setting. J Endourol. 2009;23(7): 1183–6.
67 Golan S, Baniel J, Lask D, Livne PM, Yossepowitch O. Transurethral resection of bladder tumour complicated by perforation requiring open surgical repair: clinical characteristics and oncological outcomes. BJU Int. 2011; 107(7):1065–8.
68 Balbay MD, Cimentepe E, Ünsal A, Bayrak O, Koç A, Akbulut Z. The actual incidence of bladder perforation following transurethral bladder surgery. J Urol. 2005;174(6):2260–3.
69 Patel BN, Gayer G. Imaging of iatrogenic complications of the urinary tract: kidneys, ureters, and bladder. Radiol Clin North Am. 2014;52(5):1101–16.
70 Teeluckdharry B, Gilmour D, Flowerdew G. Urinary tract injury at benign gynecologic surgery and the role of cystoscopy: a systematic review and meta-analysis. Obstet Gynecol. 2015;126(6):1161–9.
71 Venkatramani V, Panda A, Manojkumar R, Kekre NS. Monopolar versus bipolar transurethral resection of bladder tumors: a single center, parallel arm, randomized, controlled trial. J Urol. 2014;191(6):1703–7.