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Bladder Explosion during Transurethral Resection Surgery-Case Series

Hani Albadawe^{1*}

¹Johns Hopkins Aramco Healthcare, Saudi Arabia

*Corresponding Author: Hani Albadawe, Johns Hopkins Aramco Healthcare, Saudi Arabia;
Email: hani.albadawe@gmail.com

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Abstract

The explosion of the bladder or intravesical explosion is a rare but possible complication in Transurethral Resection (TUR) procedures. The chances of a bladder rupture occurring during TUR are approximately 0.02%. In all types of transurethral surgeries which involve diathermy, the possibility of bladder explosion remains. It can be in the form of a mucosal tear which is a simple or a deep rupture in the bladder. Immediate and quick intervention is important for repairing the bladder when this complication occurs. The initial cases of this complication were reported in 1926. Since then, there have only been thirty reports of such complications.

Keywords

Transurethral Resection; Ruptured Bladder; Tumor; Hypotonic Fluid

Bladder Explosion during TURP Procedures

Transurethral Resection (TUR) is considered to be one of the most common surgical procedures performed. The possibility of an intravesical explosion during any form of transurethral surgical procedure conducted through diathermy is quite low, but it can result in chronic damage to the bladder, which requires quick repair. The help of preventive measures and appropriate techniques can help in the reduction of any potential risks regarding the

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complications in TURP. Moreover, the strategies related to anesthesia also are a major interference in bladder explosion cases.

Lee, et al., attempted to provide a detailed description of the rupture in the bladder during TUR-BT conducted for the removal of the bladder tumor [1]. The study focused on the case of a male patient aged 86 years suffering from urothelial carcinoma in the lower part of the ureter on the right side. The patient had already gone through the procedures of TUR-BT for diagnosis of bladder tumor and the laparoscopic nephroureterectomy. TUR procedure was conducted on the patient for the diagnosis of bladder tumor, which had recurred. Even though all the precautionary measures, an air bubble was identified within the anterior wall. A loud sound of pop was heard and both the patient as well as the surgeon felt a slight jolt in the lower abdominal area of the patient. With the help of the cystoscopy, the surgeon identified a large laceration in the bladder. However, the ruptured bladder was quickly repaired through laparotomy.

The researchers observed that both atmospheric air as well as oxygen plays a significant role in the bladder explosion during TUR. To avoid bladder explosion, several suggestions and preventive measures were suggested based on the observations of the case report. Minimization of the air entering the bladder through irrigation and an Ellick tube or resectoscope can reduce the chances of the bladder explosion. A ureteral or suprapubic catheter can help in effectively removing the air bubble from the bladder. A reduction in the time required for the resection along with tissue's judicious coagulation can also decrease the likelihood of bladder rupture. By moderating the power of the current in the resectoscope, the bladder explosion can be avoided as the current in the instrument is responsible for the explosion or rupture in the bladder. Using a continuous irrigation system can also help decrease the possibility of the entrance of air bubbles into the bladder. During the resection process, exposure to air bubbles with the wire loop must be avoided. Most importantly, the study suggested that the position of the air bubble can be changed and it can be shifted away from the tumor existing in the bladder dome by positioning the patient in a Trendelenberg position. Moreover, the application of suprapubic pressure can also help in achieving the same result. This study suggested that these preventive measures and techniques can help effectively reduce the chances of a bladder rupture.

Gupta and Gupta, reported the bladder explosion during the TURP procedure conducted on a 60-year-old man who suffered from Benign Prostatic Hyperplasia (BPH) [2]. The research study suggested that the factors such as bladder neck contracture, urethral stricture and absence of achievement of hemostasis are the major complications associated with the TURP procedure. The sixty-year-old male patient has already been diagnosed with grade 3 prostatomegaly through a digital rectal examination. The patient showed no comorbidity. The rupture of the bladder during the TURP can lead to transurethral resection syndrome, which can prove to be fatal. Researchers found that the main reason for the explosion was the accumulation of gases as well as the increase in the presence of air near the area of the

diathermy probe. Hydrogen was found to be the dominant gas as it formed at least 35% and at most 30% due to the hydrolysis of water and the pyrolysis of the prostatic tissue. Carbon monoxide, oxygen and hydrocarbons were also found to be dominant. They were accumulated during the procedure. Several factors should be taken into account as they can control the entry of air bubbles into the bladder, such as continuous irrigation and adequately handling the evacuator bulb.

Singh, et al., examined the possibilities of the intravesical; explosion during the TUR procedure [3]. The study specifically focused on the management as well as the prevention of bladder explosion during the TUR procedure. The study found that the bladder is poorly compliant mainly due to the excessive infusion of the irrigation fluid resulting from not using a continuous drainage system. Accumulation of hydrogen, oxygen and hydrocarbons causes the rupture of the bladder during the TUR procedure. Atmospheric air comprising at least 21% oxygen has the chance of entering the bladder due to the leakage in the irrigation tube or inadequate use of the Ellick evacuator bulb. Moreover, replacing irrigation fluid bottles can also cause the entrance of oxygen into the bladder. When this highly concentrated oxygen mixes with the already accumulated hydrogen, it results in a gaseous mixture that is highly explosive. However, the researchers found that the nature or type of irrigation liquid does not influence bladder explosions. A decrease in the time allotted for the procedure also reduces the chances of an explosion. Since the raising temperature of the resectoscope loop increases the chances of the gases accumulation in the bladder. Another important finding of this study was that by adequately angling the beak of the resectoscope sheath, the air could be evacuated from the bladder. However, the loop must never be activated in the presence of an air bubble. Furthermore, the small ruptures in the bladder can be effectively dealt with conservatively by a per-urethral Foley catheter. Finally, the study concluded that rupture in the bladder during TUR is a rare complication that can be avoided by taking into account some preventive measures.

In some cases, the presence of the diverticula can cause rupture or tears. Vincent studied the bladder diverticula as a risk factor that might cause the bladder explosion during TURP [4]. The study suggested that the reason for the bladder explosion during TUR was the contact between cautery electrodes and accumulated or trapped gases in the bladder. Several preventive measures can help in avoiding the possibility of rupture in the bladder. This study presented the case of a 75 years old male who went through TUR for the diagnosis of severe urine retention. A trilobar enlargement of Grade 2 was identified in the patient. The presence of several large diverticula, as well as a large one, was confirmed in the bladder of the patient. It was observed that the bladder exploded following a loud pop during hemostasis. However, with the help of laparotomy at the lower midline, the rupture in the bladder was repaired.

Hydrolysis of the intracellular water, as well as pyrolysis of the prostatic tissues, causes the formation of hydrogen. Only the accumulation of hydrogen gas does not cause the explosion. When the oxygen from the atmosphere mixes with the gaseous mixture in the bladder, the

rupture occurs. The accumulated gases can cause an explosion in the bladder when they come in contact with the electrode loop used during the procedure. The study presented four precautionary measures which could lead to the prevention of explosion. Firstly, decreasing the time required for the resection of the tissue and moderating the power current during the phase of coagulation can reduce the chances of ruptures in the bladder. Secondly, by protecting joints and connections from any possible leaks, the chances of explosion decrease. Thirdly through the continuous evacuation of the air from the bladder, the size of the air bubble can be decreased significantly. Fourthly by angling the resectoscope's beak toward the dome of the bladder, air evacuation can be done completely without any issue. All these four preventive measures were taken into account during the procedure. However, the bladder exploded exactly at the position of the diverticulum and caused tears in both posterior as well as anterior walls. This proved that the existence of a diverticulum near the bladder area increases the risks of bladder explosion during TUR. It was recommended that by using the suprapubic trocar for continuous evacuation of the air, the bubble could have avoided the explosion occurring due to the presence of the diverticulum. But this alternative is usually not considered feasible for all types of cases. The study found that even after taking into account all the preventive measures, the rupture in the bladder still occurs due to the presence of several diverticula in the bladder. It was argued that the urologist must pay great attention to the preventive measures and operation techniques to reduce the risks of complications during the TUR.

The presence of air bubbles in the bladder dome during the procedure of TUR for the elimination of bladder tumor can interrupt the resection leading to the intravesical explosion resulting in a higher risk regarding the reimplantation of tumor cells. A simple technique and convenient technique such as routine resectoscopes can also help in successfully eliminating the air bubbles from the bladder dome. Takeshita, et al., proposed a simple technique that could help in the evacuation of air bubbles along with scum from the bladder dome during TUR of bladder tumor [5]. This study suggested that a simple and convenient technique such as routine resectoscopes can effectively help in the evacuation of air bubbles from the bladder dome during TURP. The researchers used a routine resectoscope in at least 300 TURs, proving the effectiveness as well as simplicity of this technique during the TUR. The study also revealed some important findings regarding the TUR. Firstly it was revealed that there is no scientifically proven link between bladder explosion and the dissemination of tumors. Secondly, there is a lack of any evidence which can prove that the entanglement of scum with the air bubble in the bladder might trigger the reimplantation of the tumor. The study found that after TURBT, the recurrence rate is strongly linked with the surgery's quality. Furthermore, with the evacuation of the air bubble, which is the major source of bladder explosion, the overall quality of the TURBT can be enhanced and the explosion rate of the bladder can also be reduced significantly. It will also help in lowering the recurrence rate of tumors.

A resectoscope is an instrument consisting of just a thin tube that helps in removing tissues within the body [6]. This instrument utilizes the electric current for the destruction, removal and elimination of the tissue. In some cases, it can also be proved helpful for controlling

bleeding. In male patients, it is often inserted into the prostate or the bladder through the urethra. Since resectoscope uses electric current, the possibility of the intravesical explosion also increases. It is the most commonly used instrument in TUR [7].

Hirai, et al., reported a patient suffering from a bladder explosion towards the end of TURP [8]. This study presented the case of a male patient aged 64 years who went through TURP for the treatment of stones in the bladder and BPH causing retention in urine. All the vitals of the patient were normal before the initiation of the procedure and Spinal anesthesia was preferred for the patient. The total time taken by the operation which removed the two bladder stones was approximately 85 mins. Right towards the end of the procedure, a loud and clear pop sound was heard exactly at the time when the resectoscope was removed. Following this sound which signified bladder explosion, the vitals of the patient started changing and the laparotomy was performed immediately to mitigate any kind of risk. A large laceration that ruptured the bladder was found during the laparotomy. Operations were completed after repairing the bladder. This case helped the researchers in presenting important facts regarding bladder explosions during TURP. The researcher highlighted the importance of the anesthesiologist during TUR for preventing any possibility of bladder rupture. According to the study, the anesthesiologist should discuss the adequate bed angle for patients with tumors at 12 O'clock position to prevent the accumulation of highly explosive gases in the bladder. Another important suggestion for preventing the entrance of air bubbles in the bladder stated that the nurses should prevent any such possibility by continuously replacing the irrigation bags. Moreover, there should be no noise in the operation room so that the sound of pop can be heard clearly. Most importantly, since the electric current in the resectoscope is mainly responsible for the explosion, this study suggests that during coagulation, the surgeon should use as little power as possible to avoid the risk of any complication in TUR such as bladder explosion.

Lo and Huang examined the occurrence of bladder explosion during TUR as a rare complication [9]. This study presented the case of a 69 years old male patient who suffered from an intravesical explosion during TUR. Exploratory laparotomy was conducted to repair the ruptures in the bladder through running sutures.

Electrocoagulation is used during the TUR processes for the elimination of abnormal tissues, such as lesions or tumors, with the help of heat generated from an electric current. Moreover, this procedure is also utilized for controlling the bleeding occurring during or after surgery. During this procedure electrode through which the electric current is passing is positioned near the tissue to destroy them. Electrocoagulation uses electric current, which raises the possibility of the bladder explosion by getting in contact with the explosive gases in the bladder.

Buldu, et al., provided a detailed analysis of bladder explosion during TURs with bipolar while utilizing the saline solution [10]. It was suggested that the kind of irrigation fluid, as well as electrocoagulation, are unrelated to the possibility of hydrogen gas formation, which can lead to an explosion in the bladder dome. The study presented the case of a male patient aged 73 years who suffered from chronic issues in the lower urinary tract. Towards the end of the

operation sound of a bladder, the explosion was heard clearly and loudly while resecting the prostate. At the time of the explosion, resection was done closer to the bladder neck and at the position of 12 O'clock. Oil droplets, as well as petechial hemorrhages, were observed both within and outside the walls of the bladder. Expecting the occurrence of a bladder explosion, a cystogram was performed. For primary repair, open retroperitoneal surgery was conducted. Surgeons sutured the muscle as well as mucosa tissue was sutured as separate layers. The possibility of bladder explosion during transurethral resection, whether done for bladder tumors or prostate, is low. The study supported the theory that pyrolysis, which occurs in the tissue while resecting, leads to the formation of hydrogen gas. Another theory regarding the formation of hydrogen gas was also discussed, which suggested that the intracellular water's electrolysis is responsible for the formation of hydrogen gas in the bladder dome. The explosion occurs when the hydrogen gas gets in contact with the electrocoagulation, which causes the ignition. Duration of the TUR was found to be strongly linked with the amount of accumulation of gases. Furthermore, it was revealed that the oxygen gas from the atmosphere could enter the bladder through irrigation of the bladder via an evacuator.

The possibility of explosion of the bladder during TUR is merely 0.01%. The injury resulting from TUR can either be a small tear or a large rupture. Two major forms of ruptures can be caused due to bladder explosion. These two forms are termed extraperitoneal rupture and intraperitoneal rupture. Distinguishing between the two types of bladder ruptures is important as techniques through which these ruptures are managed tend to be different. Intraperitoneal ruptures in the bladder occur due to an immediate and rapid increase in the intravesical pressure, which leads to the rupture in the dome of the bladder [11]. It has been observed that the most common location of intraperitoneal rupture is the bladder's dome [12]. In case of intraperitoneal rupture, the open repair of the bladder is necessary.

Cystography can be defined as the procedure which helps in diagnosing the problems occurring in the bladder of a patient through an imaging test. This procedure uses fluoroscopy as well as X-ray images to identify the problems in the bladder [13]. A urinary catheter is inserted in patients and contrast dye is injected into the bladder of the patient. Post-operative cystography helps in identifying and diagnosing bladder perforation even though it's a rare complication [14].

Shindo, et al., presented the case of a male patient aged 79 years who was suffering from bladder cancer and had undergone a second Transurethral Resection of Bladder Tumor (TURBT) [15]. Even though the resection was being done on the anterior wall but during the surgery, the bladder exploded, causing ruptures and tears in both the anterior as well as posterior walls of the bladder. With the help of post-operative cystography, it was observed that there was no obvious leakage towards the peritoneum. Surgeons implanted an intravesical catheter for a time of at least 14 days, which resulted in the improvement of the patient's condition, excluding the need for any further surgical procedure. Intravesical therapy like BCG and mitomycin is mostly performed after TURBT. The objective of this therapy is to eradicate

any cancer cells remaining in the bladder after the procedure. With the help of a soft catheter, the liquid drug is entered into the bladder through the urethra of the patient without causing any damage to the significant parts of the patient's body. This study showed, with the help of the case study, that even after the bladder explosion during the TURBT procedure, the intravesical therapy still showed positive impacts on the condition of the patient.

If the electrolyte imbalances during the TUR are not handled appropriately can lead to the death of a patient. Vacchiano, et al., presented the case of patient mortality where due to the delayed and inadequate handling of the electrolyte imbalances resulted in the patient's death [16]. After the explosion of the bladder during TUR, the immediate surgical procedure for the repairment of the tears and ruptures in the bladder is necessary to effectively manage the condition of the patient. This study focused on the case of a male patient aged 76 undergoing TURP for the diagnosis of BPH. Besides BPH, the patients were also suffering from hypertension and type II diabetes. Glycin was utilized for irrigation of fluids during the procedure. After approximately 55 mins. of the surgery completion, when the surgeon was performing hemostasis, a loud blow was observed, indicating the explosion of the bladder. With the help of cystography, large and deep lesions within the posterior wall of the bladder were found. After the surgery, the patient's condition started declining till he died. An autopsy showed serious damage to the nervous system of the patient. The sclerotic glomeruli were found in the kidneys of the patient. A lymph-granulocytic inflammation-causing infiltration was found in the mucosa of the bladder. Moreover, the muscular structure was also involved in this.

Resende, et al., examined the process of treating the explosion of the bladder occurring during the TUR with the help of a case report [17]. This study presented the case of a male patient aged 56 who suffered from a bladder explosion while undergoing TUR. It was argued that the technique of anesthesia used during the procedure could help in successfully dealing with the intravesical explosion during the TUR. A monopolar resectoscope was used for the procedure of resecting the lateral and median lobe along with the prostatic apical region. After almost 50 mins of the initiation of the surgical procedure, a loud and clear sound was heard, which indicated the explosion of the bladder. Even though the surgeons conducted the cystourethrography but the outcome was inconclusive. However, the lesions within the bladder walls were revealed with the help of laparotomy and showed no damage to the abdominal cavity. During the procedure, it was observed that besides other preventive measures for avoiding the possibility of intravesical explosion, the technique of anesthesia also plays an important role in reducing the chances of bladder explosion. The use of regional anesthesia during TUR allows for the tracking and monitoring of the cognitive function of the patient and detecting the bladder explosion of TUR syndrome. The complication of intravesical pressure was successful without switching from Continuous Spinal Anesthesia (CSA) to general anesthesia. According to this study, the CSA can be employed for cardiovascular patients with higher risk and can help in reducing hemodynamic changes. It enables the injection of a small amount of local anesthesia via catheter for the creation of the desired level of sensory blockade specifically for orthopedic procedures and is possible in peripheral, abdominal and urological

surgical procedures. Even though the patient had a history of obstruction in the atherosclerotic arteries, the CSA anesthesia helped in effectively dealing with the intravesical explosion during the TUR.

Bansal and Daga demonstrated the use of laparoscopic repair for repairing ruptures or tears after the explosion of the bladder during TURP [18]. The study presented the case of a male patient who was 74 years old and undergoing monopolar TURP to treat urinary retention. The patient already had a history of two failed attempts at catheter-free trials. While doing the final hemostasis, a loud and clear sound was heard after the 40 mins. had passed. The laparoscopic repairing technique was utilized to deal with the complication of bladder explosion. The study supported the notion that the explosion of the bladder has higher chances in the 12 O'clock position. Different suggestions were also presented for avoiding the possibility of bladder explosion. Firstly, with the help of the continuous flow within the resectoscope, hyper distension within the bladder should be avoided. By eliminating any possibility of leads within the connection, the entry of the air bubble into the bladder can be avoided. Moreover, the suprapubic pressure can help in shifting the air bubble from the area of resection.

Agarwal, et al., studied the intravesical explosion within the bladder diverticulum during TURP [19]. This study presented the case of a 60 years old male patient who suffered from a bladder explosion during the TURP. This study has proposed several strategies that can be used for repairing the ruptures in the bladder walls caused due to the bladder explosion. Firstly, the gases from the bladder can be removed with the help of suprapubic pressure. Secondly, the beak of the resectoscope should be angled in the direction of the bladder dome while the process of emptying the bladder. Thirdly to restrict the oxygen from entering the bladder, the lead-in connections should be avoided. Fourthly, continuous flow within the resectoscope, as well as adjusting the power at lower levels in the electrocautery settings, can also effectively help in avoiding the possibility of a bladder explosion.

Hammad and Fidal (2018) discussed the significance of the laparoscopic procedure for treating the bladder explosion occurring during TU [20]. The study presented the case of a male patient aged 45 years who underwent the TURP to treat the recurring symptoms of obstruction after the former resection of the prostate. Covidien electrosurgical generation was used during the procedure as it allows the monopolar electrocautery. The entire procedure of the resection was done under spinal anesthesia. While some of the bleeding spots within the anterior walls of the bladder neck were being coagulated, a loud sound of an explosion was observed, which signified the perforation of the bladder. It was also observed that the 12 O'clock position raises the risk of an intravesical explosion. A large tear or rupture in the walls of the bladder was observed through the endoscopic inspection. No injury on the sigmoid and rectal was revealed in the proctosigmoidoscopy.

Georgios, et al., studied the intravesical explosion during transurethral electrosurgery [21]. This study not only examined the possibility of bladder explosion but also presented some recommendations for avoiding the intravesical explosion with the help of a case report. This

presented the case of a male patient aged 70 who had to undergo Transurethral Resection for a Bladder Tumor (TUR-BT). The entire procedure went smoothly. However, towards the end of the project, a loud and clear sound of an explosion indicated the intravesical explosion. The procedure of laparotomy conducted under general anesthesia was used to repair the rupture and tears in the bladder wall. The study presented several methods and techniques to avoid bladder explosions. Out of the several methods recommended, the technique which can help in avoiding the bladder explosion is to not let atmospheric oxygen enter the body. The surgeons can eliminate the possibility of the entrance of the air bubble by angling the beak of the resectoscope. Moreover, continuous irrigation also helps in lowering the chances of bubble entry into the bladder.

Transurethral Resection of Bladder Tumor (TURBT) is important for the treatment of bladder cancer. Shindo, et al., reported the TURBT procedure for the treatment of bladder cancer in a male patient aged 79 years [15]. The entire procedure comprised of two major TUR first, TUR lead to the identification of a tumor in the bladder's anterior wall. In contrast, the preceding TUR aimed at the resection of the tumor's base. Compression with the left hand was done to get a better visualization of the bladder wall. During the procedure of resection, a loud sound was heard, signifying the intravesical explosion injuring the bladder's posterior wall. The size or magnitude of the injury was estimated to be 50 mm. During the procedure cutting current was adjusted at 280 watts, while the current for coagulation was adjusted at 80 watts. A cryptographic image helped in ensuring that there was no leakage in the peritoneum, also shown in Fig. 1.

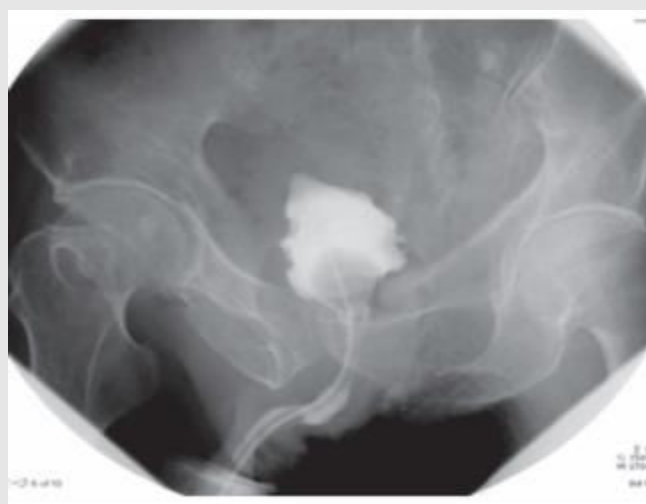


Figure 1: A cryptographic image of bladder explosion during the TURBT procedure (Shindo et al., 2013).

The study suggested that the quality of resection plays a significant role in avoiding any kind of complications during the TURBT. The presence of bladder cancer which is muscle-invasive makes the TURBT even more complicated [22]. Bladder injury during this procedure is quite

rare. Oxygen alone was not found to be responsible for the explosion; however, the mixture of this gas with the hydrogen within the bladder results in an explosive gaseous mixture.

The formation of this gaseous mixture releases massive energy, which in turn causes the explosion in the bladder dome. Some important reasons were identified that explained the cause of the explosion in the bladder. Usually, the air bubbles present in the bladder are removed by the surgeons; however, in the present scenario, it was quite difficult [20]. The bladder of the patient depicted a lower degree of compliance. Moreover, suprapubic pressure was used for manual support while resecting the anterior wall. These two reasons were found to be responsible for the transferring of air bubbles in the bladder dome.

Bipolar resecting was utilized for the procedure as there were some complications in using monopolar resection. The study found no association between the type of resection system and the possibility of bladder explosion as the explosion was caused due to the combination of oxygen and hydrogen. Evacuation of the air bubbles was deemed as an essential prerequisite for avoiding the possibility of air bubbles [22]. Surgeons must take into account the negative and dire consequences of resecting in the air bubbles. Moreover, the possibility of transferring the air bubbles from the cautery loop through manual compression in case of the bladder shows low compliance.

Resende, et al., presented the case of a 56-year-old male patient where the intravesical explosion occurred while undergoing the TURP procedure for treatment [17]. Surgeons recorded the information of the patient related to his demography and vitals. The height of the patient was 165 cm, while his weight was 55 kg. There were several other medical conditions in his medical history, such as arterial hypertension, diabetes mellitus, myocardial infarction and ischemic stroke. The patient was taking regular medications, including atorvastatin, furosemide and insulin. A week before conducting the surgical procedure, the patient was not given doses of Aspirin. The glycemia level of the patient was 100 mg.dL^{-1} while the hemoglobin level was 10 g.dL^{-1} with the tests done with normal coagulation. The ECG, echocardiography and X-rays showed the absence of any serious complication or issue which could hinder the procedure.

The condition of the patient was tracked with the help of a cardio scope. Mannitol and Sorbitol solutions were used for irrigation. The monopolar resection system was utilized for the surgical procedure. Coagulation and cutting current were adjusted at 80 W. The intravesical explosion occurred after 50 minutes of the initiation of the surgical procedure. Results of cystourethrography, which was followed immediately after the bladder explosion, were found inconclusive. Fig. 2 shows the bladder explosion during the TURP procedure. Laparotomy was conducted to locate the lesions in the bladder's interior wall without causing any damage to the abdomen. Fig. 3 shows the laparotomy procedure aimed at repairing the bladder rupture.

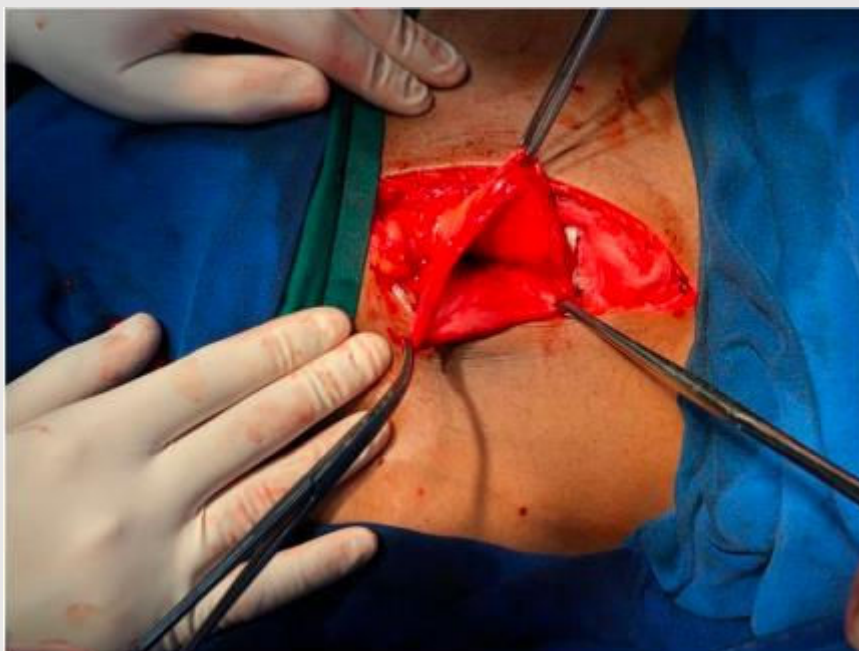


Figure 2: Bladder explosion in perioperative TURP.

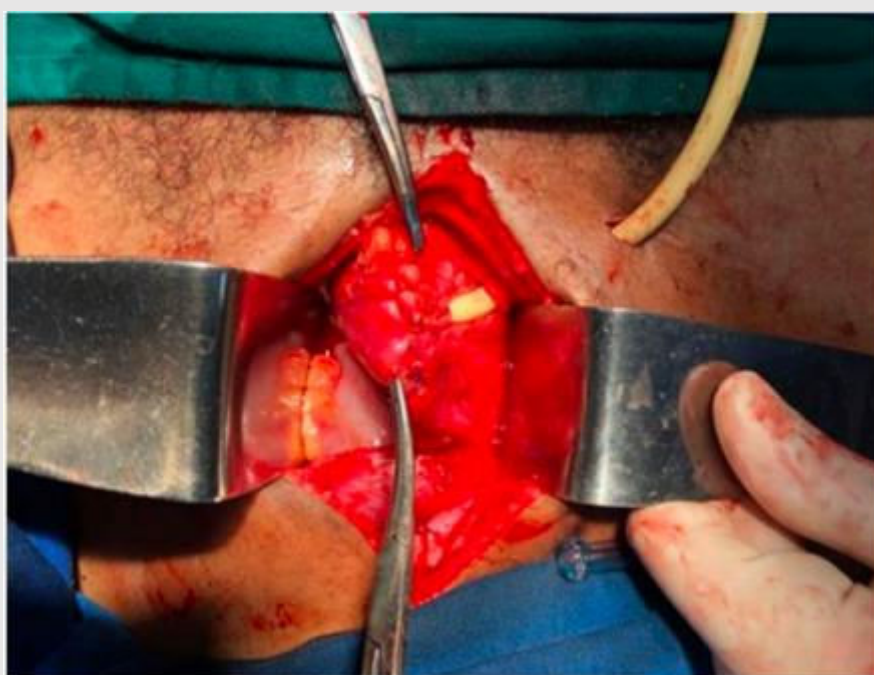


Figure 3: Repairing bladder rupture with laparotomy [17].

The major reason for the explosion in the bladder dome was identified as the combination of the predominant hydrogen gas in the bladder with the atmospheric oxygen gas [23]. When this

mixture of explosive gas gets in contact with the heat produced, resulting while resecting of the tissue. The resectoscope used for hemostasis causes an explosion in the bladder dome during transurethral surgery. The origin of the bladder explosion is due to the mixture of explosive gases, which resulted in severe pain in the abdomen. Irrigation fluid was considered to not influence the possibility of the bladder explosion. Shortening the time required for the resection is important for reducing the possibility of intravesical explosion during transurethral procedures when monopolar resection is used for conducting procedures. Placing the patients in the Trendelenburg position was also revealed to influence the possibility of bladder explosion during TURP.

Placing the body in a Trendelenburg position prevents the air bubble from getting nearer to the resection [21]. Moreover, the strategies related to anesthesia also are a major interference in bladder explosion cases. Preferring regional anesthesia for the patients on whom the TURP procedure is being conducted is important as it allows the surgeons to track the cognitive functions as well as the detection of the TUR syndrome at its earliest phase. To prevent hemodynamic changes, which are abrupt, as well as enable titration, CSA should be used among elderly patients who show higher levels of cardiovascular risk. CSA allows the injection of small doses of local anesthesia within the body via a catheter, which helps in producing the required level of the sensory blockade. This blockage of the senses is often considered most helpful during orthopedic procedures. Among the patients of IV and ASA III, this anesthetic technique is found to be effective at least 70% of the time.

The patient had already suffered from obstructive atherosclerotic arterial due to which only 5 g of the crystalloid and boluses infusion was required after gaining the instability. Blood transfusion was done as the bleeding had significantly lowered the hemoglobin levels of the patient below the normal range. In case of the possibility of any uncertainty regarding the actual position of the catheter, isobaric anesthesia should be administered. Similarly, this anesthetic should also be administered when there are odds of a higher concentration of hyperbaric glucose, which also includes a solution of local anesthetics. Moreover, it was also found that removing the spinal catheter from the patient would not lead to the development of any type of infectious and neurological complications. It was proved in through this case that the strategy or technique for the administration of the anesthesia allows the safe and easy titration for adequately managing the complications arising during the surgeries for prostatic endoscopic.

Buldu, et al., presented the case of a male patient of 73 years who had to undergo the TURP procedure for the diagnosis of the urinary tract during which the bladder dome exploded [10]. This case is one of the first procedures where the transurethral resection is conducted with the help of bipolar energy by utilizing the saline solution. Rectal examination of the patient showed the presence of benign prostate while the PSA level was 3.94 ng/ml. Moreover, the score of IPSS was found to be 28. With the help of ultrasonographic evaluations, the volume of the prostate was estimated to be 1.9 mg/dl was the recorded amount of serum creatinine, while the urinalysis levels were normal.

A resectoscope of 26 F was used for the resection during TURP. The five effects were used as the energy's power sources, while during the procedure, saline solution was used for the irrigation. After sixty minutes of the initiation of the surgical procedure, a loud sound of bladder explosion was observed. Both the oil droplets as well as petechial hemorrhages were found on the surface as well as the walls of the bladder. Performing a cystogram helps in detecting the odds of bladder explosion. Fig. 4,5 shows the cystogram image of the bladder taken before and after the surgery.



Figure 4: After Bladder explosion cystogram image [10].

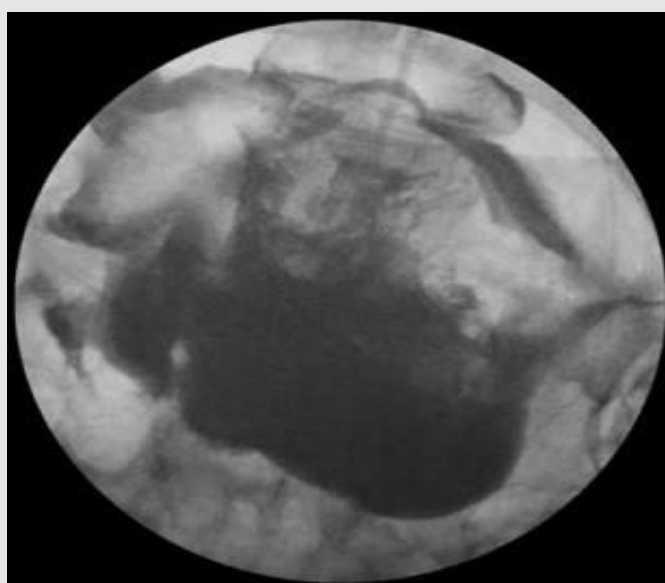


Figure 5: Bladder defect after the explosion [10].

By using the saline solution for irrigation purposes, the shortcomings of the M-TURP can be improved with the help of B-TURP. The sodium ions present in the saline solution allow the creation of plasma within the prostate which significantly reduces the resistance of tissues. It allowed the resection of prostate tissues by employing the lowest voltage possible. Different unwanted consequences associated with the TURP procedure were eliminated, such as lower retention of clots, lower levels of bleeding and the possibility of TUR syndrome [24]. It also reduced the hospitalization, irrigation as well as catheterization duration after the procedure. Usually, glycine, sterile water and mannitol are used for irrigation. With the help of retroperitoneal surgery, primary repairs were done on bladder ruptures. A defect of 8 x 8 cm was identified during the procedure, as shown in Fig. 6.

The study presented two major sources of hydrogen in the bladder. Firstly, pyrolysis can lead to the formation of hydrogen in the bladder. Secondly, intracellular water's electrolysis can cause the formation of hydrogen gas. Irrespective of the reason for the formation of hydrogen, the mixture of explosive gases comprising oxygen and hydrogen was found to be the main reason for bladder explosion. It was confirmed that when the hydrogen gas combines with the oxygen gas from the atmosphere under pressure, it leads to the formation of a mixture of explosive gases. Electrocoagulation causes the ignition leading to the intravesical explosion [10]. The number of flammable gases was found to be directly related to the time of the TURP process. The transfer of the oxygen from the atmosphere was identified to be through the evacuator during the TURP procedure. Thus emptying the bladder and using the lowest level of voltage reduces the possibility of bladder explosion.

Agarwal, et al., reported the case of a 60-year-old male patient who underwent transurethral surgery for the diagnosis of urinary retention [19]. With the help of the rectal examination done digitally, a grade 3 enlarged prostate. Moreover, the ultrasonography helped in showing the intravesical median lobe along with the 180 cc void residue. A substantial amount of the puss cells was identified during the microscopic examination of urine. The patient was already suffering from severe obstructive pulmonary disease, which was adequately controlled with the help of steroids. TURP procedure with spinal anesthesia was conducted after properly treating the urinary infection with the help of antibiotics. A resectoscope of 26 Fr was used for conducting the TURP procedure.

The cutting current was set at 110 watts, while the current for coagulation was set at 70 watts. Like many other prior cases of TURP, only glycine of 1.5% was employed for irrigation during the procedure [20]. Resection was done between the areas from the very montanum to the bladder neck. The elick evacuator was utilized for the evacuation of chips. During hemostasis in the 12 O'clock position, a loud explosive sound was heard as well as a jolt in the patient's body was also observed, indicating the bladder explosion. Again the cystography helped in showing the bladder's posterior walls of the ruptured bladder. Through an incision in the midline of the abdomen, an urgent laparotomy was conducted to repair the damaged bladder.

A 6 cm long rent extending from the anterior bladder walls to the diverticula was identified. Fig. 7 shows the extent of the rent which reaches the bladder neck.



Figure 6: Bladder perforation in the anterior midline.

However, there was an absence of any kind of bowel injury and the peritoneum was also found intact. Repairing of the bladder was done in two layers with the help of a suprapubic cystostomy. The formation of the hydrogen was found to be either due to hydrolysis or pyrolysis [2]. At least 30% to 50% of gases generated due to the electrocautery consisted of hydrogen. Another important finding was that the solution used for the irrigation had no link with the bladder explosion. Oxygen was not generated during the electrocautery. Instead, it entered the bladder from the atmosphere.

There were different sources or reasons which caused the oxygen to enter the bladder, such as leaks in the tubing, faults during the use of the Elick evacuator and faults within the connections. After entering the bladder, oxygen mixes with the hydrocarbons as well as hydrogen gas leading to a highly flammable mixture of explosive gases [12]. However, this mixture does not explode on its own. Instead, it explodes after getting in contact with the loop

used for the electrocautery loop. There are different methods and preventive measures which can help in avoiding the possibility of the bladder during the TURP procedure.

Suprapubic pressure must be applied to enable the hydrogen gas forming inside the bladder dome to escape easily. Adjusting the resectoscope's beak at the right angle is also an effective method of preventing the entrance of air bubbles into the body [17]. Faults to prevent atmospheric oxygen gas from entering the bladder. Moreover, the suprapubic catheter can help in the effective egressing of the gases accumulated in the bladder. Trendelenburg's position helps in the escape of the gases as it increases the total distance between the resectoscope and the air bubble. Avoidance of long surges of current and adjusting the settings related to power at the lowest threshold sustains the lower levels of intraurethral temperature, reducing the chances of bladder explosion.

Hammad and Fidal examined the case of a 45-year-old male patient who suffered from an intravesical explosion while undergoing the TURP procedure [20]. The damage done due to the intravesical explosion was fixed with the help of laparoscopy. The TURP procedure was conducted by using spinal anesthesia and continuous irrigation with glycine of 1.5%. The monopolar electrocautery was used through Covidien electrosurgical generator. In the 12 O'clock position, nearly at the end of the surgical procedure, when the coagulation was being conducted, a loud sound was observed indicating the intravesical explosion leading to severe rupture within the bladder. A large rent in the bladder's dome with clearly visible loops of bowel was observed with the help of endoscopy. The ruptures within the bladder were managed in a precise and methodical way. Proctosigmoidoscopy was conducted, which did not show any kind of sigmoid or rectal injury. It can be seen from Fig. 8 that in the laparoscopy, no injuries besides the ones in the bladder were identified.

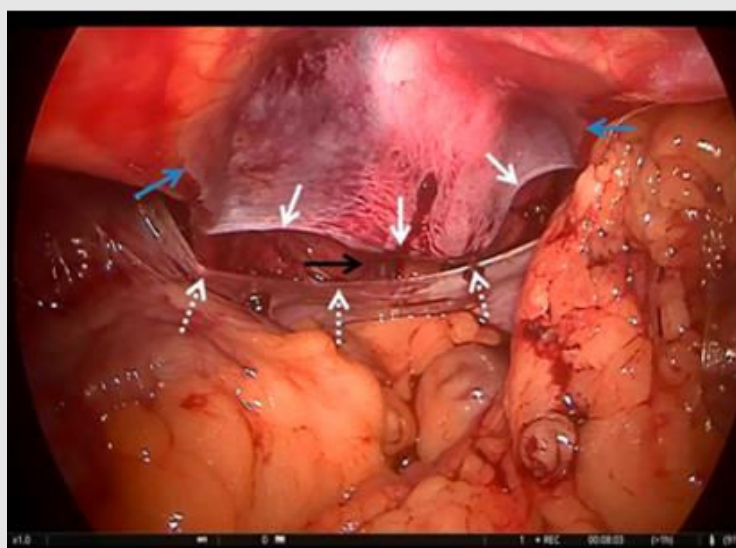


Figure 7: Ruptured bladder in laparoscopic view [20].

Repair done through the laparoscopic procedure consisted of two layers. On the 12th day, the catheter was removed while the cystography helped in confirming the absence of any possible leak. The patient recovered well after the procedure, although at a slower pace.

It was revealed that the increase in the intravesical pressure is responsible for the bladder explosion. This pressure is the result of the pressure caused due to the resectoscope. When the loop of the resectoscope gets in contact with the mixture of the explosive gases, the electrocautery causes a spark leading to ignition; improperly handling the bladder injury can lead to the death of the patient. Thus a systematic approach to handling the occurrence of this rare complication is necessary in order to avoid such dire consequences [1].

Interestingly the patient recovered even though the edges of the devascularized bladder needed to be debrided. The experience of the surgeon in this regard is extremely important, as well as the proper repair equipment. The recovery of the patient proved that the laparoscopy approach does have vivid benefits leading to postoperative recovery and helps in visualizing the organs which were deeply seated.

Ibrahimi, et al., presented the case of bladder perforation during the TURBT procedure conducted on a 61-year-old male patient with chronic TUR syndrome [22]. Monopolar resection was utilized for performing the TURBT procedure on the patient. Moreover, 1.5% glycine was utilized for irrigation. A bladder tumor which was multifocal papillary was identified during the exploration of the bladder. After the completion of the procedure, the patient was informed about the severe pain in the abdomen. Even though all the vitals of the patient showed normal values, abdominal distention was still observed. Moreover, the cystoscopy also failed in detecting bladder perforation while a urethral catheter was inserted within the body, which consisted of large-bore 22 Fr. Large amounts of the intraperitoneal fluids can be observed in the CT scans of the patient presented in Fig. 9.

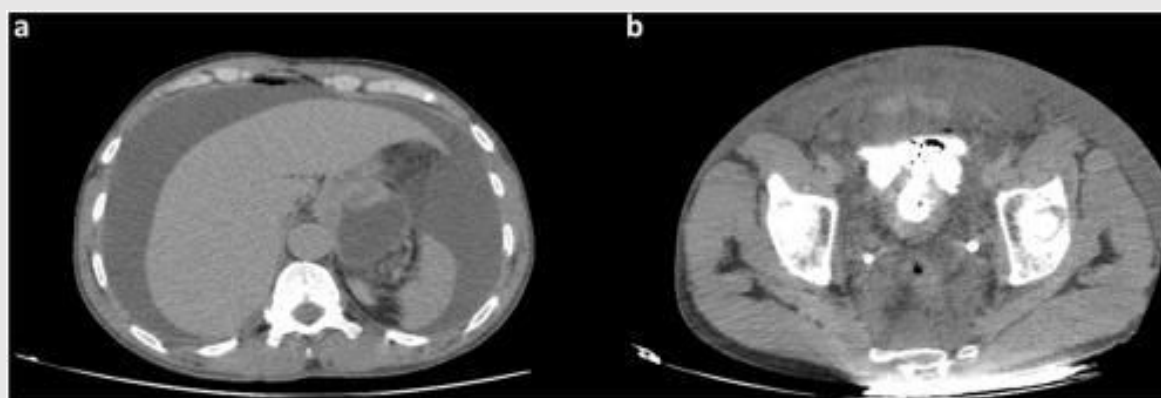


Figure 8: Intraperitoneal fluid in CT scan [22].

The accumulation of the hypotonic fluid within the peritoneal cavity while conducting the TURBT procedure can lead to TUR Syndrome. Using the bipolar resection along with the saline solution is the safest alternative as it showed lower odds of any complication as compared to the monopolar TURBT. Laparotomy was found to be the most appropriate surgical procedure for repairing intraperitoneal or bladder perforations. However, in some patients who are selected carefully, the conservative methods for conducting the transurethral surgeries are considered the safest way of dealing with the bladder perforation arising in TURBT.

Hirai, et al., presented a case of bladder explosion during the TURP procedure [8]. The study presented the case of a male patient aged 64 years who underwent the TURP procedure for the treatment of BPH and bladder stones. All the vitals, including the hemoglobin levels, were normal for the patient. However, the vitals of the patient started dropping. The BP of the patient declined to 118/68 mm Hg while the pulse was recorded to be 65 min⁻¹. An absence of the cold sensation helped in assessing the spinal block's level. To deal with this situation, midazolam 2 mg was administered to calm the nerves of the anxious patient. Contrary to other procedures, Uromatic was used for irrigation purposes as it contains a substantial amount of D-sorbitol. While conducting the operation, the patient informed the surgeon about slight pain. The entire procedure consisted of only 85 min, during which two bladder stones were removed and a 6 g prostate was resected. After the removal of the resectoscope, a loud sound was heard, which indicated the explosion in the bladder dome [15]. An immediate increase in HR, as well as BP, was observed, followed by the intravesical explosion. The patient complained about severe pain and a laparotomy procedure was conducted urgently. Large ruptures within the bladder explosion were identified, which were repaired immediately. The vitals of the patient came back to normal and the procedure the completed. The patient recovered quickly and was discharged.

The risk of bladder explosion can increase due to the use of nitrous oxide as it possesses the characteristics such as the expansion of volume and combustibility. There are several ways through which the odds of bladder explosion during the TUR procedure can be reduced. For instance, the power use limit should be adjusted to at least a lower level. Extreme care must be given to avoid the entrance of room air into the body [24-34]. There should be no noise during the operational procedure to make it easy for the surgeons to notice the sound of the explosion. The anesthesiologist must discuss the techniques for administration of the anesthesia with the urologist. All the members involved in the surgical procedure must keep the safety of the patient as their top priority.

Results and Conclusion

The analysis of the most relevant case reports has helped in providing a detailed understanding of the reasons as well as consequences of the bladder explosion occurring during the TUR

procedure. Exploding of the bladder during TUR is a rare and uncommon complication. Following are some important aspects related to the bladder explosion while conducting transurethral surgery.

Identification: Several symptoms indicate the occurrence of the bladder explosion during the procedure. One of the most common symptoms is the sound of an explosion. During the transurethral surgical procedures, a loud sound of the explosion was observed to be an indication of a bladder explosion. Another important signal is the slight pain in the abdomen of the patient, which gradually increases.

Reason: All the case studies examined suggested that the major reason for the explosion in the bladder is the contact between the resectoscope and the mixture of the explosive gasses. Either due to hydrolysis or because pyrolysis of intercellular water, the hydrogen gas from within the bladder dome. When the atmospheric oxygen due, for some reason, enters the bladder, it forms an explosive gas mixture. However, these gases do not cause explosions. Contact with the current or power due to resectoscope causes ignition in this mixture.

Irrigation Fluids: The irrigation fluids, in most cases, were found to be unrelated to the possibility of bladder explosion. Glycine, uromatic and saline solution are the most common fluids used for irrigation. However, Hirait, et al., have highlighted the negative consequence of using nitrous oxide for irrigation. The combustibility characteristic of nitrous oxide makes it highly vulnerable to explosion. As soon as the current gets closer to it, it explodes. Thus the use of nitrous oxide as an irrigation fluid must be avoided during the TUR procedure.

Anesthesia Technique: The technique of anesthesia can also help in reducing the chances of bladder explosion during the TUR procedure. In the case of patients with higher risks of cardiovascular diseases, the CSA technique of anesthesia administration helps in preventing any hemodynamic changes. By injecting small doses of local anesthesia, CSA techniques allow the production of the required levels of the sensory blockade. When the actual position of the catheter is not certain, isobaric anesthesia should be administered. The adequate and appropriate technique of the anesthesia enables convenient and safe titration, allowing the adequate management of the complications resulting during the surgeries related to transurethral resection.

M-TURP vs. B-TURP: Monopolar and Bipolar are two different resection systems for the TUR procedure. B-TUR is more effective in reducing the chances of bladder explosion during transurethral surgical procedures. B-TUR uses a lower amount of electric charge as compared to the Monopolar resection system. B-TUR is a significant improvement in TUR. By performing the procedure with normal saline, B-TUR improved a major shortcoming of the M-TUR procedure. Moreover, the B-TUR has also resulted in a significant reduction in clot retention and the possibility of TUR syndrome. As compared to M-TUR, bipolar TUR gives a better and clearer view.

Prevention: Several measures are formulated based on the findings of the case reports which can prevent bladder explosion. By continuously changing the irrigation bags carefully, the entrance of air bubbles within the body can be avoided. These air bubbles can cause a bladder explosion during the resection of the prostate. Adjustment of the resectoscope's beak at an adequate angle can effectively prevent the entrance of air into the body. Using the right anesthetic technique also helps in avoiding the possibility of an intravesical explosion. In short, the prevention of the entrance of air into the body decreases the chances of the accumulation of the gases within the bladder, which can cause bladder explosion during TUR.

Conflict of Interest

Author declares no conflicts of interest.

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