

Xu L & Cheng S. (2023) LINKING SINGLE-PORT EXTRAPERITONEAL ROBOT-ASSISTED LAPAROSCOPIC RADICAL PROSTATECTOMY WITH SPORTS FITNESS AND ATHLETES. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 23 (93) pp. 560-571.

DOI: <https://doi.org/10.15366/rimcafd2023.93.037>

ORIGINAL

LINKING SINGLE-PORT EXTRAPERITONEAL ROBOT-ASSISTED LAPAROSCOPIC RADICAL PROSTATECTOMY WITH SPORTS FITNESS AND ATHLETES

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Recibido 29 de agosto de 2022 **Received** August 29, 2022

Aceptado 28 de octubre de 2023 **Accepted** October 28, 2023

ABSTRACT

Background: As the da Vinci robot system (S and Si models) remains predominant in global surgical settings, leveraging this equipment for single-port robot-assisted surgeries marks a significant focus in the field of minimally invasive surgery. This study investigates the application of these existing models for single-port extraperitoneal robot-assisted laparoscopic radical prostatectomy (SP-RALP), assessing its efficacy and short-term outcomes in a sports and athlete-centered context. **Methods:** This retrospective analysis included 41 patients who underwent SP-RALP at the Department of Urology, Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, from July 2019 to September 2020. The procedure utilized a single-port setup through a 100mm wound protection fixator, with operations performed using the da Vinci Si HD robot system. Perioperative data were meticulously collected and analyzed. **Results:** The study documented 41 procedures, with a median operation time of 155.9 minutes (range: 90-245 minutes) and median intraoperative blood loss of 53.9 ml (range: 20-150 ml). Postoperative recovery was swift, with median times of 5.7 days for drainage tube removal and 13.8 days for catheter removal. The median hospital stay was 5.2 days. Pathologically, 70.8% of patients were staged at pT2 postoperatively, with the remainder classified as pT3a (14.6%) and pT3b (14.6%). All patients were diagnosed with acinar adenocarcinoma. Urinary continence was regained within one-month post-operation in 26.8% of patients and within three months in 73.2%. **Conclusion:** The preliminary application of SP-RALP using the da

Vinci Si system proves to be a feasible and safe approach for treating localized prostate cancer. Its benefits, such as minimal incision, ease of tissue sampling and abdominal closure, and rapid postoperative intestinal recovery, are particularly advantageous for athletes focused on minimizing recovery time and swiftly returning to training and competitive sports. Further research is required to validate these preliminary findings and explore the full scope of benefits for athletic rehabilitation and performance post-procedure.

KEYWORDS: Extraperitoneal; Single-port; SP robot; Radical prostatectomy; Prostate Cancer

1. INTRODUCTION

Prostate cancer remains one of the most commonly diagnosed malignancies among men worldwide, necessitating advancements in surgical techniques that not only improve oncological outcomes but also minimize recovery times and long-term side effects (J. H. Kaouk et al., 2008). The introduction of robot-assisted laparoscopic radical prostatectomy (RALP) has marked a significant evolution from traditional surgical approaches, offering reduced pain, shorter hospital stays, and quicker recoveries (Autorino et al., 2013; Merseburger et al., 2013). Among these innovations, the single-port extraperitoneal robot-assisted laparoscopic radical prostatectomy (SP-RALP) using the da Vinci robot system emerges as a cutting-edge procedure aimed at further optimizing patient outcomes through even less invasive methods (Raman, Bensalah, Bagrodia, Stern, & Cadeddu, 2007).

1.1 Historical Context and Technological Advancements

The da Vinci robot systems, particularly the S and Si models, have been instrumental in pioneering minimally invasive surgical techniques across various medical specialties. These systems allow for precise movements and reduced trauma to surrounding tissues, which are crucial in delicate procedures like prostatectomies. Despite newer models entering the market, the S and Si models remain widely used due to their proven efficacy and widespread availability. However, adapting these systems for single-port surgeries has presented unique challenges and opportunities in surgical practice (J. H. Kaouk et al., 2016; J. H. Kaouk et al., 2014; Tugcu et al., 2017; White et al., 2010).

1.2 Single-Port Surgery: Innovations and Applications

Single-port surgery, a technique involving a single incision site for operational access, has gained traction for its potential to reduce scarring, decrease postoperative pain, and shorten recovery time compared to multi-port laparoscopic procedures. In urology, applying this technique to prostatectomy poses specific challenges due to the complex anatomy and the precision required for cancer control and preservation of nerve and muscle

function(Agarwal et al., 2020; Dobbs et al., 2019; J. Kaouk, Valero, Sawczyn, & Garisto, 2020).

1.3 Study Rationale

Given the high physical demands placed on athletes, both professional and amateur, recovering from major surgeries can significantly impact their careers and lifestyles. The transition to SP-RALP could potentially offer a significant benefit for this population, offering minimal disruption and faster return to physical activities(Chen & Jayaraman, 2016). Thus, understanding how single-port extraperitoneal approaches can be implemented using the existing da Vinci systems not only contributes to the broader field of minimally invasive surgery but also addresses specific needs within sports medicine and athlete health management(Barret et al., 2009).

1.4 Objectives

This study aims to evaluate the feasibility, safety, and short-term outcomes of SP-RALP performed with the da Vinci Si HD robot system at Sir Run Run Shaw Hospital(Chang et al., 2019). By analyzing perioperative data and postoperative recovery, this research seeks to assess how single-port techniques can be optimized to benefit athletes needing prostate cancer surgery, with a particular focus on minimizing downtime and facilitating a quicker return to peak physical performance.

2 Methods

2.1 Patients

The study conformed to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Sir Run Shaw Hospital. Patients had been followed up for sufficient time and reports were adopted from our institute and other local hospitals.

2.2 Surgical instruments and materials

Da Vinci Si HD Robot system (Sunnyvale Intuitive Surgical) with instruments: two robotic arms, monopolar scissors and bipolar grasper for intraoperative dissection and hemostasis, two needle holders for bladder neck-urethral anastomosis and other operations. The diameter 100mm specification disposable incision protection retractor (Disposable incision protective retractor holder, Nantong Angel Medical Products Co., Ltd.) was used to establish a single port approach.

2.3 Surgical procedures

Under general anesthesia, the head low and foot high lithotomy position

(foot elevation, 15 °) was used for surgery and a 5cm transverse incision was made three fingers (15cm) above the pubis. The skin, subcutaneous tissue, muscle and fat were incised layer by layer up to the preperitoneal space. A working space was enlarged in the preperitoneal by self-made balloon dilation with 600ml of air for 5mins. 12mm Trocar as the lens hole was inserted at 12 o'clock direction, 8mm Trocar as the operation hole was inserted at 3 o'clock and 9 o'clock direction respectively, and 12mm Trocar as the auxiliary hole was inserted at 6 o'clock; The access incision and additional ports for surgical instruments were covered with a wound retractor (Nantong Angel Medical Instruments Co., Ltd., China). The incision protection retractor was fixed to the incision (Figure 1). A 30 ° lens upward was used throughout the surgical procedure. The procedure is consistent with the standard porous robot-assisted laparoscopic radical prostatectomy (Figure 2). After operation, a drainage tube and catheter were routinely placed beside the umbilical cord.

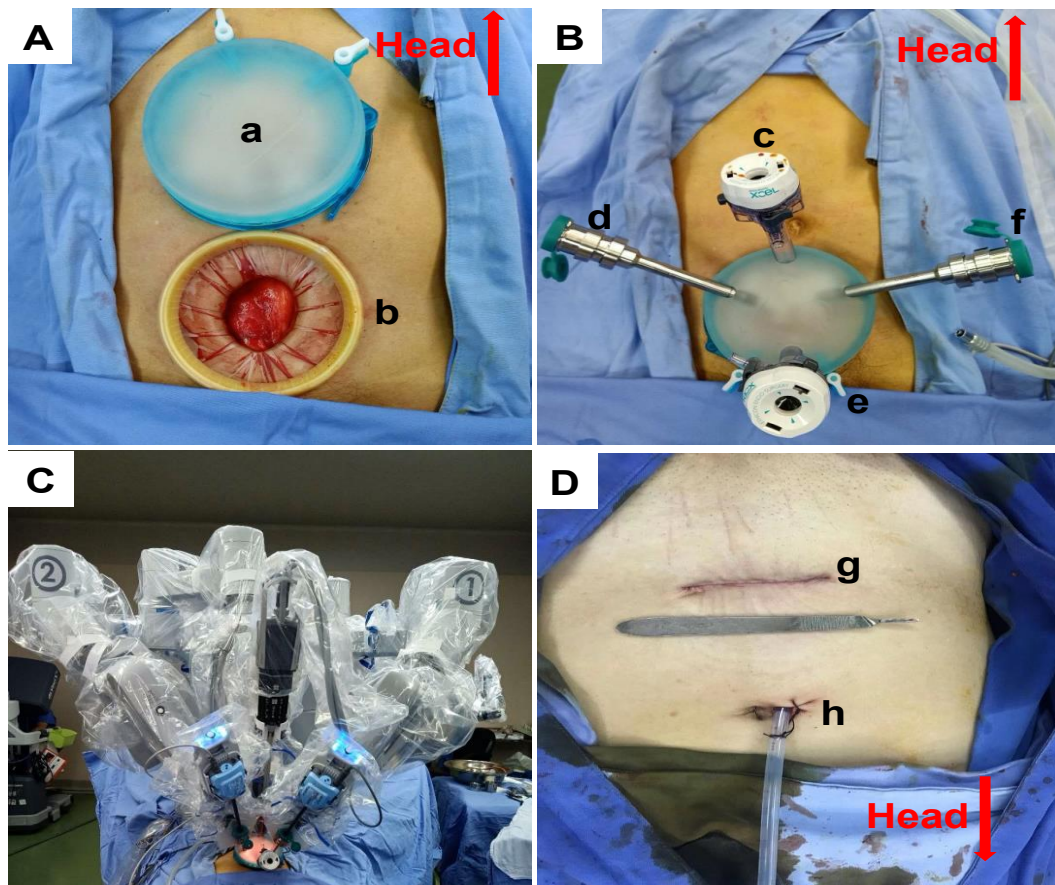


Figure 1: The establishment of robotic single-port approach (A) Establishment of preperitoneal space after the placement of wound retractive fixator; a-gel seal cover, b-wound retraction fixator; (B) 12mm Trocar as the lens hole was inserted at 12 o'clock direction , 8mm Trocar as the operation hole was inserted at 3 o'clock and 9 o'clock direction respectively, and 12mm Trocar as the auxiliary hole was inserted at 6 o'clock; c-lens hole, d-operation hole, f-auxiliary hole; (C) single-port robot installation was completed. (D) The position and size of incision and drainage tube; g-incision, h-umbilical drainage tube

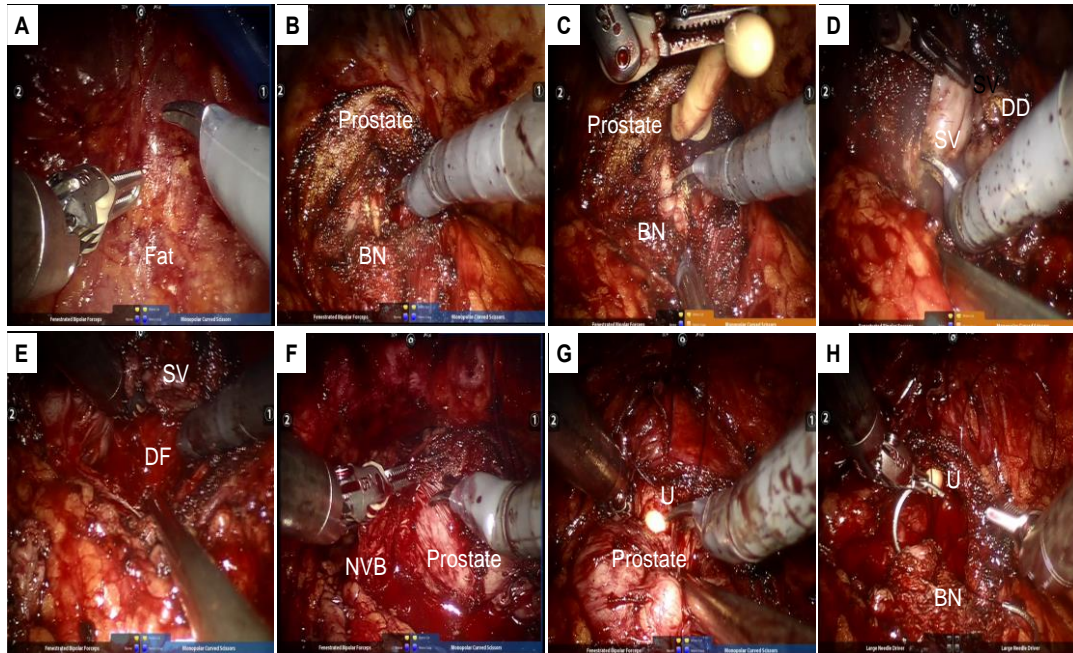


Figure 2: Single-port robot-assisted radical prostatectomy (an intrafascial approach). (A) Fully dissociate the preperitoneal space and carefully protect the blood vessels; (B) and (C) sharp division of the anterior and posterior aspects of the BN (D) exposure and dissection of both DDs and SVs; (E) exposure of the Denonvillier fascia; (F) Separation of prostate from the deep fasciae; (G) dissection of both vasa and preservation of the urethra (H) urethrovesical anastomosis with 3-0 monocryl running suture. BN, bladder neck; SV, seminal vesicle; DD, ductus deferens; DF, Denonvillier fascia; NVB, neurovascular bundles; U, Urethra. VD, vas deferens

2.4 Statistical analysis

Study sample size was based on the number of patients with complete data regarding preoperative diagnostic, histopathological evaluation, and follow-up data. Descriptive statistics were used to describe clinical characteristics, premorbid conditions, and post-operative complications. Statistical analysis was performed as indicated using GraphPad Prism version 7.0.

3 Results

3.1 Pre-operative condition

A total of 41 patients were enrolled in this study, with a median age of 69 (58-84) years and an average body mass index (BMI) of 22.7 (16.4-27.7). 9 cases (21.9%) had a history of abdominal or pelvic surgery. **Table 1** enumerates the characteristics of these patients. The median prostate volume was 30.9 (13.5-52.1) ml, and the median PSA before surgery was 9.6 (0.17-22.52) ng/ml. 29 patients had clinical stage cT2a/b, 12 patients had clinical

stage cT2c. Gleason score was 6 in 13 cases, Gleason score was 7 in 25 cases, Gleason score was 8 in 3 cases.

Table 1: Patients' Basic Characteristics

PARAMETER	COHORT (N=41)
AGE AT RP (YR), MEDIAN (IQR)	69 (58-84)
BMI (KG/M ²), MEDIAN (IQR)	22.7 (16.4-27.7)
PRIOR ABDOMINAL SURGERY, N (%)	9 (21.9)
VOLUME OF PROSTATE (ML), MEDIAN (IQR)	30.9 (13.5-52.1)
PSA BEFORE RP (NG/ML), MEDIAN (IQR)	9.6 (0.17-22.52)
CT STAGE BEFORE RP, N (%)	
CT2A/B	29 (70.7)
CT2C	12 (29.3)
PGLEASON SCORE AT RP, N (%)	
6	13 (31.7)
7	25 (60.9)
8	3 (7.4)

IQR = interquartile range; BMI = body mass index; PSA = prostate-specific antigen; RP = radical prostatectomy.

3.2 Intraoperative condition

All the 41 cases were successfully performed, of which no cases were converted to open surgery and the operating hole were increased during the operation. The median operation time was 155.9 (90-245) minutes. The median intraoperative bleeding volume was 53.9 (20-150) ml.

3.3 Postoperative condition

All patients had no blood transfusion during and after operation. When the drainage volume was less than 50ml within 24 hours, the drainage tube was removed. The median time for removal of drainage tube was 5.7 (1-21) days, the median time for catheter removal was 13.8 (12-21) days, and the median hospital stay was 5.2 (4-10) days. 29 patients (70.8%) had postoperative pathological staging of pT2 stage, 6 cases (14.6%) pT3a stage, and 6 cases (14.6%) pT3b stage. The postoperative pathological type of all patients was acinar adenocarcinoma.

The Gleason score of 9 cases was 6, the Gleason score of 28 cases was 7, and the Gleason score of 4 cases was 8. Urinary continence was restored in 11 patients (26.8%) within 1 month after operation (1 tablet of daily urine pad), and in 30 cases (73.2%) within 3 months after operation. One month after operation, the median PSA0.02 (0-4.27) ng/ml, was 3 months after the median PSA0 (0-0.04) ng/ml see Table 2.

Table 2: Patients' Perioperative Characteristics

PARAMETER	COHORT (N=41)
OR TIME (MIN), MEDIAN (IQR)	155.9(90-245)
EBL (ML), MEDIAN (IQR)	53.9(20-150)
LENGTH OF STAY (D), MEDIAN (IQR)	5.2(4-10)
CATHETERIZATION DURATION (D), MEDIAN (IQR)	13.8 (12-21)
DRAINAGE TUBE DURATION(D),MEDIAN (IQR)	5.7(1-21)
PT STAGE AFTER RP, N (%)	
PT2	29(70.8)
PT3A	6(14.6)
PT3B	6(14.6)
POSITIVE MARGIN, N (%)	13(34.2)
PGLEASON SCORE AFTER RP, N (%)	
6	9 (21.9)
7	28 (68.3)
8-10	4 (9.8)
URINARY CONTINENCE (IN 1MONTH), N (%)	11 (26.8)
URINARY CONTINENCE (IN 3MONTHS), N (%)	30 (73.2)
PSA AFTER RP(1 ST MONTH, NG/ML),MEDIAN (IQR)	0.02(0-4.27)
PSA AFTER RP(3 RD MONTH, NG/ML),MEDIAN (IQR)	0(0-0.04)

EBL = estimated blood loss; OR = operative time

4. Discussion

For any new surgical technique, it is important to evaluate its feasibility and safety. All the 41 cases of SP-RALP in our hospital were performed by doctors with more than 200 cases of robotic surgery experience, and none of them opened or increased the operating hole. The median operation time was 155.9 (90-245) minutes. Hari T et al. compared the data of 113 cases of mp-RALP and 50 cases of SP-RALP from December 2018 to November 2019 and found that there was no significant difference in operation time (median operation time SP-RALP 230 mins vs mp-RALP 240mins)(Vigneswaran, Schwarzman, Francavilla, Abern, & Crivellaro, 2020). The data in the current study are still preliminary, and after more surgeons overcoming their learning curves, the time of SP-RALP surgery should be further reduced and maintained stable. The median intraoperative bleeding volume was 53.9 (20-150) ml. Intraoperative bleeding was basically controlled within 200ml, and no case needed intraoperative or postoperative blood transfusion which shows that the SP-RALP procedure is completely feasible and safe. In 2003, Salomon for the first time proposed the "three consecutive wins" criteria for comprehensive evaluation of the effect of RP, regarding postoperative tumor control, urinary continence and sexual function recovery as the three major indicators of the evaluation system(Salomon et al., 2003). Ficarra et al then include the positive

rate of postoperative incisional margin and the incidence of perioperative complications into the evaluation system, and put forward a more comprehensive "five-game winning streak" standard (Ficarra, Novara, Ahlering, et al., 2012). Hari T. et al found that the positive rate of cutting edge between mp-RARP and SP-RARP was the same (SP-RALP 42% vs SP-RALP 42%) (Vigneswaran et al., 2020). One month after operation, the median PSA was 0.02 (0-4.27) ng/ml. 3 months after operation, the median PSA was 0 (0-0.04) ng/ml, and reached the radical standard. This study had relatively short follow-up periods, the long-term follow-up data need to be further observed. The incidence of postoperative complications was 13.2%. Urine leakage occurred in 2 cases, belonging to Clavien-Dindo grade 1, which was cured after conservative treatment. 3 cases had incision infection, which occurred probably because of the liquefaction of incision fat. Daniel et al. systematically reviewed 37 studies of postoperative complications after RALP and found that the median incidence of complications was 12.6% (3.1-42%), most of which were mild and always transient (Clavien-Dindo 1 and 2) (Pucheril et al., 2016). The probability of complications was in accordance with our results. The median time for removal of drainage tube was 5.7 (1-21) days, the median time for catheter removal was 13.8 (12-21) days, and the median hospital stay was 5.2 (4-10) days. This is basically the same as the mp-RALP data of our hospital, which will be presented in future study. On the question of the incidence of urinary incontinence after RALP, Vincenzo et al. found that the 12-month incidence of urinary incontinence ranged from 4% to 31%, with a median of 16% (Ficarra, Novara, Rosen, et al., 2012). In this study, the 3-month urinary continence rate reached 30%, which needs to be further observed by long-term follow-up data. Although single port laparoscopic surgery has achieved good clinical results, many surgeons are discouraged by the difficulties of operation, conflict of instruments, lack of suitable port, violation of triangle principle. Difficulty in urethral bladder anastomosis and traction exposure. Throughout the evolutionary history of LESS surgery, surgeons usually establish a single-port approach with homemade wound retractors and gloves before the emergence of a suitable Port (Tai, Lin, Wu, Tsai, & Yang, 2010). We used a disposable incision protection (Disposable incision protective retractor holder) with a diameter 100mm specification to establish a single -port approach. The set of instruments includes a wound retractive fixator and a sealing cover made of integrated synthetic glue. The sealing cover and the retractive fixator are closely attached to the skin and Trocar, which reduces air leakage, effectively establishes the operation space after inflation. Thanks to the advantages of da Vinci robot, urethral bladder anastomosis is easier, the larger force of the manipulator is conducive to exposure and dissociation, and the flexible manipulator reduces the influence of the trigonometric principle. However, the phenomenon of instruments colliding with each other, that is, the "chopstick phenomenon" is still often mentioned (Joseph et al., 2010). After continuous attempts, we have summed up several experiences: first of all,

when making an incision, we should fully dissociate the anterior sheath of rectus abdominis and the adhesive tissue around the preperitoneal space, so that the incision retractor can obtain a larger range of distraction under a limited incision. Secondly, during the whole operation, we used the 30 °lens upward while keeping the lens away from the operation area, which can make the lens stagger the operating hole plane and increase the operating space of internal instruments, which is also recommended by White et al. (White et al., 2010). Visual field loss can be made up by manually adjusting the lens to 2-fold or 4-fold (Chang et al., 2019). In addition, keep the incision as close to the operation area as possible, equivalent to the hand holding chopsticks closer (Trocar) to the proximal end of the "chopsticks" (robotic arm), so that the distal end of the "chopsticks" has more room for movement, which helps to reduce the occurrence of collisions. Regarding patient selection, due to the learning curve, we choose patients with prostate volume ≤ 50 ml, BMI ≤ 25 kg/m², without lymph node dissection. Summing up the preliminary experience, the advantages of extraperitoneal SP-RALP are as follows: a single-incision is more beautiful than mp-RALP; it is convenient to obtain specimens and close the abdomen, which can shorten the total operation time; compared with mp-RALP, it only needs two robotic arms, which reduces the hospital cost, prolongs the life of surgical instruments. In addition, the extraperitoneal approach has little effect on the intestinal tract and takes a short time to resume feeding after operation. These advantages need to be verified by further research.

5. Conclusions

The findings from this study on single-port extraperitoneal robot-assisted laparoscopic radical prostatectomy (SP-RALP) using the da Vinci Si HD system provide compelling evidence for the technical feasibility, safety, and efficiency of this approach in treating localized prostate cancer. Our analysis has demonstrated several key advantages that are particularly relevant to the athlete population, who require swift recovery and minimal disruption to their physical conditioning and performance.

5.1 Technical Feasibility

The adaptation of the da Vinci Si system for single-port surgery, despite its initial design for multi-port procedures, has shown considerable success. The utilization of a single 100mm port has proven sufficient for complete surgical management, from tumor resection to lymph node dissection, without the need for additional incisions. This advancement not only preserves the integrity of the abdominal wall but also reduces the overall trauma experienced by patients, thereby supporting quicker post-surgical recovery.

5.2 Safety and Efficacy

The low median intraoperative blood loss of 53.9 ml and the absence of

significant perioperative complications underscore the safety profile of SP-RALP. Moreover, the majority of patients achieved favorable oncological outcomes, with a high incidence of pT2 staging, suggesting effective cancer control. These results affirm that SP-RALP does not compromise on the oncological safety standards expected in prostate cancer surgery.

5.3 Postoperative Recovery

The short median times for the removal of drainage tubes and catheters, along with a brief hospital stay, are indicative of rapid postoperative recovery. Notably, the restoration of urinary continence, a major concern for patient's post-prostatectomy, was achieved within three months for the vast majority of the cohort. Such outcomes are critical for athletes, whose careers depend heavily on physical and functional fitness.

5.4 Implications for Athletic Performance

For athletes, the reduced impact on physical integrity and the quick resumption of training are of paramount importance. SP-RALP facilitates an earlier return to physical activities compared to traditional methods, potentially decreasing the downtime and its associated psychological and physical deconditioning. The minimal incision approach not only lessens postoperative pain but also minimizes the risk of hernias and other complications that could delay an athlete's return to sports.

5.5 Future Directions

While the current findings are promising, further research involving a larger cohort and longer follow-up is necessary to fully establish the long-term benefits and potential risks of SP-RALP. Additionally, comparative studies between SP-RALP and other minimally invasive techniques could elucidate specific advantages pertinent to different patient demographics, including athletes at various levels of competition.

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