ORIGINAL RESEARCH

Breaking Barriers in Robotic Surgery: Efficiency and Safety of a Low-Cost, Single-Port Extraperitoneal Robotic-Assisted Radical Prostatectomy

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Introduction and Objective: The increasing demand for cost-effective surgical techniques has driven innovations in robotic-assisted radical prostatectomy (RARP). While single-port robotic surgery reduces invasiveness and improves cosmesis, its widespread use is limited by high costs and technical constraints. This study evaluates the safety, feasibility and cost-effectiveness of extraperitoneal single-port robotic-assisted radical prostatectomy (espRARP) using a modified Da Vinci Si HD system, employing a wound protector and surgical glove as a low-cost multi-channel laparoscopic port.
Methods: Ten patients with localized prostate cancer underwent espRARP using a three-arm Da Vinci Si system and side docking to enhance instrument access. A homemade multi-channel port was constructed using an Alexis® wound protector and surgical gloves. Perioperative outcomes—including operative time, blood loss, complications and oncologic results were analyzed descriptively.
Results: All cases were completed without conversion to open surgery. The mean operative time was 215.8 minutes with an estimated blood loss of 200 mL. No positive surgical margins were recorded, and 20% of patients exhibited pathological upgrading. The average hospital stay was 3.4 days. One patient developed a Clavien–Dindo II complication; no major complications occurred.
Limitations: This pilot study is limited by its small sample size (n = 10), single-surgeon, single-institution design, short follow-up period, and absence of functional outcome assessment. Only descriptive analysis was performed without statistical comparison.
Conclusion: The modified espRARP technique using a low-cost glove-port and three-arm Da Vinci Si system is safe, feasible and cost-efficient. Comparable perioperative and oncologic outcomes to conventional multi-port and proprietary single-port systems were achieved at a fraction of the cost. This approach provides a practical and accessible alternative for robotic prostatectomy in resource-limited healthcare settings.

Key words: robotic surgery, single-port; radical prostatectomy, cost-effective innovation, extraperitoneal approach

Introduction

Radical prostatectomy (RP) has undergone substantial advancements in recent years, transitioning from conventional open surgeries to minimally invasive techniques. Robotic-assisted radical prostatectomy (RARP) has emerged as the "gold standard" for the treatment of localized

prostate cancer (PCa) as a result of its enhanced precision, improved visualization, and reduced recovery time.[1,2]

The development of single-port (SP) robotic systems has further advanced minimally invasive surgery by reducing incisions and enhancing cosmetic outcomes.[3,4] Since the first report of single-port RARP (spRARP) in 2008[4], the technique has not only generated excitement but also challenges, mainly limited working space, instrument collisions and a steep learning curve.[4,5,6]

In 2011, Lee et al[7] from Yonsei University demonstrated the feasibility of robot-assisted laparoendoscopic single-site surgery (R-LESS) using an improvised single-port device that was made from an Alexis® wound retractor and surgical glove. Their 68-case experience proved that such improvised systems could offer adequate range of motion and flexibility, establishing the foundation for subsequent adaptations in various urologic procedures. The launch of the da Vinci SP® system in 2018 reignited global interest by allowing surgeons to control three articulating instruments and a 3-D camera through a single 2.5 cm access port.[8] Chang et al[9] later documented their initial experience with single-port transperitoneal robotic-assisted radical prostatectomy utilizing the Da Vinci Si system, demonstrating encouraging results despite the technical constraints associated with early SP setups.

Alongside these innovations, the extraperitoneal approach to RARP has demonstrated comparable efficacy to the transperitoneal approach, while offering added benefits such as shorter hospitalization, less bowel disturbance and quicker recovery[10,11] More recently, Wang et al. (2025) demonstrated that an extraperitoneal single-site robotic prostatectomy using a commercial multi-channel port and the da Vinci Xi system can achieve excellent perioperative results without entering the peritoneal cavity.[12] Their findings suggest that success in single-port robotic surgery depends more on surgical technique and innovation than on access to specialized equipment.

However, the challenge of making single-port robotic surgery is not only technically feasible but also economically attainable, especially in developing healthcare systems where access to advanced SP platforms remains limited. This study aimed to address that gap by evaluating the safety, feasibility and cost-effectiveness of performing extraperitoneal single-port robotic-assisted radical prostatectomy (espRARP) using the Da Vinci Si HD system. This technique involves the innovative use of a wound protector and surgical gloves to create a functional multi-channel laparoscopic port. This provides a more economical alternative to conventional robotic systems, reducing procedural costs while maintaining the efficacy and precision of single-port robotic surgery. Through this study, the authors seek to demonstrate that such modifications can deliver comparable outcomes without compromising patient care.

Methods

This retrospective study included ten male patients, aged 54 to 77 years, with biopsy-confirmed prostate cancer (PCa) who underwent extraperitoneal single-port robotic-assisted radical prostatectomy (espRARP) between October 2023 and June 2024. Institutional Review Board (IRB) approval was obtained, and all patients provided written informed consent prior to surgery.

Preoperative evaluation included multiparametric magnetic resonance imaging (mpMRI) and prostate-specific membrane antigen positron emission tomography (PSMA PET) scans. Imaging revealed localized disease in nine patients and locally-advanced PCa in one. Pelvic lymph node dissection was performed in a single case based on PSMA PET findings demonstrating nodal involvement.

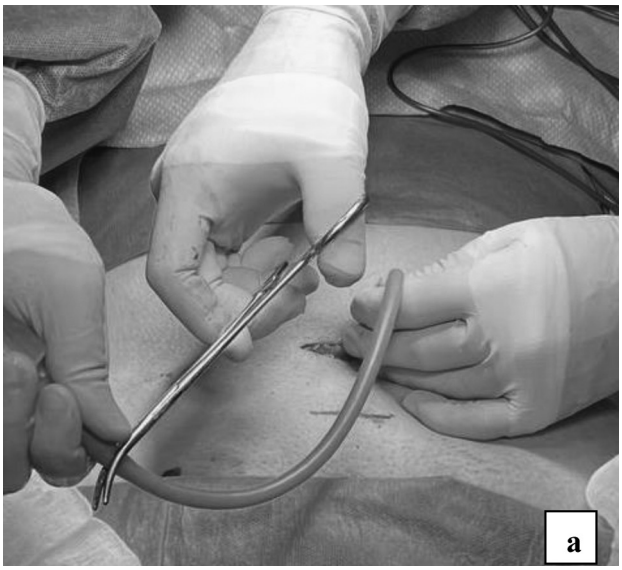
Surgical Technique

A 4–5 cm transverse incision was made approximately 5 cm above the pubic symphysis. The anterior rectus fascia was incised, and the rectus abdominis muscle was separated from the peritoneum by blunt finger dissection. An extraperitoneal working space was created using a surgical glove inflated with approximately 400 mL of saline as a homemade balloon dilator (Figure 1a). An assistant 12-mm trocar was inserted approximately 8 cm lateral to the primary incision. A wound protector was placed beneath the rectus muscle, over which a size 8 surgical glove was

tightly secured to create a multi-channel glove port (Figure 1b). Camera and robotic trocars were introduced through the finger portions of the glove and secured with 2-0 silk sutures (Figures 2a & 2b). After insertion of a 20 Fr Foley catheter, the extraperitoneal space was insufflated with CO_2.

The patient was positioned in a Trendelenburg position, and the da Vinci Si robotic system was side-docked. A 12-mm, 30° laparoscope was inserted and maintained in a 30° upward orientation to minimize instrument collision. Monopolar curved scissors and Maryland bipolar forceps were used for dissection.

After removal of the anterior prostatic fat, the lateral endopelvic fascia was incised. The dorsal venous complex was ligated with 0-Vicryl on a CT-1 needle. The bladder neck was identified and transected, and the vasa deferentia were ligated, followed by dissection of the seminal



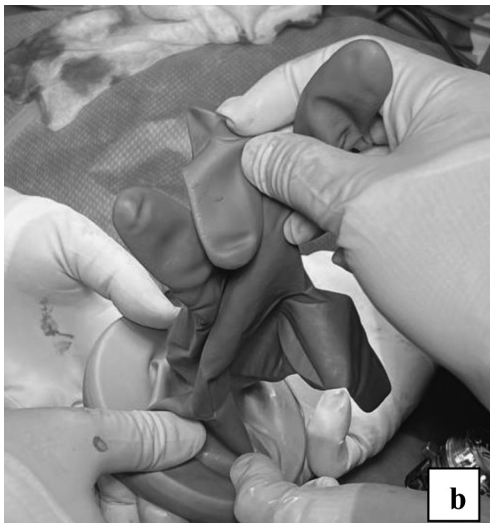
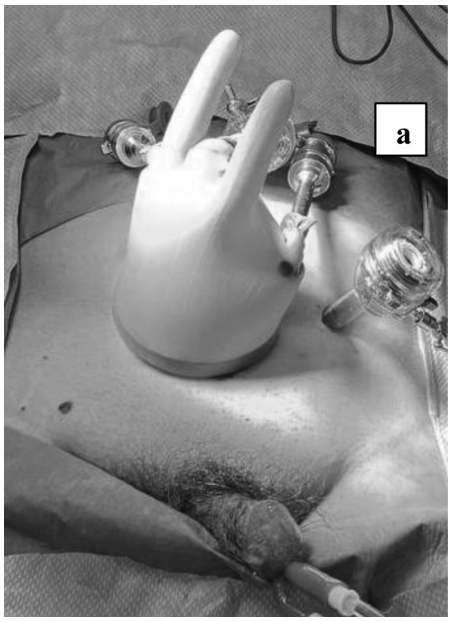


Figure 1 (a) Creation of the extraperitoneal space using a 20 Fr Foley catheter as a homemade balloon dilator. **(b)** A multi-channel glove port constructed from a size 8 sterile surgical glove and an Alexis® wound protector.



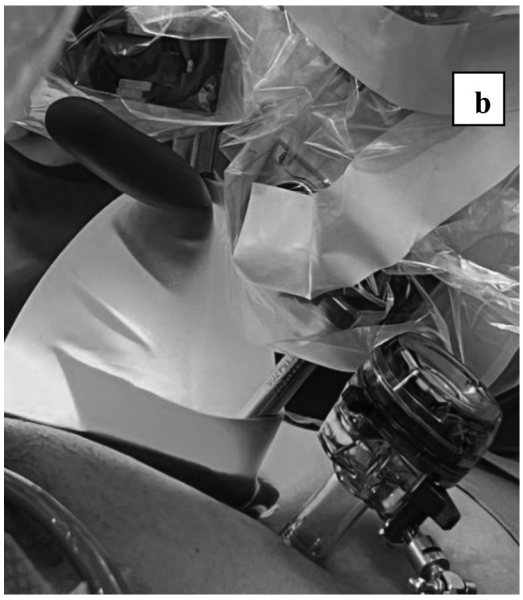


Figure 2 (a) Multichannel laparoscopic glove port with an assistant 12-mm trocar placed in the retropubic space. **(b)** Robotic arms docked to the glove port and camera port in a three-arm configuration.

vesicles. Intra-fascial dissection of the prostate was performed, with Hem-o-lok clips used to control the neurovascular bundle. Apical dissection was then carried out, and the distal urethra was transected. The prostate specimen was placed in an endoscopic retrieval bag for extraction. A rectal integrity test was performed using a rectal tube, and hemostasis was ensured.

The urethrovesical anastomosis was completed using 3-0 V-Loc™ barbed sutures in two running layers: one from 5 o'clock to 11 o'clock and another from 4 o'clock to 12 o'clock. A bladder leak test confirmed anastomotic integrity. The 20 Fr Foley catheter was then replaced with an 18 Fr catheter.

A Jackson-Pratt drain was inserted through the assistant port, the specimen was retrieved, and the incision was closed in layers.

Data Collection

Preoperative and postoperative parameters, including patient demographics, perioperative outcomes and complications, were recorded and analyzed. Prostatectomy specimens were assessed for surgical margin status and final pathological staging, which was determined according to the 2017 TNM classification system.[13] Postoperative complications were classified using the Clavien–Dindo grading system.[14]

Results

A total of 10 patients were included in this study. The mean age of the patients was 66 years, with a mean body mass index (BMI) of 25.6. The mean preoperative prostate-specific antigen (PSA) level was 11.37 ng/mL. Clinical staging indicated that 7 patients (70%) presented with cT1c disease, while 3 patients (30%) were diagnosed with cT2a-c disease. Pathological outcomes showed that 8 patients (80%) had a Gleason score of 7 (Grade Group 2-3), and 2 patients (20%) had a Gleason score of 8-10 (Grade Group 4) [Table 1].

All surgeries were completed without conversion to open procedures. The median operative time was 215.8 minutes, and the median console time was 141.1 minutes. The estimated blood loss (EBL) had a mean of 200 mL across the cohort. The median length of hospital stay was 3.4 days. Catheter duration averaged 8.9 days. The surgical technique successfully controlled bleeding and reduced operating time as experience with the modified approach progressed. No major intraoperative complications occurred, confirming the feasibility of the procedure [Table 2].

Table 1. Baseline characteristics

Parameter	N= 10 (mean)
Age at RP	66
BMI	25.6
Prior Abdominal Surgery	0
PSA	11.37
cT stage at RP	
cT1c	7
cT2a/b/c	3
cT3	0
p Gleason score at RP	
6 (grade group 1)	0
7 (grade group 2-3)	8
8-10 (grade group 4-10)	2

Table 2. Outcomes

Parameter	N= 10 (mean)
OR time	215.8 minutes
Console Time	141.1
EBL	200 cc
Positive margin	0
Length of hospital stay	3.4 days
Catheter duration	8.9 days
Complications	
Clavien I	0
Clavien II	1
Clavien III	0

Importantly, no patients in this cohort experienced positive surgical margins (PSM), indicating complete cancer resection. Pathological analysis revealed that 2 patients (20%) had an upgrade in pathological staging compared to their preoperative clinical stages, reflecting more aggressive disease than initially expected [Table 3]. These findings suggest that the modified approach is oncologically safe, yielding results comparable to standard multi-port RARP.

The overall complication rate in this study was 10%. One patient experienced a Clavien-Dindo II

complication, which involved back pain that was successfully treated with analgesics. No Clavien-Dindo III or higher complications were observed. There were no cases of rectal injury, and no major postoperative complications were recorded.

Table 3. Pathological data

PSM, n	0
PSM risk	
Low risk	0
Favorable intermediate risk	5
Unfavorable intermediate risk	3
High risk	2
Biopsy Grade Group	
Grade Group 1	0
Grade Group 2	5
Grade Group 3	3
Grade Group 4	2
Grade Group 5	0
Pathological Stage	
T2a	2
T2b	4
T2c	2
T3a	1
T3b	1
Upgrade	2

Discussion

This study demonstrates the safety and feasibility of performing extraperitoneal single-port robotic-assisted radical prostatectomy (espRARP) using a cost-effective, improvised multi-channel port. The da Vinci Si system was adapted to function as a single-port platform, employing only three robotic arms instead of the conventional four-arm configuration commonly used in multi-port procedures. Despite this simplified setup, the technique achieved perioperative and oncologic outcomes comparable to those reported in contemporary single-port and multi-port robotic series, supporting the practicality and potential applicability in resource-limited settings.

The mean operative time was 215.8 minutes, slightly longer than the 161 minutes reported by Agarwal et al. (da Vinci SP)[15] and similar to the 210 minutes reported by Wang et al. (2025, da Vinci Xi). The longer operative time is probably due to the absence of a fourth robotic arm, additional setup time for the homemade glove port, and the expected learning curve associated with the modified technique. A slight decrease in operative time after the fifth case was observed, demonstrating improved efficiency and familiarity with the single-port configuration as experience accumulated.

The mean estimated blood loss was 200 mL, which is consistent within the range reported for single-port RARP. Chang, et al reported 100 mL using a transperitoneal da Vinci Si approach, while Wang et al. documented 50 mL in extraperitoneal single-site prostatectomy with extended lymph-node dissection. Although slightly higher, current finding confirms that single-port surgery, whether using a commercial or improvised system, allows meticulous dissection and reliable hemostasis under enhanced magnified visualization. Importantly, the simplified three-arm Si configuration did not increase bleeding risk compared with multi-port setups, emphasizing that surgical skill and surgeons' experience, rather than proprietary technology, are the primary determinants of intraoperative safety and hemostatic efficiency.

The mean hospital stay was 3.4 days, slightly longer than the one-day stay reported by Agarwal and Wilson but comparable to the 2.8 days described by Chang et al.[16] This difference likely reflects variations in discharge protocols, drain management, and the early learning phase of the technique. With growing familiarity and optimized perioperative coordination, hospital stays are expected to shorten, consistent with recovery trends reported in other single-port series.

All patients in this study achieved negative surgical margins, comparable to or better than the 8–10% positive-margin rates reported in prior single-port studies.[15,16] Although encouraging, this finding should be interpreted with caution, given the small sample size and limited follow-up. Nonetheless, it demonstrates that a well-executed, low-cost modification can maintain oncologic precision and completeness of resection without reliance on dedicated SP instrumentation.

Only one patient (10%) experienced a Clavien–Dindo II complication (back pain), and no major (≥ grade III) events occurred. This aligns with reported complication rates in single-port series (8% in Agarwal, et al, 0% in Wilson, et al[17]), affirming that the combination of a homemade

glove-port and a three-arm da Vinci Si system does not introduce additional procedural risk and can be safely applied in appropriate candidates.

Using a customized glove-port with a three-arm da Vinci Si configuration markedly reduces procedural cost without compromising safety or surgical quality. The glove-port made with an Alexis® wound protector (≈ USD 50) and a standard surgical glove costs under USD 60 in total, which is much cheaper than the USD 500–1,000 needed for commercial multi-channel ports or the USD 1,500–2,000 for proprietary da Vinci SP® kit access systems.[18] This configuration makes robotic prostatectomy more accessible, especially in facilities with limited resources, by reducing the number of instruments needed and doing away with the need for specialized SP equipment. Biebel et al.[18] reported that the average operating-room cost of da Vinci SP RALP was USD 3,100, which is a 36% increase per case compared to USD 2,271 for Xi RALP. The use of only three robotic arms in the current setup further reduced overall costs by eliminating the need for an additional robotic instrument and drape typically required in four-arm configurations.

Overall, this study illustrates that innovation does not need to be expensive. Through simple, thoughtful modification, using existing hardware and readily available materials, comparable surgical outcomes can be achieved at a fraction of the cost. This approach provides a practical and scalable solution for expanding access to robotic prostatectomy in developing healthcare environments, without compromising safety, precision, or oncologic efficacy.

Limitations

This study is limited by its small sample size (n = 10), single-surgeon and single-institution design, and short follow-up period, which preclude definitive conclusions about long-term functional and oncologic outcomes. Functional outcomes such as continence and sexual function were not included due to the short postoperative observation window and the study's focus on perioperative feasibility. Furthermore, the results were analyzed using descriptive statistics only, without inferential testing. While early outcomes are promising, larger multicenter prospective studies with longer follow-up are warranted to validate these findings, assess the learning curve, and evaluate functional recovery and quality-of-life outcomes.

Conclusion

The modified extraperitoneal single-port robotic-assisted radical prostatectomy (espRARP) using a three-arm da Vinci Si system and a homemade glove-port is a safe, feasible, and cost-effective alternative to conventional multi-port and proprietary single-port robotic systems. Despite its simplified design, the technique achieved comparable operative times, blood loss, hospital stay, complication rates, and oncologic outcomes to contemporary single-port series.

By using readily available materials, an Alexis® wound protector and standard surgical glove, this technique dramatically reduces costs while maintaining surgical precision. The findings highlight that technical innovation, surgical skill and efficiency can overcome technological limitations, making advanced robotic surgery more accessible to resource-limited healthcare systems. Further long-term studies with larger patient cohorts are recommended to confirm its oncologic durability and functional outcomes.

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