ORIGINAL ARTICLE

Nerve-sparing total prostatectomy with or without adjuvant chemotherapy is associated with a low rate of surgical complications, long-term continence and improved survival in 22 dogs with T1 to T3 prostatic tumours

S. A. Giulia*, C. L. Elena †,1, C. Filippo ‡ and M. Federico§

*Aura Veterinary, Guildford, UK
†Klinik für Kleintierchirurgie, Vetsuisse-Fakultät, Universität Zürich, Zürich, Switzerland
‡Surgery Department, San Marco Veterinary Clinic and Laboratory, Veggiano, Italy
§Clinica Veterinaria Nervianese, Nerviano, Italy

[1]Corresponding author email: lavinia.chiti@gmail.com

Objectives: To evaluate surgical outcomes, urinary continence and survival in dogs with stage T < 4 prostatic tumours or preneoplastic lesions treated with nerve-sparing total prostatectomy.

Materials and Methods: A retrospective review of 22 dogs that underwent nerve-sparing total prostatectomy between 2018 and 2024 was conducted. Inclusion criteria included histologically confirmed prostatic neoplasia or preneoplastic lesions, complete preoperative staging (contrast-enhanced CT and urethrocystoscopy), absence of nodal or distant metastases (N0, M0) and no invasion of adjacent structures (<T4). Data collected included surgical complications, urinary continence (modified Byron scale), histopathology, adjuvant treatment, tumour progression and survival.

Results: Fifteen dogs were staged as T2N0M0, five as T3N0M0 and two as T1N0M0. The average surgical time was 72.5 minutes. One minor intraoperative complication occurred, with no major postoperative complications observed. All dogs were incontinent immediately after catheter removal; however, improvement was seen in all cases during follow-up. Fifteen dogs (68.2%) regained full continence, while seven (31.8%) experienced persistent mild (grade 1) incontinence. No dogs developed severe permanent incontinence. Tumour progression was observed in six dogs (27.3%) at a median of 150 days post-surgery. The median follow-up and survival times were 570 and 900 days, respectively.

Clinical Significance: In carefully selected dogs with early-stage (T < 4) prostatic disease, nerve-sparing total prostatectomy is associated with a low complication rate, favourable long-term continence and encouraging survival outcomes. This approach offers a viable treatment option for dogs with limited local disease.

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INTRODUCTION

Prostatic tumours are rare in dogs, but they are of great interest because of their potential as a spontaneous translational cancer model. Current treatment options do not provide satisfactory or reliable tumour control and patient outcomes (Gibson & Culp, 2024). The most common tumour type affecting the canine prostate is carcinoma, which may present as urothelial carcinoma (or transitional cell carcinoma), adenocarcinoma or a mixed urothelial and glandular phenotype. Proliferative inflammatory atrophy can also be encountered and is considered a preneoplastic lesion (Fonseca-Alves et al., 2017; Palmieri et al., 2019). According to the TNM staging system (Owen, 1980), T is defined by tumour extension within the prostatic parenchyma, capsule invasion and invasion of nearby structures, while the N and M categories indicate spread to regional lymph nodes and distant organs, respectively (Table 1). Because symptoms of prostatic cancer are often subtle and non-specific, and screening tests such as BRAF mutation analysis are still not widely used (Mochizuki et al., 2015), diagnosis often occurs at advanced stages (Withrow & Vail, 2006). Previous studies report that the prevalence of lymph node metastases ranges from 15% to 72% and distant metastases from 8% to 50% at presentation (Iizuka et al., 2022). Extracapsular invasion has been documented in 44% to 80% of dogs (Bennett et al., 2018; Iizuka et al., 2022). These factors greatly limit the potential for effective long-term tumour control.

Available treatment options include medical management with NSAIDS and/or cytotoxic agents, radiation therapy and surgery. For medical management, a recent study reported a significantly longer median survival time and time to progression with a combination of NSAIDS and chemotherapy compared to NSAIDS alone. However, median survival remained poor in both groups (106 and 51 days) (Ravicini et al., 2018).

Radiation therapy (curative intent external beam or brachytherapy) has been used for local tumour control in dogs with prostatic neoplasia; however, outcomes have been disappointing, with locoregional failure reported in up to 75% of cases, complications occurring in 39% to 56% of cases (Gibson & Culp, 2024) and a risk of permanent urinary incontinence at 31% (Clerc-Renaud et al., 2021).

Table 1. TNM staging adapted for canine prostatic cancer

T stage	T=1, tumour confined within the prostatic parenchyma
	T=2, tumour involving invasion of the prostatic capsule
	T=3, tumour extending beyond the prostatic capsule but not invading neighbouring organs
	T=4, tumour invading neighbouring structures/organs
N stage	N=0, no spread to regional lymph node(s)
	N=1, spread to regional lymph node(s)
M stage	M=0, no spread to distant organs
	M=1, spread to distant organs

T refers to the local extension of the primary tumour, N to the locoregional spread to the lymph nodes and M to tumour spread to distant sites

More recently, interventional oncology approaches such as prostate artery embolisation or intra-arterial chemotherapy have been described (Gibson & Culp, 2024); however, long-term data have not yet been reported.

Median survival times for dogs treated with prostatectomy alone or combined with various medical therapies are reportedly between 231 and 337 days. Compared to dogs managed with NSAIDs, with or without chemotherapy, surgically treated dogs experienced significantly longer survival times (337 days vs. 90.5 days), and a median survival of 510 days has been reported for dogs undergoing total prostatectomy (Iizuka et al., 2022). The high rate of surgical complications and permanent urinary incontinence remains a major drawback of radical prostate surgery (Stans, 2020). Permanent urinary incontinence can significantly impair quality of life and has been observed in 32% to 80% of cases in two recent studies (Bennett et al., 2018; Iizuka et al., 2022). Interestingly, urinary incontinence does not seem to occur when prostatectomy is performed for non-oncological conditions (Schulz et al., 1996), and it has been hypothesised that the disease itself may contribute to postoperative permanent urinary incontinence (Basinger et al., 1987). The neurovascular supply to the lower urinary tract, which is crucial for continence, runs dorsally to the prostate; therefore, tumour invasion and/or surgical dissection in this region may impair its function. In the study by Iizuka et al. (2022), severe permanent incontinence affected exclusively dogs that underwent total prostatocystectomy, while dogs receiving total prostatectomy were either continent long-term or only mildly incontinent. This suggests that the extent of surgery and/or tumour invasiveness may influence the severity of postoperative incontinence. However, data are still lacking regarding the impact of extracapsular invasion and surgical technique on postoperative complications and permanent urinary incontinence following total prostatectomy.

The aim of this retrospective study is to report the surgical outcomes and the incidence of transient and permanent postoperative incontinence in dogs undergoing nerve-sparing total prostatectomy for prostatic tumours without major invasion of the urethra or adjacent structures (stage T < 4). We hypothesised that, in these selected low-stage cases, total prostatectomy can be performed with a lower incidence of surgical complications or severe postoperative permanent urinary incontinence.

MATERIALS AND METHODS

Study design

Clinical records of dogs presented to Clinica Veterinaria Nervianese and Clinica Veterinaria San Marco for total prostatectomy between 2018 and 2024 were retrospectively reviewed.

Medical record search

Keywords used to retrieve cases were "prostatectomy", "prostatic carcinoma", "prostatic adenocarcinoma", "transitional cell carcinoma", "preneoplastic" and "mixed carcinoma". If the search function was not available in the medical record system, the investigator's case log was searched instead.

Data extraction

Data retrieved included signalment, presenting clinical signs, preoperative urinary continence status, results of preoperative abdominal ultrasonography and prostatic cytology or histopathology (if available), CT and urethrocystoscopy findings, TNM stage, surgical technique and duration, postoperative urinary catheter use and duration, intraoperative and postoperative complications, postoperative urinary continence and its duration, histopathological diagnosis and margins, adjuvant therapy, disease progression (local recurrence, nodal or distant metastases), survival status and follow-up time.

Urethrocystoscopy was performed in all included cases for local staging and to accurately assess tumour extension into the lower urinary tract. Briefly, with the dog under general anaesthesia and positioned in dorsal recumbency, a flexible cystoscope (Flex XC, 2.7 mm, STORZ, Germany) was inserted retrogradely into the penile urethra until reaching the urinary bladder, then retracted slowly to allow for complete exploration of the bladder and urethra. Cystoscopic biopsies were obtained if indicated. Pre- and postoperative scoring of urinary incontinence was conducted through in-person or telephonic interviews with the owners.

Surgical technique

Dogs were induced into general anaesthesia, moved into the operating theatre and placed in dorsal recumbency. After aseptic surgical preparation, a caudal median celiotomy extending from the subumbilicus to the pubis was performed. A rigid urinary catheter was placed retrogradely into the urethra. The prostate was identified and dissected from surrounding tissues using an ultrasonic surgical scalpel (Harmonic™, Ethicon Endo-Surgery, Cincinnati, OH, USA) to dissect while preserving all the vascular and nerve supply to the bladder neck and urethra, staying as close as possible to the prostatic capsule without penetrating the organ. A vessel sealing device (LigaSure™, Medtronic, Minneapolis, MN, USA) was used only to seal small bleeding from the prostatic arteries near the prostatic serosal layer when necessary. Great care was taken to preserve the tissues dorsal to the prostate and urinary bladder, where the neurovascular plexus is located. The deferens were retracted into the abdomen and resected with the prostate at their insertions dorsocranially. Once the prostate was completely dissected dorsally and ventrally, the urethra was sharply transected cranially and caudally. The urinary catheter was replaced with a Foley catheter to guide during the anastomosis. An end-to-end anastomosis was performed around the urinary catheter using a single interrupted pattern with polydioxanone 5 to 0 or 6 to 0, starting dorsally and ventrally on both sides. After completing the anastomosis, the omentum was retracted caudally to cover the suture line, and abdominal closure was routine.

Urinary incontinence and surgical complications definitions

Urinary incontinence was defined and scored according to the modified Byron scale (Bennett et al., 2018) as follows: Grade 0 = fully continent; grade 1 = urine soiling of bedding more than 50% of the time during sleep, does not dribble urine or have wet prepuce/ventrum when awake; grade 2 = urine soiling of bedding more than 50% of the time during sleep, dribbles urine or has a wet prepuce when awake up to 25% of the time; grade 3 = poorly continent, urine soiling of bedding more than 50% of the time during sleep, wet prepuce/ventrum 25% to 75% of the time; grade 4 = continuously incontinent, dribbles urine at all times, constantly has a wet prepuce/ventrum and leaves urine when rising from a sitting to standing position.

Surgical complications, other than postoperative urinary incontinence, were defined as any unattended or undesired event and were categorised into intraoperative, if they occurred from induction until recovery from general anaesthesia, and postoperative if they occurred any time between recovery from general anaesthesia until 30 days postoperatively (Chiti et al., 2023); they were considered as major if they required surgical revision and minor otherwise (Cantatore et al., 2014).

Follow-up

Clinical re-examinations were performed at 10 and 30 days postoperatively to assess urinary continence and identify potential surgical complications. Additional evaluations were scheduled as required. Long-term follow-up was obtained by telephone from the referring veterinarian or the owner.

Local recurrence, nodal involvement or distant metastasis was suspected based on clinical examination or diagnostic imaging and, where possible, confirmed through cytological or histopathological analysis. Cause of death was categorised as tumour-related or unrelated.

Inclusion and exclusion criteria

Inclusion criteria included: histologically confirmed prostatic neoplasia or preneoplastic lesions; total prostatectomy performed by a board-certified surgeon; preoperative staging using contrast-enhanced total-body CT and urethrocystoscopy; and no evidence of locoregional or distant metastasis at presentation (N0, M0). Dogs were excluded if there was macroscopic urethral invasion beyond the seminal colliculi, invasion of adjacent structures (T4), postoperative follow-up of less than 30 days or incomplete clinical records.

Statistical analysis

Median, IQR and range were used to summarise continuous variables, while categorical variables were summarised as the percentage of each modality of the total cases.

Follow-up time was calculated for each dog as the interval (in days) between surgery and the last available clinical assessment via telephonic contact for dogs that were alive or lost to follow-up, or the date of death for those that died during the study period. Median follow-up time and 95% confidence intervals were estimated using the reverse Kaplan–Meier method.

Overall survival was defined as the interval (in days) from surgery to death from any cause, with dogs still alive at the end of the study or lost to follow-up being censored at the time of last follow-up. Median survival time (MST) and 95% confidence intervals were estimated using the standard Kaplan–Meier method.

Statistical analysis was performed with Python (version 3; custom survival scripts). Part of the data processing and statistical scripting was performed with the assistance of artificial intelligence-based tools (OpenAI). This study was retrospective in nature and did not involve any experimental procedures. All data were obtained from existing medical records of client-owned dogs presented for diagnostic and therapeutic purposes, with informed owner consent. According to institutional guidelines, formal ethical committee approval was not required.

RESULTS

Study population

A total of 22 dogs met the inclusion criteria. Median age at presentation was 9.6 years (range 5.5 to 13 years; IQR 3.6 years), and median body weight was 20.9 kg (range 4.5 to 65 kg; IQR 22.1 kg). There were six (27.3%) mixed-breed dogs, two (9.1%) dachshunds and one (4.5%) each of poodle, Cane corso, Irish setter, schnauzer, beagle, Rhodesian Ridgeback, American Staffordshire terrier, Greyhound, English setter, French Bulldog, Labrador retriever, Pit Bull terrier, Australian shepherd and shih-tzu. One dog (4.5%) was an intact male, while the remaining 21 dogs (95.5%) were neutered males.

Presenting complaints included stranguria and pollakiuria in seven cases (31.8%) with concurrent haematuria in one case and with faecal tenesmus in another dog; severe urinary incontinence in five cases (22.7%), faecal tenesmus in three cases (13.6%), haematuria alone in one case, lethargy and apathy in one case. In six dogs (27.3%), the prostatic lesion was an incidental finding during abdominal ultrasonography performed for re-evaluation of prostatic hyperplasia or prostatitis.

Abdominal ultrasonography was performed on all dogs. Findings included heterogeneous prostatic parenchyma in 12 dogs (54.5%), prostatomegaly in seven (31.8%) and both heterogeneous parenchyma and prostatomegaly in one (4.5%). A distinct prostatic nodule was identified in seven dogs (31.8%). In two additional dogs (9.1%), a focal lesion was present without marked alteration of the surrounding parenchyma.

Whole-body contrast-enhanced CT confirmed the ultrasonographic findings and ruled out distant metastases in all dogs. Medial iliac lymphadenomegaly was observed in two dogs; however, histopathology after lymphadenectomy showed no metastatic disease in both cases. Based on imaging and histopathology, 15 dogs (68.2%) were staged as T2N0M0, five (22.7%) as T3N0M0 and two (9.1%) as T1N0M0.

Surgery

Nerve-sparing total prostatectomy was performed on all included dogs. Prostate dissection was performed using a vessel sealing device: a combination of an ultrasonic surgical scalpel and a vessel sealing device in 13 cases (59.1%) or an ultrasonic surgical scalpel alone in nine cases (40.9%). In one case, two perineal cutaneous lesions were removed simultaneously, while no other concurrent procedures were performed in the remaining dogs. The median surgical time was 72.5 minutes (range 35 to 95 minutes; IQR: 21.5 minutes). In one case (4.5%), an intraoperative complication involved minor bleeding from the right prostatic artery, which was controlled with a vessel sealing device without any cardiovascular consequences to the dog. No postoperative complications other than urinary incontinence were recorded in any of the included dogs.

Histopathology and adjuvant treatments

At histopathology, 11 cases were adenocarcinomas (50%), six were transitional cell carcinomas (27.3%), four were preneoplastic lesions (18.2%), and one was an undifferentiated malignant neoplasm characterised as a carcinoma with a mixed phenotype, with concurrently excised perineal lesions identified as cutaneous metastasis (4.5%). Margins were histologically free of disease (R0) in 21 cases and involved (R1) in only one case. Regional lymph nodes were removed in 19 cases (86%), and none were reported as metastatic.

Adjuvant treatment was administered in 11 cases (50%), consisting of chemotherapy alone in nine cases (carboplatin $n = 5$; doxorubicin $n = 1$, carboplatin and doxorubicin $n = 1$, palladia $n = 1$, mitoxantrone $n = 1$), chemotherapy (mitoxantrone, chlorambucil and meloxicam) in one case and meloxicam alone in one case. All dogs that received adjuvant treatment had either a transitional cell carcinoma, adenocarcinoma or mixed carcinoma. The rationale for administration of adjuvant treatment was to reduce the chances of recurrence or distant metastases (Stans, 2020). In the other seven cases with transitional cell or adenocarcinoma, chemotherapy was suggested but refused by the owner.

Urinary incontinence

Preoperatively, 11 dogs (50%) were fully continent (grade 0). Of the remaining dogs, urinary incontinence was graded as grade 1 in five (22.7%), grade 2 in three (13.6%), grade 3 in one (4.5%) and grade 4 in two (9.1%). An indwelling urinary catheter was maintained postoperatively for a median of 7 days (range 6 to 9 days; IQR 0.75 days).

Immediately following catheter removal, all dogs were incontinent: Grade 1 in four dogs (18.2%), grade 2 in nine (40.9%), grade 3 in six (27.3%) and grade 4 in three (13.6%). Improvement in urinary continence was observed in all dogs during the follow-up period. Ultimately, 15 dogs (68.2%) regained complete urinary continence (grade 0), while seven (31.8%) retained mild, persistent incontinence (grade 1). No dogs exhibited moderate or severe long-term incontinence (grade ≥ 2). The median time to improvement in continence was 60 days (range 30 to 180 days; IQR 60 days). Phenylpropanolamine was administered in nine dogs (40.9%): in seven it was continued long term and in two cases it was discontinued after 4 months following achievement of complete continence (grade 0). Urinary continence scores at the different time points are summarised in Table 2.

Outcomes and survival

At the end of the study period, ten dogs were alive without signs of tumour progression, one dog was alive with local recurrence

Table 2. Demographics and urinary continence outcomes of the study population

Signalment (breed, sex (M/MC), age (years. Months) weight (kg))	Urinary incontinence score pre-op (0 to 4)	Postoperative urinary catheter duration (days)	Urinary incontinence level score following catheter removal (0 to 4)	Final urinary incontinence level score (0 to 4)	Days to final urinary incontinence score (days)
1. Poodle, MC, 10.8, 7.8	0	7	2	0	90
2. Cane corso, MC, 8.3, 65	3	7	4	1	60
3. Mixed breed, MC, 9.5, 7.6	0	7	1	0	30
4. Irish setter, MC, 9.3, 32	0	7	3	0	60
5. Standard Schnautzer, MC, 9, 16	1	7	3	0	120
6. Beagle, MC, 8.5, 20.7	0	7	4	2	30
7. Dachshund, MC, 12.1, 12	2	7	3	1	30
8. Rhodesian Ridgeback, MC, 6.5, 48	0	7	4	2	30
9. Mixed breed, MC, 12.2, 40	0	7	1	0	60
10. Mixed breed, MC, 9.6, 15.6	0	7	2	0	30
11. Mixed breed, MC, 12.2, 40	0	7	3	0	90
12. Amstaff, MC, 9.9, 28	0	7	2	1	30
13. Greyhound, MC, 6, 4.5	4	7	3	0	120
14. English setter, MC, 11.9, 22	0	7	2	0	90
15. French Bulldog, MC, 5.8, 11.9	0	7	1	0	30
16. Labrador retriever, MC, 9.6, 31.9	4	7	2	1	30
17. Shih-tzu, MC, 8, 7.2	2	8	2	0	120
18. Mixed breed, MC, 11, 30	1	8	3	0	180
19. Pit Bull terrier, MC, 13, 40	1	8	2	1	90
20. Dachshund, MC, 12, 7	1	9	1	0	30
21. Australian sheepdog, M, 5.4, 21	1	8	2	0	90
22. Mixed breed, MC, 12.3, 25	2	8	2	1	150

For each included dog, signalment, preoperative urinary incontinence score, postoperative incontinence score immediately after catheter removal, long-term incontinence score, days with urinary catheter and time to reach the final score are reported. Urinary incontinence severity was graded using the modified Byron scale ranging from 0 (complete continence) to 4 (continuous leakage). The final score represents the last continence assessment available. Time to final score was calculated from surgery
MN Male castrated, M Male intact

and bladder involvement (which occurred at 540 days after surgery), eight dogs had died, of which five were due to tumour progression, and three dogs were lost to follow-up at 180, 210 and 330 days without tumour progression.

Overall, tumour progression occurred in six dogs (27.3%) at a median of 150 days after surgery (range 90 to 540 days): distant metastases in 5 cases, including one with lymph node involvement, and local recurrence in one case (Table 3).

Median follow-up time was 570 days (95% CI: 370 to 720 days) (Fig 1), and MST was 900 days (95% CI: 480 to 900 days) (Fig 2). When stratified by histotype, MST was 900 days (95% CI: 540 to 900 days) for adenocarcinoma and 540 days (95% CI: 120 to 540 days) for transitional cell carcinoma, whereas it was not reached in dogs with preneoplastic lesions.

DISCUSSION

In this retrospective cohort of dogs with T < 4 prostatic cancer or preneoplastic lesions, we report favourable outcomes following nerve-sparing total prostatectomy and chemotherapy, with a median survival time of 900 days and long-term restoration of partial or complete urinary continence in all dogs (grade 0 or 1).

Tumour progression occurred in 27% of the dogs included in this study. Both the incidence of progression and the median survival times we observed compare favourably with previously published data. Bennett et al. (2018) reported a median survival time of 231 days after total prostatectomy, with tumour relapse in 52% of cases. Similarly, Iizuka et al. (2022) documented a median survival time of 337 days in dogs undergoing either total prostatectomy or prostatocystectomy. The improved survival time in our cohort is likely due to case selection. We included only dogs with T < 4 tumours, no bladder invasion and no urethral involvement beyond the colliculi, confirmed by CT and urethrocystoscopy. In contrast, previous studies included dogs with more extensive local disease, including invasion of adjacent organs (Bennett et al., 2018; Iizuka et al., 2022). Notably, Iizuka et al. (2022) reported longer survival in dogs undergoing total prostatectomy than in those treated with prostatocystectomy, further suggesting that dogs with less invasive tumours, and thus candidates for less extensive resections, may have a more favourable outcome.

When MST was stratified by histotype, dogs with transitional cell carcinoma showed a lower MST compared to dogs with adenocarcinoma and preneoplastic lesions. This finding suggests that tumour type may influence oncological outcomes following prostatectomy. However, due to the limited sample size, MST was not compared among groups in this study, and future investigations are needed to statistically assess the impact of tumour type on long-term survival of dogs with prostatic tumours.

Eleven dogs in our study received adjuvant treatments after prostatectomy, possibly contributing to the favourable long-term prognosis. Although studies are lacking on the efficacy of adjuvant treatments in canine prostatic tumours, it has been suggested that they may reduce the risk for local recurrence and development of distant metastases (Stans, 2020). Further, prospective, randomised studies are needed to determine the benefits of adjuvant treatment in low-stage cases amenable to total

Table 3. Histological diagnosis and oncological outcome of the study population

Signalment (breed, sex (M/MC), age (years. Months) weight (kg))	Histological diagnosis (ADC, SCC, MIX, PRE)	Long-term follow-up (days)	Relapse/disease progression (yes/no)	Disease-free interval (days)	Status (dead, alive, lost to follow up)	Cause of death (related or unrelated)
1. Poodle, MC, 10.8, 7.8	ADC	900	No	900	Dead	Unrelated
2. Cane corso, MC, 8.3, 65	MIX	130	Yes	120	Dead	Related
3. Mixed breed, MC, 9.5, 7.6	ADC	90	Yes	90	Dead	Related
4. Irish setter, MC, 9.3, 32	PRE	1080	No	1080	Alive	
5. Standard Schnautzer, MC, 9, 16	ADC	540	Yes	540	Dead	Related
6. Beagle, MC, 8.5, 20.7	ADC	180	No	180	Lost	
7. Dachshund, MC, 12.1, 12	PRE	720	No	720	Alive	
8. Rhodesian Ridgeback, MC, 6.5, 48	ADC	1170	No	1170	Alive	
9. Mixed breed, MC, 12.2, 40	TCC	585	Yes	540	Alive	
10. Mixed breed, MC, 9.6, 15.6	PRE	570	No	570	Alive	
11. Mixed breed, MC, 12.2, 40	ADC	540	No	540	Alive	
12. Amstaff, MC, 9.9, 28	TCC	330	No	330	Lost	
13. Greyhound, MC, 6, 4.5	PRE	370	No	370	Alive	
14. English setter, MC, 11.9, 22	ADC	240	No	240	Alive	
15. French Bulldog, MC, 5.8, 11.9	TCC	180	No	180	Alive	
16. Labrador retriever, MC, 9.6, 31.9	TCC	120	Yes	120	Dead	Related
17. Shih-tzu, MC, 8, 7.2	ADC	270	Yes	180	Dead	Related
18. Mixed breed, MC, 11, 30	TCC	480	No	480	Dead	Unrelated
19. Pitbull terrier, MC, 13, 40	ADC	210	No	210	Lost	
20. Dachshund, MC, 12, 7	ADC	210	No	210	Dead	Unrelated
21. Australian sheepdog, M, 5.4, 21	ADC	690	No	690	Alive	
22. Mixed breed, MC, 12.3, 25	TCC	540	No	540	Alive	

For each included dog, histological diagnosis, long-term follow-up, reported relapse or disease progression, disease-free interval and status with cause of death if dead at time of last follow-up is reported. Follow-up time and disease-free interval are reported in days from surgery. Relapse or progression included local recurrence and/or distant metastases
Histological diagnosis abbreviations
ADC Adenocarcinoma, TCC Transitional cell carcinoma, PRE Preneoplastic, MIX Mixed carcinoma

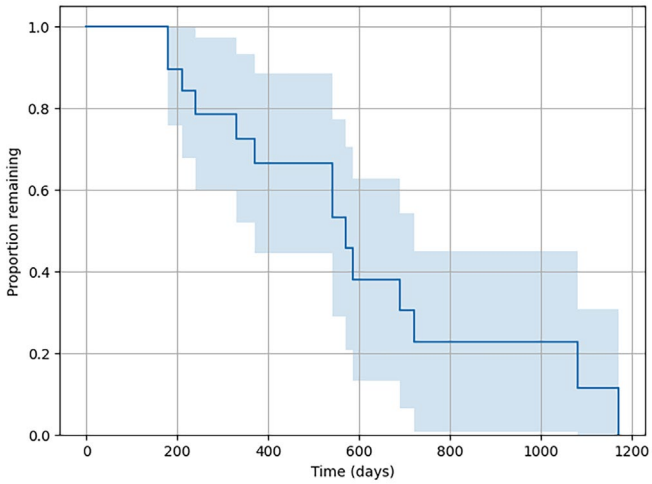

FIG 1. Overall follow-up time calculated with the reverse Kaplan–Meier method. The solid line represents the estimated follow-up distribution; the shaded area indicates the 95% confidence interval.

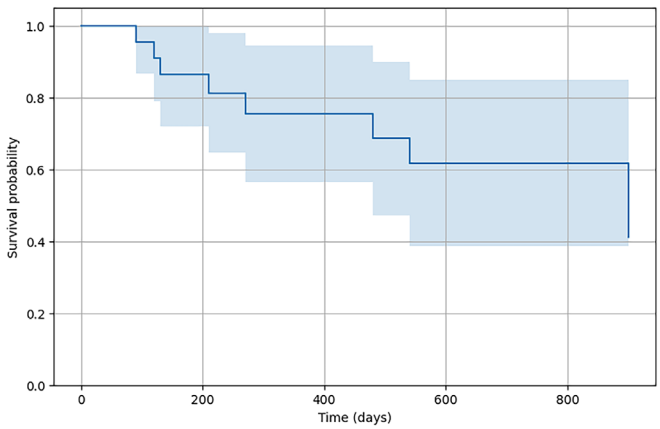

FIG 2. Overall median survival time calculated with the Kaplan–Meier method. The solid line represents the survival estimate; the shaded area indicates the 95% confidence interval.

prostatectomy. The impact of adjuvant therapies on incontinence is also poorly understood and warrants further investigation.

Permanent urinary incontinence is a significant drawback of total prostatectomy, as it can substantially affect quality of life. Previous studies have shown permanent postoperative urinary incontinence in 32% to 80% of cases, including severe incontinence in 30% of dogs in one study and grade > 1 incontinence in 24% of cases in another (Bennett et al., 2018; Iizuka et al., 2022). In our study, all dogs experienced postoperative urinary incontinence; however, most dogs (68.2%) fully regained continence and were continent at long-term follow-up. Permanent urinary incontinence was observed in 31.8% of dogs, but it remained mild (grade 1) and did not affect their perceived quality of life, as assessed by the owners. Unlike previous reports, no cases of severe permanent urinary incontinence were seen in our cohort. This lower incidence, especially of severe incontinence, likely reflects the inclusion of only early-stage disease (T < 4). Limited local invasion allowed surgeons to minimise dissection around the prostate, preserving neurovascular structures and possibly reducing the risk of permanent neurologic injury. It has also been hypothesised that prostatic disease itself may contribute to urinary incontinence, since dogs undergoing prostatectomy for non-oncologic reasons rarely develop this complication (Basinger

et al., 1987; Schulz et al., 1996). Prostatic tumours invading surrounding tissues might further impair neurologic control of micturition. Therefore, including dogs with less invasive tumours may have played a key role in the lower incidence of permanent incontinence observed, not only through more effective nerve-sparing surgery but also because the disease had not yet compromised continence. This idea is supported by the fact that, even preoperatively, most dogs showed only mild incontinence.

A major therapeutic challenge in canine prostatic tumours is that diagnosis is often delayed until advanced stages due to nonspecific clinical signs. However, molecular screening tests are increasingly incorporated into routine diagnostics and may enable earlier detection. A droplet digital PCR assay has been validated for the detection of the canine BRAF V595E mutation in urogenital tumours, demonstrating 85% sensitivity for prostatic carcinoma and allowing detection of the mutation in 83% of free-catch urine samples (Mochizuki et al., 2015). More recently, it has been suggested that this test could be used to screen predisposed breeds, potentially enabling earlier diagnosis and improved outcomes (Appenzeller et al., 2025). In this scenario, prostatic tumours may be detected at earlier stages and could be more suitable for nerve-sparing total prostatectomy.

The main strengths of our study include the relatively homogeneous cohort, with inclusion limited to T < 4 tumours thoroughly staged using CT and urethrocystoscopy. Additionally, all surgeries were performed by two experienced, board-certified specialists, reducing procedural variability. However, this study also has several limitations, primarily its retrospective design and small sample size, which limited the ability to develop statistical models to assess the influence of patient- and tumour-related variables, such as preoperative continence grade, tumour type and tumour size, on long-term outcomes. Furthermore, the small sample size and heterogeneity of adjuvant treatment protocols hampered the possibility to determine whether postoperative chemotherapy may improve survival times.

Future prospective randomised studies with larger cohorts are needed to better clarify how these variables affect both oncologic and functional outcomes, especially long-term continence, and to more accurately identify which subpopulations of dogs with prostatic tumours are most suitable for surgical treatment. Moreover, outcomes for early-stage patients should be compared across surgical management and emerging therapies like radiation therapy and interventional oncology procedures (Gibson & Culp, 2024).

In conclusion, nerve-sparing total prostatectomy is a viable treatment option for dogs with prostatic tumours or preneoplastic lesions of stage T < 4. In our cohort, it was associated with acceptable survival times and favourable functional outcomes, with minimal to no long-term urinary incontinence.

Author contributions

S. A. Giulia: Investigation; writing – original draft; data curation. **C. L. Elena:** Investigation; writing – original draft; methodology; formal analysis; data curation. **C. Filippo:** Investigation; writing – review and editing; data curation; supervision. **M. Federico:** Investigation; conceptualization; data curation; writing – review and editing; supervision.

Conflict of interest

The authors declare no conflict of interest.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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