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Nerve-sparing vs. non-nerve-sparing open radical prostatectomy: correlations between International Index of Erectile Function and corpus cavernosum electromyography

Otvorena radikalna prostatektomija sa i bez poštede neurovaskularnog snopa: korelacije između Internacionalnog indeksa erektilne funkcije i elektromiografije kavernoznih tela

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Abstract

Background/Aim. Erectile dysfunction (ED) increases with age, and the importance of sexual health has become more widespread in therapeutic practice. The aim of this study was to evaluate the correlation between subjective and objective measures of ED in patients undergoing nerve-sparing vs. non-nerve-sparing open radical prostatectomy for localized prostate cancer. **Methods.** This prospective controlled study included 50 patients with diagnosed prostate cancer and normal preoperative erectile function (EF). Patients were divided into nerve-sparing (n = 25) and non-nerve-sparing (n = 25) groups. EF was assessed preoperatively and at six months using the International Index of Erectile Function (IIEF) questionnaire, while corpus cavernosum electromyography recorded spontaneous smooth muscle activity. Statistical analysis included paired *t*-tests and Spearman's correlations. **Results.** Postoperative IIEF scores declined significantly in both groups (nerve-sparing: 22.04 ± 2.10 to 17.87 ± 3.83, $p < 0.001$; non-nerve-sparing: 21.67 ± 2.64 to 6.42 ± 1.51, $p < 0.001$). Bilateral nerve-sparing preserved superior EF compared to unilateral preservation (19.87 ± 2.80 vs. 14.13 ± 2.42, $p < 0.001$). No significant correlation was found between corpus cavernosum electromyography parameters (amplitude, mean wave, phase reversals) and IIEF scores ($p > 0.05$). **Conclusion.** Nerve-sparing open radical prostatectomy, particularly bilateral techniques, significantly reduces ED severity. However, corpus cavernosum electromyography did not correlate with patient-reported outcomes, suggesting its limited standalone utility in postoperative ED assessment.

Key words:
electromyography; erectile dysfunction; penile erection; prostatectomy; prostatic neoplasms.

Apstrakt

Uvod/Cilj. Erektilna disfunkcija (ED) se povećava sa godinama, a značaj seksualnog zdravlja postao je sve rasprostranjeniji u terapeutskoj praksi. Cilj rada bio je da se proceni korelacija između subjektivnih i objektivnih parametara ED kod bolesnika koji su podvrgnuti otvorenoj radikalnoj prostatektomiji, sa i bez poštede neurovaskularnog snopa, zbog lokalizovanog karcinoma prostate. **Metode.** Prospektivna kontrolisana studija obuhvatila je 50 bolesnika sa dijagnostikovanim karcinomom prostate i normalnom preoperativnom erektilnom funkcijom (EF). Bolesnici su podeljeni u grupu sa poštedom neurovaskularnog snopa (n = 25) i grupu bez poštede neurovaskularnog snopa (n = 25). EF je procenjivana preoperativno i nakon šest meseci korišćenjem upitnika za procenu Internacionalnog indeksa eretkilne funkcije (IIEF), dok je elektromiografija kavernoznih tela registrovala spontanu aktivnost glatkih mišića. Statistička analiza uključivala je upareni *t*-test i Spearmanove korelacije. **Rezultati.** Postoperativni rezultati IIEF su se značajno smanjili u obe grupe (poštedna tehnika: 22,04 ± 2,10 na 17,87 ± 3,83, $p < 0,001$; nepoštedna tehnika: 21,67 ± 2,64 na 6,42 ± 1,51, $p < 0,001$). Bilateralnom poštedom neurovaskularnog snopa očuvana je superiornija EF u poređenju sa unilateralnom tehnikom (19,87 ± 2,80 vs.14,13 ± 2,42, $p < 0,001$). Nije nađena značajna korelacija između parametara elektromiografije kavernoznog tela (amplituda, srednji talas, fazni preokreti) i rezultata IIEF ($p > 0,05$). **Zaključak.** Otvorena radikalna prostatektomija sa poštedom neurovaskularnog snopa, naročito bilateralna tehnika, značajno smanjuje težinu ED. Međutim,

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elektromiografija kavernoznih tela nije korelirala sa ishodima koje su prijavili bolesnici, što ukazuje na njenu ograničenu samostalnu primenljivost u postoperativnoj proceni ED.

Ključne reči:
elektromiografija; erektilna disfunkcija; penis, erekcija; prostatektomija; prostata, neoplazme.

Introduction

Erectile dysfunction (ED) can be defined as an occasional or persistent inability to achieve and sustain a sufficient penile erection for satisfying sexual intercourse. The significance of sexual health, particularly ED, has become more prevalent in therapeutic practice over the past three decades. The prevalence of ED increases with age, affecting 40% of men aged 40 to 70 years and impacting millions of men globally [1, 2]. The cause of ED is multifactorial, involving a complex interaction of vascular, neurological, hormonal, and psychological variables. Moreover, vascular irregularities in the penile blood supply and erectile tissue are significantly linked to cardiovascular disease and its risk factors. A previous meta-analysis revealed ED as an independent predictor of cardiovascular events [3–5]. Vascular variables primarily influence ED at the local level, but neurogenic factors may affect ED at all levels of the nervous system, encompassing local supply *via* the autonomic nervous system, the genital apparatus, and extending to the spinal, supraspinal, and higher cerebral centers [1]. The European Association of Urology Guidelines on Sexual and Reproductive Health recommend redefining the etiology of ED into a binary categorization of primary organic and primary psychogenic, given that most cases are of mixed etiology. Over the past two decades, extensive information has emerged concerning the relationship between several modifiable and unmodifiable risk factors and the pathophysiology of ED. Prevalent etiologies of ED encompass psychological disorders (depression, anxiety, and stress), neurological disorders (stroke, Alzheimer's disease, spinal cord injury), hormonal imbalances, prostate problems [such as radiation and/or surgery for prostate cancer (PCa)], and cardiovascular diseases. Certain medications used for chronic conditions (such as antidepressants, antihistamines, and antihypertensives) or lifestyle factors (including alcohol or substance misuse and obesity) may precipitate ED [6, 7]. Among men, PCa ranks as the second most prevalent solid tumor and the fifth leading cause of cancer-related death. Age, race, familial history, and genetic mutations are recognized non-modifiable risk factors for PCa, but metabolic syndrome, obesity, and smoking are considered potential modifiable risk factors. The largest age-standardized incidence rates are observed in Western and Northern Europe, Australia/New Zealand, South and North America, and Southern Africa [8–11]. Standard treatment modalities for clinically localized PCa include active monitoring/surveillance, radical prostatectomy (RP), radiotherapy, and brachytherapy. As a standard surgical approach for localized prostate cancer, RP involves excision of the entire prostate gland along with adequate adjacent tissue to ensure negative margins [8, 12, 13]. The International Index of Erectile Function (EF)-5 (IIEF-5) questionnaire is a commonly used assessment for evaluating ED of several origins, particularly in patients post-RP. The IIEF has five domains: EF, orgasmic function, sexual desire, intercourse satisfaction, and overall satisfaction [14, 15]. Among the various surgical options for PCa, RP can be conducted using numerous approaches, with open RP (ORP) and laparoscopic RP (LRP) being predominant until the introduction of robot-assisted RP (RARP). Following RP, patients face a considerable risk of postoperative complications, most notably ED. Postoperative ED is a significant problem for patients that can impact quality of life and mental well-being, perhaps affecting the choice to pursue surgical intervention [16, 17]. Corpus cavernosum (CC) electromyography (EMG) – CC-EMG measures the spontaneous electrical activity of cavernous smooth muscles during flaccidity, reflecting integrated sympathetic tone. Unlike invasive needle electrodes, surface electrodes provide reliable recordings without disrupting tissue integrity. CC-EMG potentials diminish during erection, validating their association with cavernous smooth muscle contractility [18].

The aim of this study was to evaluate the correlations between subjective and objective parameters of ED in patients who underwent nerve-sparing vs. non-nerve-sparing ORP, for localized PCa.

Methods

The study was conducted at the Clinic of Urology, University Clinical Center of Vojvodina, Novi Sad, Serbia, between June 2021 and July 2022. The study was approved by the Ethics Committee of the University Clinical Center of Vojvodina (No. 00-02/595, from November 20, 2009) and conducted in accordance with the Declaration of Helsinki. Prior to their acceptance into the study, all patients were required to provide informed consent.

The study's inclusion criteria were as follows: male aged > 40 years; localized PCa [pT1b-T3a, Gleason score ≤ 7, prostate-specific antigen (PSA) < 20 ng/mL]; normal preoperative EF (IIEF-5 score ≥ 17). The study's exclusion criteria were as follows: declining to sign the informed consent form; metastatic PCa; presence of neurological disorders or diabetes mellitus; previous chemotherapy or pelvic radiotherapy; PSA recurrence during follow-up; technical failures in EMG recording.

Patients were divided into two groups: 25 patients undergoing nerve-sparing group (NSG) ORP (either unilateral or bilateral neurovascular bundle preservation) and 25 patients treated with the non-nerve-sparing group (NNSG) technique based on established oncological criteria. All patients underwent diagnostic procedures, including transrectal ultrasound prostate scans and PSA level laboratory findings.

PCa was diagnosed after transrectal ultrasound-guided prostate biopsy. Pelvic computed tomography scan and skeletal scintigraphy were performed to exclude metastatic progression of disease. Each patient underwent ORP, performed by a single surgeon.

Using the IIEF-5 questionnaire administered preoperatively and at six-month postoperative follow-up, EF was clinically evaluated. The questionnaire consists of five questions, each rated on a five-point scale. A maximum of 25 points can be attained, and a score of 21 indicates ED. The severity of ED is classified into four grades: severe (1–7 points), moderate (8–11 points), mild to moderate (12–16 points), and mild (17–21 points) [14].

CC-EMG recordings were performed using the Solar® urodynamic system with Neuro Module (Medical Measurement Systems, Netherlands), following the methodology described by Roaiah et al. [18]. Surface electrodes were placed on the mid-shaft of the penis (over both corpora cavernosa) after standard skin preparation with abrasive gel (NuPrep®, Weaver and Co., USA) and alcohol disinfection to reduce impedance. A reference electrode was positioned on the ipsilateral knee. Recordings were conducted in a quiet, temperature-controlled environment (22–24 °C) with patients in a supine position (30° trunk elevation) to minimize sympathetic arousal artifacts. Each 20-min flaccid-state recording captured spontaneous electrical activity, which was subsequently analyzed for three key parameters: wave amplitude (average, maximal, and minimal values expressed in μV), wave complexity (number of peaks *per* complex and phase reversals or "turns"), and baseline slow-wave activity patterns.

Statistical analysis

Statistical analyses were performed using the SPSS 26.00 software. Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data or median with interquartile range for non-parametric distributions, and normality was assessed using Shapiro-Wilk testing. Group comparisons utilized Student's *t*-test for parametric data and Mann-Whitney *U* test for non-parametric datasets. Paired comparisons employed the Wilcoxon signed-rank test, while associations between parameters were evaluated using Spearman's correlation coefficient (ρ). A two-tailed p-value < 0.05 was considered statistically significant throughout all analyses.

Results

The baseline demographic characteristics of the analyzed patient groups showed no statistically significant variation in age distribution between NSG and NNSG (Table 1). The average age in NSG was 62.59 ± 4.51 years (range: 55–70), whereas in NNSG, it was 62.90 ± 3.10 years (range: 58–67). These findings confirm demographic homogeneity and allow valid comparison of functional outcomes between the groups.

The distribution of preoperative and postoperative Gleason scores between the study groups showed that preoperative analysis showed no significant difference in Gleason score 6 vs. Gleason score 7 distribution between NSG (64% vs. 36%) and NNSG (44% vs. 56%) ($p > 0.05$). Similarly, postoperative Gleason scores revealed no statistically significant differences ($p > 0.05$), confirming oncological comparability across the cohorts (Table 2).

The descriptive parameters of EF evaluation before and after RP in NSG and NNSG showed that the mean value in NSG patients was 22.04 ± 2.10 preoperatively and 17.87 ± 3.83 postoperatively. Both numbers demonstrate maintained EF in all participants. Student's *t*-test revealed a very significant difference in EF evaluation pre- and post-RP in NSG ($t = 5.053$, $p = 0.000$), indicating considerably lower values postoperatively. The mean score among NNSG patients was

Table 1

Baseline demographic characteristics of the study groups

Age	Group		*p*-value
	nerve-sparing	non-nerve-sparing	
Years (mean ± SD)	62.59 ± 4.51	62.90 ± 3.10	> 0.05
Range (min–max)	55–70	58–67	–

SD – standard deviation; min – minimum; max – maximum.

Table 2

Preoperative and postoperative Gleason score distribution in nerve-sparing and non-nerve-sparing groups

Gleason score category	Group (n = 25)		*p*-value
	nerve-sparing	non-nerve-sparing	
Preoperative			
Gleason score 6	16 (64)	11 (44)	> 0.05
Gleason score 7	9 (36)	14 (56)	
Postoperative			
Gleason score 6	14 (56)	13 (52)	> 0.05
Gleason score 7	11 (44)	12 (48)	
Total	25 (100)	25 (100)	–

All values are given as numbers (percentages)
n – number.

21.67 ± 2.64 prior to the procedure and 6.42 ± 1.51 after the intervention, therefore substantiating the incidence of ED in NNSG patients pre-RP. Student's *t*-test for dependent samples revealed a very significant difference in EF evaluation before and after RP in NNSG (t = 14.488, p = 0.000), indicating considerably lower values post-intervention (Table 3).

The non-parametric correlation coefficients (Spearman's correlation coefficient ρ, significance level p) between the evaluation of EF values (IIEF-5 score) and the observed CC-EMG characteristics (amplitude, mean wave, turn) pre- and post-RP in the cohort of NSG patients showed that no significant correlation was identified among the observed parameters (Table 4).

The preoperative EF (IIEF-5) scores in NSG did not exhibit a significant difference between the unilateral and bilateral subgroups (p = 0.459). A statistical analysis of the average score post-surgery revealed a significant difference among the patient subgroups (t = 4.897, p = 0.000), with notably elevated values in the cohort with bilateral sparing (Table 5). A comparison of postoperative scores to preoperative values indicated a considerably higher change in the unilateral NSG (Mann-Whitney Z = 3.608, p = 0.000).

No significant difference (p = 0.933) was seen in preoperative ED scores between patients undergoing nerve-sparing procedures (mean = 4.65, median = 5.00, SD = 0.49) and those not undergoing nerve-sparing procedures (mean = 4.67, median = 5.00, SD = 0.49). The postoperative ED score values indicate a statistically significant difference (Mann-Whitney Z = 4.829, p = 0.000) between NSG (mean = 3.96, median = 4.00, SD = 0.93) and NNSG patients (mean = 1.33, median = 1.00, SD = 0.49).

Figure 1 displays the mean score values [95% confidence interval (CI)] post-surgery for both NSG and NNSG patients.

Figure 2 presents the ED score values alongside the 95% CI pre- and post-RP in NSG patients.

Table 3

Assessment of erectile function (IIEF-5 score) pre- and post-radical prostatectomy in the nerve-sparing and non-nerve-sparing groups

Groups	Mean ± SD	Median (Min–Max)
Nerve-sparing		
preoperative	22.04 ± 2.10	22 (17–25)
postoperative	17.87 ± 3.83	17 (11–23)
Non-nerve-sparing		
preoperative	21.67 ± 2.64	22 (17–25)
postoperative	6.42 ± 1.51	6 (5–9)

IIEF – International Index of Erectile Function; SD – standard deviation; Min – minimum; Max – maximum.

Table 4

Correlation between IIEF-5 questionnaire and CC-EMG findings, pre- and post-radical prostatectomy, in the nerve-sparing group of patients

Characteristics of CC-EMG	IIEF-5 score			
	preoperative		postoperative	
	Spearman's ρ	*p*-value	Spearman's ρ	*p*-value
Average amplitude	0.024	0.913	0.027	0.904
Maximal amplitude	-0.164	0.455	0.057	0.795
Mean wave	0.090	0.683	0.081	0.713
Turn (phase reversals)	-0.055	0.804	0.223	0.306

IIEF – International Index of Erectile Function; CC-EMG – corpus cavernosum electromyography.

Table 5

Assessment of erectile function (IIEF-5 score) pre- and post-radical prostatectomy, in unilateral and bilateral subgroups of the nerve-sparing group patients

Subgroups	IIEF-5 score			
	preoperative		postoperative	
	mean ± SD	median (min–max)	mean ± SD	median (min–max)
Unilateral	22.50 ± 1.41	22 (21–25)	14.13 ± 2.42	14 (11–17)
Bilateral	21.80 ± 2.40	22 (17–25)	19.87 ± 2.80	22 (16–23)
Total	22.04 ± 2.10	22 (17–25)	17.87 ± 3.83	22 (11–23)

IIEF – International Index of Erectile Function; SD – standard deviation; min – minimum; max – maximum.

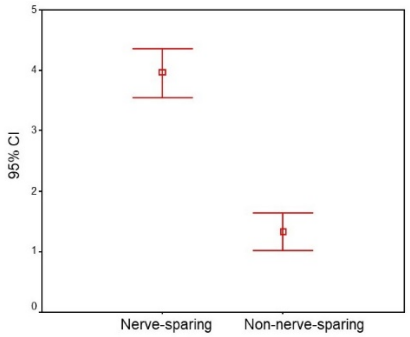

Fig. 1 – Assessment of erectile function (ED score) post radical prostatectomy in nerve-sparing vs. non-nerve-sparing groups. ED – erectile dysfunction; CI – confidence interval.

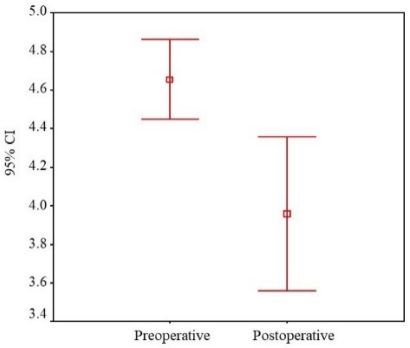

Fig. 2 – Assessment of erectile function (ED score) pre- and post-radical prostatectomy in the nerve-sparing group. For abbreviations, see Figure 1.

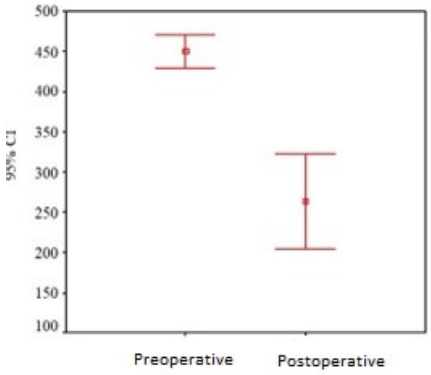

Fig. 3 – Electromyographic parameters of corpus cavernosum function (average amplitude) pre- and post-radical prostatectomy in the non-nerve-sparing group. For abbreviations, see Figure 1.

Figure 3 illustrates the mean amplitude values together with the 95% CI for NNSG patients, both pre- and post-surgery.

Discussion

The objective of RP is to entirely excise the tumor while minimizing surgical morbidity, such as urine incontinence and reduced sexual function. RP is the gold standard therapy for localized PCa and produces excellent oncological results. Systematic reviews indicate that RARP is superior to LRP in decreasing ED, yet comparable to ORP. However, some studies have found no difference in ED outcomes between the two surgical methods. Urologists frequently assert that the surgeon's expertise is more critical than the surgical technique employed in RP regarding functional results, particularly EF [12, 13, 17, 19]. In our institution, both ORP and LRP are routinely performed; however, ORP was selected for this study based on the surgeon's preference.

This prospective controlled study evaluated the effect of RP, with or without neurovascular bundle preservation, on postoperative EF in patients with localized PCa. Employing

both subjective (IIEF-5 questionnaire) and objective (CC-EMG) evaluation methodologies, we wanted to clarify the processes behind post-prostatectomy ED and the prospective protective function of nerve-sparing surgical approaches. The findings provide valuable insights into the functional outcomes associated with different surgical approaches while highlighting the potential role of electrophysiological testing in postoperative evaluation.

Our data show that ED is a common and substantial outcome of RP. The NSG cohort had a statistically significant reduction in EF at six months postoperatively; however, it retained scores predominantly within the "mild" dysfunction range. In contrast, individuals in the NNSG cohort had a significant decline in EF, with the majority transitioning into the "severe" ED category. The dorsal penile nerve plays a dual role in EF through both sensory innervation and autonomic connections with cavernous nerves. Its anatomical proximity to the prostatic apex makes it susceptible to surgical injury during RP, potentially contributing to postoperative ED through combined sensory and neurovascular mechanisms. This vulnerability may explain functional outcomes even in nerve-sparing procedures [20].

No significant preoperative variation in IIEF-5 scores was seen within groups, indicating comparable baseline EF. This highlights that the postoperative decrease is mostly due to the surgical method, rather than inherent functional disparities. Moreover, subgroup analysis indicated that bilateral NSG was markedly more effective than unilateral preservation in maintaining EF, underscoring the need for whole neurovascular preservation when possible. In our study, EMG analysis of corpus cavernosum function did not reveal any statistically significant correlation with subjective EF (IIEF-5), either preoperatively or postoperatively. The role of CC-EMG in evaluating EF post-RP remains incompletely defined. Although previous work by Roaiah et al. [18] suggested that EMG could provide insight into the functional status of smooth muscle tissue within the corpora cavernosa, our data suggest limited clinical utility in this context, particularly when evaluated in isolation. Several factors may explain this lack of correlation. First, the flaccid-state CC-EMG recordings may be less sensitive to subtle functional changes. Second, the neurogenic component of EF, though important, may be overwhelmed by vascular or psychogenic elements post-surgery. These findings align with the comprehensive review of Kyriazis et al. [21], which demonstrated that bilateral nerve-sparing techniques, particularly intrafascial approaches, optimize EF preservation. The observed functional decline even in nerve-sparing cases supports the findings of Yildiz et al. [20] regarding dorsal penile nerve vulnerability during apical dissection. This research highlights the necessity for athermal techniques and accurate nerve mapping to reduce neuropraxia while ensuring oncological safety [18–23].

This study confirms that bilateral nerve-sparing techniques better preserve EF post-prostatectomy, with outcomes aligning with established evidence. Younger patients (< 60 years) with good preoperative function showed superior recovery, while CC-EMG parameters lacked correlation with subjective outcomes, suggesting limited clinical utility. In the study of Prabhu et al. [24], long-term data indicate functional decline, particularly in older patients, underscoring the need for individualized preoperative counseling. Postoperative EF recovery is a protracted process, often requiring years rather than months. While nerve-sparing approaches, particularly bilateral preservation, correlate with better outcomes, even optimal techniques cannot guarantee immediate functional restoration [25, 26].

This study's limitations include a reduced sample size, shortened follow-up duration, and the omission of additional influential factors, including body mass index, smoking status, and prior psychiatric comorbidities. Although a six-month follow-up provides valuable insights into the early postoperative recovery of EF, long-term evaluation (12–24 months) would offer a more comprehensive picture and should be considered in future studies. Despite these constraints, our findings further endorse the application of nerve-sparing methodologies in PCa surgery, which is clinically justified. Furthermore, they propose that although EMG may possess theoretical significance in evaluating cavernous nerve or smooth muscle function, its clinical applicability remains unclear without a more robust link to subjective or functional results.

Conclusion

This study suggests that nerve-sparing methods, especially bilateral preservation, substantially enhance the recovery of erectile function following radical prostatectomy. Although corpus cavernosum electromyography provided objective electrophysiological data, its association with patient-reported IIEF-5 scores proved limited, suggesting that these methods are complementary rather than interchangeable in post-surgical evaluation. These findings underscore the importance of surgical precision in preserving neurovascular bundles, while highlighting the need for further research to improve functional assessment methods. The observed discrepancy between expected and obtained corpus cavernosum electromyography findings may partly reflect the limited number of patients in each subgroup.

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