



# Comparison of ultrasound-guided pulsed radiofrequency versus steroid injection in the treatment of carpal tunnel syndrome

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## Abstract

**Background** Carpal tunnel syndrome (CTS) is the most widespread form of nerve entrapment neuropathy results from increase compression pressure of the median nerve at the wrist under the transverse carpal ligament.

**Aims** To compare ultrasound (US)-guided median nerve steroid injection and pulsed radiofrequency (PRF) on pain intensity, functional status, and patient satisfaction in the treatment of CTS.

**Methods** A total of 90 hands of 59 patients who underwent steroid injection at the level of proximal carpal tunnel or PRF for CTS were retrospectively analyzed. Demographic and clinical characteristics of the patients were recorded. The pain severity was assessed using the Numerical Rating Scale (NRS), and the functional status and clinical outcomes were assessed using the Boston Carpal Tunnel Questionnaire (BCTQ) before the procedure and at Week 1, Month 1, and Month 3 after the procedure. Time to pain relief was evaluated at week 1. Patient satisfaction was evaluated at Month 3.

**Results** There was no significant difference in the NRS and BCTQ scores between the two treatment methods ( $p > 0.05$  for both). In addition, a significant decrease in the NRS and BCTQ scores were detected at all follow-ups compared to baseline in treatment groups ( $p < 0.001$ ). The mean time to pain relief was significantly shorter in the PRF group ( $p < 0.001$ ). Patient satisfaction was similar at Month 3 between the treatment methods ( $p > 0.05$ ).

**Conclusions** Our study results suggest that both US-guided steroid injection to the median nerve and PRF are effective and safe methods in the short-term in the treatment of CTS.

**Keywords** Carpal tunnel syndrome · Corticosteroid injection · Median nerve · Pulsed radiofrequency · Ultrasound-guided injection

## Introduction

Carpal tunnel syndrome (CTS) is the most widespread form of nerve entrapment neuropathy results from increase compression pressure of the median nerve at the wrist under the transverse carpal ligament [1, 2]. It accounts for approximately 90% of all entrapment neuropathies [3]. Its prevalence ranges from 2.7 to 5.8% in the adult population with a lifetime incidence of about 10% [4]. It is characterized by clinical signs and symptoms, paresthesia, numbness, tingling in the median nerve sensory distribution, and thenar atrophy [3]. These symptoms usually become worse at night or in the morning [5]. The diagnosis of CTS is made using patient history, clinical signs, and electrophysiological study findings [6].

Treatment of CTS includes analgesics, physical therapy modalities, splints, steroid injections, and surgery [7]. Local corticosteroid injection is a simple and effective method

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which is commonly used in daily practice with satisfactory short- and mid-term outcomes [4, 8, 9]. Several studies have shown that steroid injection under the guidance of ultrasound (US) is associated with a higher efficacy rate [10, 11]. There is an increasing number of evidence suggesting that steroid injection is a favorable alternative to surgery and that it can be used as a bridging therapy until surgery [12]. However, potential side effects of steroid injection limit its use in the clinical practice, and alternative methods have been sought in the treatment of CTS [13].

Pulsed radiofrequency (PRF) delivers electric bursts to the target nerve and/or tissue by preserving the adjacent structures and using a temperature not exceeding 42 °C at the tip of the electrode [14]. In recent years, the use of PRF has been increasingly adopted in the treatment of peripheral neuropathic pain [13]. However, there is a limited number of data regarding the PRF application to the median nerve in CTS. In a recent single-blind, randomized-controlled study, US-guided PRF in addition to night splint and night splint alone was compared and US-guided PRF yielded more favorable outcomes for pain relief in CTS patients [6].

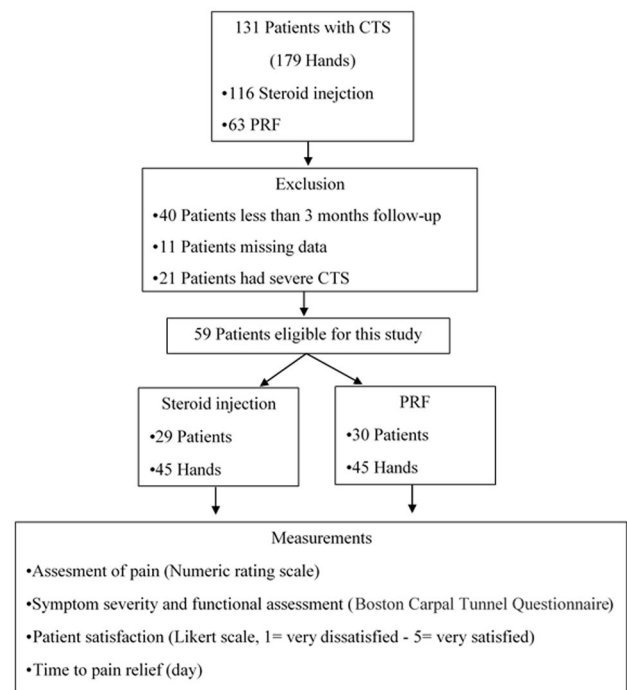
To the best of our knowledge, there is no study comparing steroid injection to US-guided PRF in patients with CTS in the literature. In the present study, we, for the first time, aimed to compare the treatment efficacy of US-guided median nerve steroid injection and PRF in the treatment of CTS.

## Materials and methods

### Study design and study population

This single-center, retrospective study was conducted at the department of pain medicine of a tertiary care center between January 2018 and January 2020. A total of 131 patients (179 hands) who were diagnosed with CTS based on clinical symptoms, physical examination, and electrophysiological study findings and underwent US-guided corticosteroid + local anesthetic injection at a standard dose or PRF to the median nerve were screened. A total of 59 patients who fulfilled the inclusion criteria were included in the study (Fig. 1).

Inclusion criteria were as follows: age 18–65 years, presence of paresthesia and pain in median nerve distribution, severity of pain based on Numerical Rating Scale (NRS)  $\geq 4$ , persistent symptoms for 3 months or longer, mild to moderate CTS confirmed by nerve conduction study, and having complete follow-up data for 3 months. Exclusion criteria were as follows: having severe CTS, previous CTS surgery, and having steroid injection or PRF to the median nerve two or more.



**Fig. 1** Flow diagram of the study

The presence of CTS was evaluated using nerve conduction studies, and classification was made based on the American Academy of Neurology Summary Statement [15]. Accordingly, (i) mild CTS was defined as the presence of prolonged median distal sensory latency (DSL) ( $> 3.5$  ms) and normal median distal motor latency (DML), (ii) moderate CTS as prolonged DSL and DML ( $> 4.2$  ms), and (iii) severe CTS as the absence of median sensory nerve action potential or absent compound muscle action potentials.

For all procedures, a written informed consent was obtained from all patients. The study protocol was approved by the institutional Ethics Committee (No: 2021/106). The study was conducted in accordance with the principles of the Declaration of Helsinki.

### Data collection and assessment

Demographic and clinical characteristics of the patients including age, sex, body mass index (BMI), symptom duration, symptom severity, affected side, and dominant hand and procedural data and treatment outcomes were retrieved from the hospital database. The pain severity was assessed using the NRS (0 to 10, verbal), and the symptom severity and functional status were assessed using the Boston Carpal Tunnel Questionnaire (BCTQ) before the procedure and at Week 1, Month 1, and Month 3 after the procedure. The BCTQ is a self-assessment tool which contains two subscales: Symptom Severity Scale (SSS) and Functional Status Scale (FSS) [16].

Both subscales have a total of 19 items including 11 in the SSS and 8 in the FSS. Each subscale is scored on a 5-point Likert scale from 1 (no or mild symptoms/best functional capacity) to 5 (severe symptoms/the worst functional capacity). Higher scores indicate more severe symptoms or poor functional capacity. Patient satisfaction was evaluated using a 5-point Likert scale (1 = very dissatisfied, 5 = very satisfied) at three months. Time to pain relief was obtained from the follow-up forms of the patients. It was defined as the day when the NRS score decreased by 40% or more relative to the pre-procedure NRS score and it was evaluated at week 1.

In addition, procedure-related complications such as bleeding, ulnar artery, ulnar nerve or median nerve injury, transient pain over the median nerve due to the compression caused by the injection fluid, and increased paresthesia and postoperative complications such as steroid-induced skin lesions and infection at the injection site were noted.

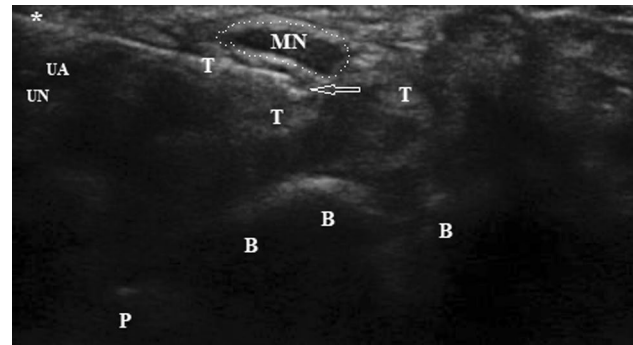
In our clinic, the same treatment algorithm is applied to both hands of patients who are diagnosed with bilateral CTS and scheduled for steroid injection or PRF. In addition, NRS pain scores, BCTQ scores, and patient satisfaction are separately assessed for each hand and documented.

### Treatment protocol

The patient was placed in the sitting position with the forearm supinated and wrist slightly flexed (dorsal flexion). Both treatment methods were performed under the sterile conditions. The skin was cleaned with povidone-iodine, and the US probe was covered with a sterile drape. Both treatment methods were carried out by a single physician under the guidance of US (Esaote 10–18 MHz linear probe, MyLab 30 Gold, Italy) via in-plane technique to the median nerve using an ulnar approach at the level of proximal carpal tunnel [17].

During the procedure, the transducer was inserted to the proximal carpal tunnel via the transverse route. The median nerve was detected beneath the pisiform, ulnar artery, ulnar nerve, flexor tendons, and flexor retinaculum (Fig. 2). The needle was placed parallel to the transducer using the in-plane technique from the ulnar side in both treatment methods. The median nerve was reached through the ulnar artery and ulnar nerve. After bleeding control for steroid injection, a mixture containing dexamethasone 8 mg and 0.5 cc of bupivacaine 0.5% was injected under the median nerve. The median nerve was separated from the underlying structures by hydrodissection during the injection (Fig. 2).

PRF was performed with a NeuroTherm NT1000 (NeuroTherm, Inc., Middleton, MA, USA) radiofrequency generator. The median nerve was visualized using the transverse view of the proximal carpal tunnel through US, as described above. A 22-gauge, 50-mm radiofrequency cannula with a 5-mm active tip was advanced through the in-plane technique, and the median nerve was reached advancing



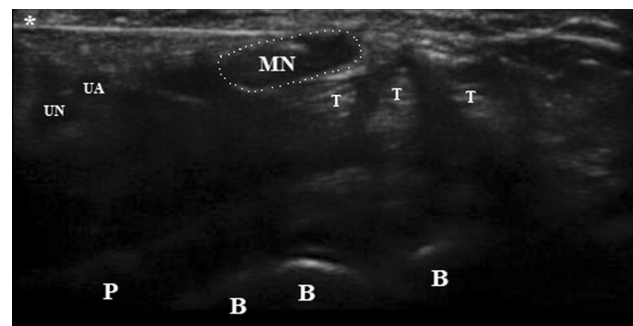
**Fig. 2** Ultrasound-guided median nerve steroid injection via in-plane technique. Final position of the needle deep to the median nerve. MN: median nerve, UA: ulnar artery, UN: ulnar nerve, T: flexor tendons, P: pisiform, B: carpal bones, Asterisk: needle, white arrow: injection fluid

through the ulnar nerve and ulnar artery. The cannula was placed very proximate to the superior of the median nerve (Fig. 3). After positioning the cannula, sensory and motor tests were performed. Using selective stimulation of sensory fibers (50 Hz) below 0.5 V, paresthesia occurred in the distal first four fingers, as confirmed by the patient. During motor stimulation, contraction of the thenar muscles was observed at below 1 V. After the sensory and motor stimulation, the PRF cycles were applied for 120 s with a pulse frequency of 2 Hz and pulse width of 20 ms at 42 °C [6].

All patients were recommended using a wrist splint for 3 months after the procedure. The patients were discharged after no complications were observed in the first hour after the treatment.

### Statistical analysis

Descriptive values of the data obtained were calculated as mean, standard deviation (SD), median (25th and 75th



**Fig. 3** Ultrasound-guided median nerve pulsed radiofrequency treatment via in-plane technique. Final position of the radiofrequency needle superior to the median nerve. MN: median nerve, UA: ulnar artery, UN: ulnar nerve, T: flexor tendons, P: pisiform, B: carpal bones, Asterisk: needle

quartiles), and mean rank. The differences between two treatment groups (steroid and pulse rf) and the between four periods, and also group X period interaction effects in terms of NRS, SSS, and FDS were evaluated by using F1-LD-F1 design and adjustment pairwise comparisons. The F1-LD-F1 is non-parametric factorial design and takes different names according to different number of factors. The first “F1” is called the between-subjects factor and shows the difference between the treatments applied (treatment effect). The second “F1” is called the within-subjects factor and, in this study, it refers to the difference between the periods. This model also contains interaction effect (treatment X period).

The relationships between the categorical variables were examined with the Pearson chi-square analysis. Independent samples *t*-test was used to compare the two groups in terms of mean symptom duration and in terms of the average day the pain began to subside. The Mann–Whitney *U*-test was used to compare the two groups in terms of patient satisfaction. All analyses were performed in R (v.4.1.1) and “nparLD” library used for non-parametric repeated F1-LD-F1 designs. A *p* value of <0.05 was considered statistically significant.

## Results

Of a total of 90 hands of 59 patients (54 females and 5 males) were included in the study. Twenty-nine patients (45 hands) were included in the steroid injection group, while 30

patients (45 hands) were included in the PRF group (Fig. 1). The mean age was 49.17 ( $\pm 8.97$ ) years in the steroid injection group and 47.97 ( $\pm 9.48$ ) years in the PRF group ( $p > 0.05$ ). The mean symptom duration was 10.02 ( $\pm 5.99$ ) months in the steroid injection group and 9.11 ( $\pm 5.70$ ) months in the PRF group ( $p > 0.05$ ). Demographic and clinical characteristics of the patients were similar between the groups (Table 1).

There was no significant difference in the NRS and BCTQ (SSS, FSS) between the treatment groups at different time points. Similarly, there was no significant difference in the size and direction of the measurements at all time points, indicating no significant interaction between the treatment and time points for all scales ( $p > 0.05$  for all) (Table 2).

Irrespective of the treatment applied, there was a significant decrease in the NRS, SSS, and FSS scores at all time points ( $p < 0.001$ ) (Table 2). These results were available for both treatment groups, as there was no significant interaction between the treatment and time points.

Patient satisfaction was similar at three months between the treatment methods ( $p > 0.05$ ) (Table 3). The mean time to pain relief was significantly shorter in the PRF group ( $1.41 \pm 0.62$ ) than the steroid injection group ( $2.56 \pm 1.14$ ) ( $p < 0.001$ ) (Table 3).

None of the patients experienced procedure-related complications. Although three patients in the steroid injection group had fullness at the thenar side of the hand and distal fingers due to compression of the injection agent, this complication was transient and resolved spontaneously within 1 h.

**Table 1** Distribution of demographic and clinical parameters

		Treatment method				<i>P</i>
		Steroid		PRF		
		<i>n</i>	%	<i>n</i>	%	
Sex	Female	26	89.7	28	93.3	0.612
	Male	3	10.3	2	6.7	
Age (years)		49.17	8.97	47.97	9.48	0.618
BMI (kg/m <sup>2</sup> )		29.12	3.56	29.05	3.65	0.943
Duration of symptoms (months)		10.02	5.99	9.11	5.70	0.513
NRS (pre-procedure)		7	(5–8)	7	(5–8)	0.703
Dominant hand	Right	27	93.1	26	86.7	0.671
	Left	2	6.9	4	13.3	
Is the dominant hand affected?	Affected	26	89.7	27	90.0	0.999
	Not affected	3	10.3	3	10.0	
Involved side	Bilateral	16	55.2	15	50.0	0.691
	Unilateral	13	44.8	15	50.0	
CTS severity	Mild	22	48.9	27	60	0.290
	Moderate	23	51.1	18	40	
	Total hands	45	100	45	100	

BMI body mass index, NRS Numerical Rating Scale, CTS carpal tunnel syndrome

**Table 2** Comparison of NRS, SSS, and FSS scores between treatment methods

	<i>n</i> = 45	Treatment	Mean	SD	Percentiles			Rank means	Wald-type statistic (WTS)		
					25th	Median	75th		<i>P</i> <sub>grup</sub>	<i>P</i> <sub>time</sub>	<i>P</i> <sub>int</sub>
NRS	Pre-procedure	Steroid	6.80	1.85	5	7	8	299.01	0.250	<b>0.001</b>	0.200
		PRF	6.67	1.69	5	7	8	297.58			
	Week 1	Steroid	1.73	1.79	1	1	2	106.02			
		PRF	2.18	1.63	1	2	3	132.15			
	Month 1	Steroid	2.27	2.06	1	2	3	131.43			
		PRF	2.78	2.02	1	2	4	155.9			
Month 3	Steroid	2.76	2.18	1	2	4	154.21				
	PRF	3.02	2.04	1	3	4.5	167.68				
SSS	Pre-procedure	Steroid	28.33	7.7	22	27	33.5	280.16	0.82	<b>0.001</b>	0.481
		PRF	28.44	8.45	21	28	34	278.34			
	Week 1	Steroid	15.6	6.63	12	14	16.5	127.83			
		PRF	15.56	7.01	11	14	17	122.33			
	Month 1	Steroid	16.87	7.72	12	14	18	145.28			
		PRF	18.62	9.63	11.5	15	21	158.78			
Month 3	Steroid	17.82	7.87	13	15	20	161.54				
	PRF	19.31	9.57	12.5	17	22	169.73				
FSS	Pre-procedure	Steroid	21.22	7.73	15	19	27	267.28	0.856	<b>0.001</b>	0.611
		PRF	21.2	8.74	15	18	30	260.42			
	Week 1	Steroid	12.56	6.06	8	11	14.5	143.31			
		PRF	12.64	6.63	8	11	13	139.37			
	Month 1	Steroid	13.29	7.07	8	12	15.5	151.62			
		PRF	13.67	7.64	8	11	14	154.04			
Month 3	Steroid	13.82	6.89	9	12	16	166.26				
	PRF	14.07	7.76	9	11	14	161.7				

NRS Numerical Rating Scale, SSS Symptom Severity Scale, FSS Functional Status Scale, SD standard deviation

### Discussion

In our study, we compared the treatment efficacy of US-guided median nerve steroid injection and PRF in the treatment of CTS. Our study showed that both methods yielded a significant improvement in the NRS and BCTQ scores at all follow-ups compared to baseline. At 3 months of the treatment, the NRS pain scores and BCTQ scores were similar

between the groups. In addition, patient satisfaction levels at the third month of follow-up were similar in both treatment methods. The mean time to pain relief was significantly shorter in the PRF group.

Steroid injection to the median nerve has been proven to be effective in CTS in the short term [4, 8, 9, 18–20]. In a double-blind, randomized-controlled study, Hsu et al. compared the effect of US-guided steroid injections (10 mg or 40 mg triamcinolone acetate) in mild to moderate CTS patients [18]. They observed a significant and similar improvement in the pain and BCTQ scores at 12 weeks in both groups. In another double-blind, randomized-controlled study, Karimzadeh et al. compared the efficacy and safety of two local corticosteroid injections (triamcinolone versus methylprednisolone) at two different doses (20 versus 40 mg) in mild to moderate CTS patients [19]. The authors reported a significant and similar improvement in the pain scores at three months in both groups. Moghtaderi et al. applied 4 mg dexamethasone injection to the median nerve of 20 pregnant women with carpal tunnel syndrome [21]. They reported significant improvement in pain and electrophysiological

**Table 3** Comparison of the time to pain relief and patient satisfaction between the groups

	Treatment method				<i>P</i>
	Steroid		PRF		
	Mean	SD	Mean	SD	
Time to pain relief (post-procedural) (day)	2.56	1.14	1.41	0.62	<b>0.001</b>
Patient satisfaction (at three month)	4.38	0.91	4.02	1.18	0.164



findings at 3-week follow-up. In the literature, it is observed that injection of different steroids at different doses is effective in CTS [18, 19]. Similarly, in our study, the NRS pain and BCTQ scores were significantly decreased at 3 months in the steroid injection group, consistent with the literature.

Although the exact mechanism of steroid injection in CTS has not been fully elucidated yet, it theoretically exerts its potent anti-inflammatory effects by decreasing inflammation and edema in the nerves and tendons, improving the spatial relationship between the carpal tunnel and median nerve and tendons, and reducing the intracarpal pressure [7, 9, 22]. In addition, steroids combined with local anesthetics contribute to the pain relief through its anti-inflammatory effects [23]. In the current study, the mean time to pain relief was significantly longer in the steroid injection group than the PRF group that can be attributed to the late onset of the anti-inflammatory effects of the steroid injection.

Recurrent exacerbations of symptoms are commonly encountered in CTS patients and treatment usually requires multiple injections. Corticosteroids can temporarily relieve painful symptoms in these patients; however, there is a concern regarding the possible side effects of these agents [18]. The most common side effects of corticosteroid injections include skin depigmentation and atrophy, disturbance in menstruation, flushing, transient hyperglycemia, and chronic granulomatous inflammatory reactions [18, 24]. Due to the possible side effects of steroids, new treatment modalities are needed in patients with CTS [13].

Several studies have demonstrated that PRF is an effective, safe, non-destructive, and reproducible alternative with long-term outcomes in painful conditions [6]. However, data regarding the PRF application to the median nerve in CTS are limited. In a case report, PRF to the wrist was applied to the cubital fossa level, not the carpal tunnel level in a patient with CTS who had persistent complaints and severe pain despite two surgical interventions and a revision surgery [25]. Three cycles of PRF to ventral, dorsal, and medial aspects of the median nerve were performed under the guidance of US over 90 s for each dose. A 70% reduction in pain was achieved during a 12-week follow-up period. In a randomized-controlled study, Chen et al. compared the pain and BCTQ scores in CTS patients receiving a single-dose US-guided PRF (120 s) in addition to night splint (intervention group) and night splint alone (control group) [6]. The authors reported a statistically significant decrease in the pain score and BCTQ scores in all time points in the PRF group compared to the control group. In our study, the PRF was similarly applied to the ventral aspect of the median nerve for 120 s. Although there is a number of studies showing the effectiveness of PRF in painful conditions, the exact mechanism of PRF has not been fully understood yet [26]. Some authors have advocated that PRF exerts its effect through neuromodulation by activating descending

adrenergic and serotonergic pathways and inhibiting the stimulation of nociceptive C fibers [27]. In addition, L5 dorsal root ganglion PRF treatment applied to rats with sciatic nerve injury has been shown to inhibit various proinflammatory cytokines (such as TNF- $\alpha$  and Interleukin-6) [28].

Interventional procedures to the median nerve can be performed using a blind technique or under the guidance of US in CTS. Although these procedures are safe and well-tolerated, tendon rupture, arterial occlusion, and median nerve injury can be rarely seen in injections through the blind technique [12, 29]. In recent years, US-guided steroid injections have been increasingly used owing to high accuracy and low median nerve injury rates [6]. Additionally, US allows an accurate visualization of the delivery of the injection agent with less or no discomfort for the patient [11]. Recent studies have demonstrated that steroid injections to the median nerve under the US guidance yield a higher rate of effectiveness [10, 11, 30]. In our clinical practice, steroid injections to the median nerve and PRF are performed under the guidance of US in the treatment of CTS. In our study, none of the patients experienced any serious complications. This can be attributed to the accurate visualization of the median nerve and adjacent structures through US. In the present study, three patients in the steroid injection group had fullness at the injection site which can be due to the transient compression on the median nerve via the injection agent.

There are some limitations of this study. The most important limitation is the retrospective design. Other limitations are small sample size and short-term follow-up. Nevertheless, this study is the first to compare the US-guided steroid injection and PRF in CTS patients and is valuable, as it provides additional information to the body of knowledge on this topic in the literature.

In conclusion, both US-guided steroid injection to the median nerve and PRF are effective and safe methods in the short-term in the treatment of CTS. Considering the side effects of steroid injection, PRF can be an important alternative. However, further prospective, randomized-controlled studies with long-term follow-up are needed to gain a better understanding of the effects of PRF in the long-term.

**Author contribution** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Alp Eren Çelenlioğlu, Hanzade Aybüke Ünal Artık, and Gülen Güler. The manuscript was written by Alp Eren Çelenlioğlu. All authors read and approved the final manuscript.

## Declarations

**Conflict of interest** The authors declare no competing interests.

**Research involving human participants and/or animals** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research

committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed consent** Written informed consent was obtained from all patients.

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