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A Retrospective Comparison of Computed Tomography and Fluoroscopic Guided Percutaneous Nephrostomy for Evaluating Radiation Exposure

Bilgisayarlı Tomografi ve Floroskopi Kılavuzluğunda Perkütan Nefrostomi İşlemlerindeki Radyasyon Maruziyeti İçin Bir Retrospektif Kıyaslama

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ABSTRACT

Aim: The study aimed to compare the radiation doses absorbed by the patient in first-time percutaneous nephrostomy under computed tomography (CT) and nephrostomy replacement under fluoroscopy.

Material and Methods: Eighty-nine hydronephrotic patients referred for nephrostomy were included in this retrospective study. Seventy-five of these patients had the nephrostomy for the first-time under CT-guidance. Fourteen patients had the nephrostomy replacement operation under fluoroscopy guidance. Absorbed radiation doses were compared between these operations.

Results: The groups showed no statistically significant differences in means of demography (age, sex, and pathology) and operational parameters (intervention side and complications) except the absorbed radiation dose. The median effective radiation doses were 1.18 mSv and 1.68 mSv for CT and fluoroscopy, respectively. The first-time nephrostomy operations under CT were completed with radiation doses significantly lower than those in nephrostomy replacement under fluoroscopy ($p < 0.001$).

Conclusion: Ultra-low-dose and fast-acting CT-guided nephrostomy is a safe, user-friendly procedure that leads patients to less radiation exposure than expected.

Keywords: Computed tomography, Fluoroscopy, Hydronephrosis, Nephrostomy, Radiation dose

ÖZ

Amaç: Bu çalışmada bilgisayarlı tomografi (BT) eşliğinde gerçekleştirilen ilk perkütan nefrostomi işleminde ve floroskopi eşliğinde gerçekleştirilen nefrostomi değiştirme işleminde hasta tarafından emilen doz miktarının kıyaslanması amaçlanmıştır.

Gereç ve Yöntemler: Bu retrospektif çalışmaya nefrostomi işlemine yönlendirilmiş 89 hidronefroz hasta dahil edilmiştir. Bu hastalardan 75'inde BT eşliğinde ilk defa nefrostomi işlemi gerçekleştirilmiştir. 14 hastada ise floroskopi eşliğinde nefrostomi değiştirme işlemi yapılmıştır. Bu işlemler sırasında emilen doz miktarları kıyaslanmıştır.

Bulgular: Gruplar demografik (yaş, cinsiyet ve pataloji) ve işlem parametreleri (işlem tarafı ve komplikasyonlar) açısından istatistiksel farklılık göstermemiştir. Ancak emilen radyasyon doz miktarı açısından iki grup arasında istatistiksel farklılık gözlemlenmiştir. Ortanca emilen radyasyon dozu BT grubunda 1,18 mSv iken, floroskopi grubunda 1,68 mSv olarak tespit edilmiştir. İlk kez gerçekleştirilen BT eşliğinde nefrostomi işlemleri, floroskopi eşliğinde gerçekleştirilen nefrostomi değiştirme işlemlerine kıyasla istatistiksel olarak anlamlı bir şekilde daha düşük radyasyon dozu ile tamamlanmıştır (p < 0,001).

Sonuç: Ultra-düşük-doz ve hızlı BT eşliğinde nefrostomi güvenli, kullanımı kolay, hastaya beklenenden daha düşük doz uygulayan bir işlemdir.

Anahtar Sözcükler: Bilgisayarlı tomografi, Floroskopi, Hidronefroz, Nefrostomi, Radyasyon dozu

INTRODUCTION

While the success rate of ultrasound-guided percutaneous nephrostomy (PCN) is approximately 84%, the rate of unsuccessful cases is negligible under CT-guidance (1, 2). Meanwhile, fluoroscopy guidance usually is necessary for guidewire introduction, dilatation, and final tube-catheter placement. In this case, not only the patient but also the interventional radiology staff is exposed to the radiation.

Indications for primary nephrostomy placement has declined with the advancement of contemporary endourological techniques. However, PCN indications for more complicated therapeutic interventions that need more precise access, has increased (3). Some of these could be listed as; stone removal, dilatation or stenting of a ureteral stricture, endopyelotomy, foreign body retrieval (e.g., fractured stent), ureteral occlusion for urinary fistula, tumor fulguration, delivery of medications and chemotherapy, and biopsy of a urothelial lesion.

CT guidance gives the convenience of getting detailed images of the PCN zone, and consequently, the procedure can be accomplished safely and easily. Under CT, the PCN procedure can be successfully done even in subjects with a retro-renal colon, ectopic kidney, obesity, or scoliosis (4, 5). PCN under CT can be done with fewer punctures and without any other imaging modalities. Above all, it can be efficiently done in cases with no or insignificant hydronephrosis and variations in the kidneys' anatomy (5, 6).

CT-guided PCN operations also could be finished with acceptable complication rates, procedure technique, and times (4, 6, 7) whereas the interventional radiology staff is not exposed to radiation. The only concern is the radiation exposure of the patient. It has been reported that fluoroscopy-guided operations (lumbar puncture (8) and scoliosis surgery (9)) can be completed with lower exposure doses compared to CT-guided operations. On the other hand, this has not been validated for PCN. Therefore, we compared the exposed radiation doses between CT- and fluoroscopy-guided nephrostomy operations.

MATERIALS and METHODS

Subjects

The main objective was to compare the absorbed radiation doses in nephrostomy tube implantation under CT and nephrostomy tube replacement under fluoroscopy. Nephrostomy cases performed in the interventional radiology unit of Namık Kemal University hospital between May 2017 and November 2019 were screened. Patients in whom a nephrostomy catheter was inserted under CT guidance or patients whose nephrostomy catheter was changed under fluoroscopy guidance were included in the study. A few Ultrasound-guided nephrostomy cases were excluded. Seventy-five of these patients (39 male and 36 female, age: 60.19 ± 11.72 years old) had the nephrostomy procedure for the first time under computed tomography guidance (CT group). Nephrostomy tube changes were performed for the rest (7 male and 7 female, age: 67.00 ± 13.40 years old) under fluoroscopy guidance (Fluoroscopy group). Demographic data were summarized in Table 1. There was no statistically significant difference between the two groups regarding age, gender, and pathology type. All nephrostomies were performed by one board-certified interventional radiologist with 17 years of experience in CT-guided interventions. The study was approved by the institutional Non-Interventional Clinical Research Ethics Committee.

CT-Guided Nephrostomy

A consent form explaining the technique, potential risks, and expected results of the procedure were obtained from all patients in the study group. The international normalized ratio, prothrombin time, partial thromboplastin time, and thrombocyte count were normal or had been corrected adequately before the procedure. The patients were placed on the CT table in a prone position. 160 slice Toshiba CT scanner (Aquilion One; Toshiba, Tochigi Pref., Japan) used. In all cases, contiguous 3-mm thick slices were acquired encompassing the entire target. Images were acquired at the ultra-low-dose setting of the device. The angle of the CT gantry was zero unless a malrotation kidney was identified. Malrotation kidney was observed in only one patient where we provided a +20° angle to the gantry to access the target safely. To specify the entry point, non-enhanced CT imaging was performed. Sedation was not given before or during the operation to ensure complete cooperation of the patient during the procedure. The relative avascular zone at the intersection of the posterior one-third, and the anterior two-thirds of the renal parenchyma, which is known as the Brodel's bloodless line, was selected for the needle transgression. A dilated calyx was preferred to the renal pelvis

Table 1: Demographic Data.

Characteristic	CT Group n = 75 (84.27%)	Fluoro Group n = 14 (15.73%)	*p* value
Mean Age ± Standard Deviation	60.19 ± 11.72	67.00 ± 13.40	0.054[a]
Sex ratio (female/male)	36/39	7/7	0.891[b]
Pathology:			0.738[b]
- Malignancies;			*0.910*[b]
Bladder cancer	27	6	
Prostate cancer	2	1	
Colon cancer	3	1	
Pelvic cancer	2	1	
Cervix cancer	1	0	
Endometrial cancer	1	0	
Rectum cancer	3	0	
- Ureteric stone;			*0.530*[b]
Ureterolithiasis proximal	15	2	
Ureterolithiasis middle	4	0	
Ureterolithiasis distal	6	0	
- External compression;			n/a
Pancreatitis	1	0	
Ureteral ligation	1	0	
- Other;			*0.295*[b]
Ureteropelvic junction stenosis	0	1	
Ureteral rupture	1	0	
Cystitis	7	2	
Unknown	1	0	
Hydronephrosis grade (0-4) (median [0.25 and 0.75 quantiles])	2 [1, 2]	n/a	

[a]Two-sample t-test. [b]χ^2 test. **n/a:** not applicable.

because of fewer vessels and less likely hemorrhagic complications. 20 ml of 2% prilocaine hydrochloride solution (Pricain; Polifarma Pharmaceutical Ind., Tekirdag, Turkey) was injected subcutaneously via a 21 gauge needle. Deeper anesthesia of the perirenal area was accomplished using an 18 G × 15 cm Chiba needle (Vigeo SRL, Bagnolo San Vito, Italy). The calyceal puncture was performed with the 18 G Chiba needle to access the dilated collecting system. With a spontaneous flow of urine through the Chiba needle, it was understood that the needle was in the collecting system. If no urine flow was observed, the needle position was checked with a 15-mm thick control slices and the needle's trajectory was aligned again towards the target. After verifying the location of the Chiba needle at the target, an 82-cm Lunderquist Stainless Steel Guidewire J curve (Argon Medical Device, Frisco, TX, USA) was placed in a safe position at the collecting system. If there was a problem with the advancement of the wire, a control scan was conducted to verify the position within the collecting system. First, a 6 F renal dilator was inserted over the guidewire, and then a straightened 6-8 F pigtail external drainage catheter was placed. The pigtail catheter was anchored with a suture tugging on the catheter to prevent accidental removal. (Figure 1) A 10-12 F catheter was favored if pus was aspirated.

We accomplished all PCN procedures in the CT unit without moving patients to the C-arm fluoroscopy unit. We finally acquired control CT scans following the PCN to affirm the final catheter position in the pelvicalyceal system and to determine any complication. Therefore, it was not necessary to give contrast material and take an antegrade nephrostogram. The dose was taken at this stage, also included in the overall. Postprocedure administration included bed rest for 2 hours and antibiotic treatment if infected urine was identified. Following decompression of the renal collecting system, the nephrostomy catheter was allowed for free drainage and a control nephrostogram was conducted in a week. Nephrostomy catheters can be used as access for following antegrade stent placement.

Fluoroscopy-Guided Nephrostomy Replacement

All procedures were performed in the INNOVA IGS 540 omega angiography suite (GE Healthcare, Chicago, IL, USA) that had only continuous fluoroscopy mode. The patient was instructed and prepared as in CT-guided nephrostomy (see above). S/he was placed on the angiography suite table in a prone position. The distal segment of the pigtail catheter within the collecting system was verified under fluoroscopy by applying 20 ml of 50% contrast

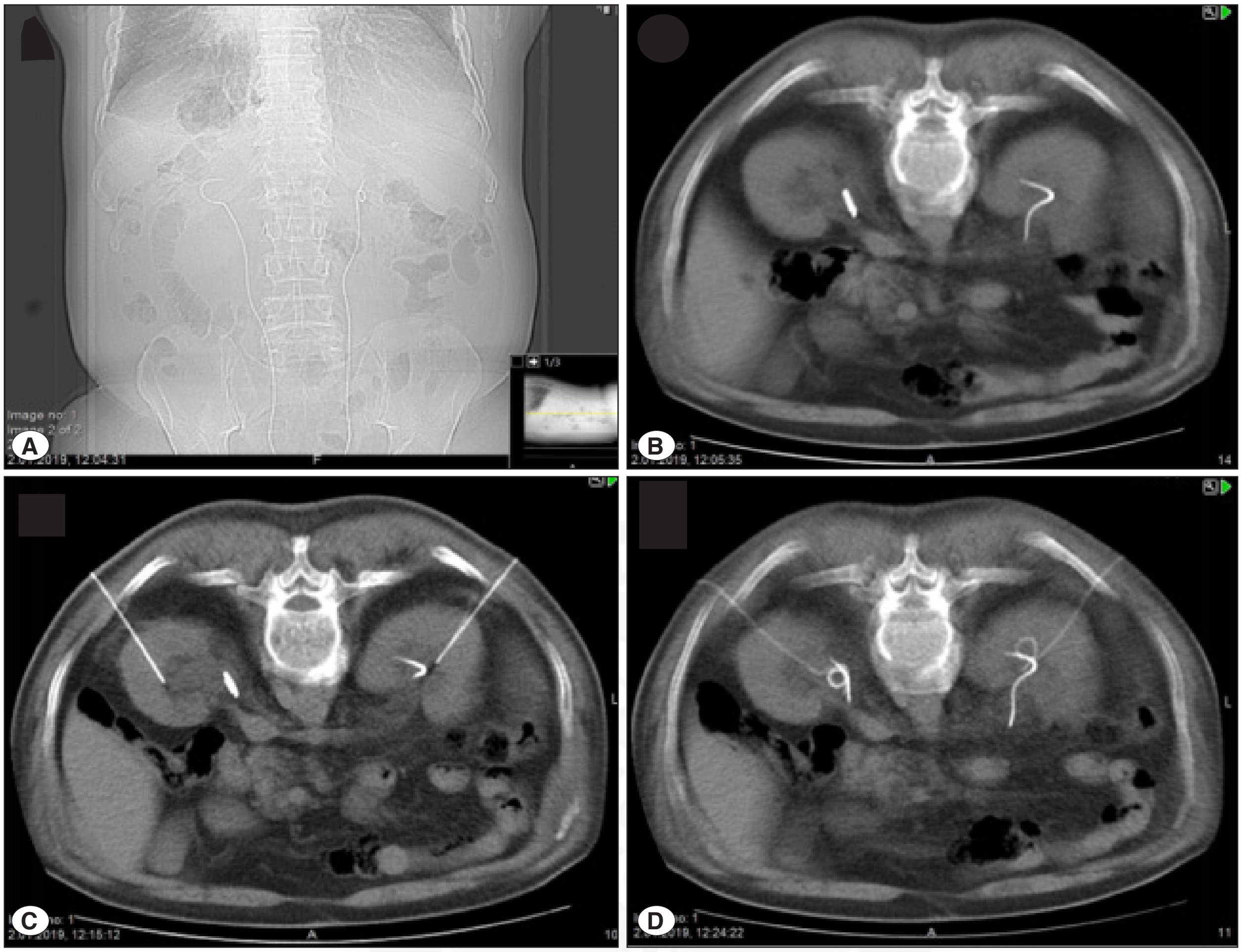

Figure 1: Bilateral percutaneous nephrostomy in a patient with urinary bladder cancer and obstructed bilateral double J stent catheter. **(A)** Scanogram of the patient. **(B)** Axial CT imaging for entry point detection. **(C)** 18-G Chiba needle inside the renal pelvises. **(D)** 6-F pigtail catheters placed in both renal pelvises.

material (OptiRay 350; Guerbet, Istanbul, Turkey) and 50% saline solution through the catheter. Then, the proximal part of the catheter was cut to release the anchoring on the distal part. An 82-cm Lunderquist Stainless Steel Guidewire J curve was advanced through the catheter. After finding a safe position at the collecting system, the catheter was removed out and a new catheter was placed over the guidewire. The rest of the procedure was the same as in a first-time nephrostomy.

Effective Dose Estimation

For the CT-guided PCN, we recorded the CT-dose index volume (CTDIvol) and the dose-length product (DLP). For the fluoroscopy-guided PCN replacement, we recorded the total dose-area product (DAP). We estimated the effective dose by multiplying a normalized coefficient for the abdomen with DLP in CT and with DAP in fluoroscopy (10). The coefficients were 0.015 $mSv.mGy^{-1}.cm^{-1}$ for CT (11) and 0.16 $mSv.Gy^{-1}.cm^{-2}$ for fluoroscopy (12).

Statistics

The distribution of data was tested with the Kolmogorov-Smirnov test after calculating z-scores. The age was normally distributed and tested with two-sample t-test between groups. The absorbed radiation dose had a non-normal distribution and was tested with the non-parametric Mann-Whitney U test. Categorical data (e.g. gender, pathology, intervention side, and complications) were tested with $\chi 2$ test. All statistical tests were performed in MATLAB (2016a; The MathWorks, Natick, MA, USA). The significance level was 0.05. The achieved statistical power for the comparison of radiation dose with a two-tailed Mann-Whitney U test is 0.611 given the effect size of 0.5 (Fluro Group - CT Group = 1.68 - 1.18 = 0.5, see Table 2), α=0.05, group sizes of 91 for CT and 28 for Fluoro (number of operations).

Table 2: Procedure data.

	CT Group (91 operations)	Fluoro Group (28 operations)	*p*
Intervention side in procedure: (Right/Left/Bilateral)	33/29/29	6/11/11	0.343[a]
Procedure duration (minutes) (mean ±standard deviation)	17.20 ± 8.79	8.18 ± 2.93	**<0.001**[b]
Procedure-related complication rate			0.623[a]
- Major	0%	0%	
- Minor;	3%	0%	
Subcapsular hematoma	*3%*	*0%*	
Procedural success rate	100%	100%	
Effective radiation dose (mSv) (median [0.25 and 0.75 quantiles])	1.18 [0.90, 1.82]	1.68 [1.39, 2.52]	**<0.001**[c]

[a]χ^2 test. [c]Two-sample t-test. [c]Mann-Whitney U test.

RESULTS

Nephrostomy Procedures

We studied the data of 75 patients referred for nephrostomy tube implantation under CT guidance and 14 patients referred for nephrostomy tube replacement under fluoroscopy guidance. Operations were summarized in table 2. A total of 91 operations (three times in three patients, two times in 10 patients, and one time in 62 patients) were performed in the CT group where 120 nephrostomy tubes were implanted. Of these procedures, 29 were bilateral and 62 were unilateral. In the fluoroscopy group, 39 tube replacements were performed in 28 operations (five times in one patient, four times in two patients, three times in one patient, two times in two patients, and one time in 8 patients). Of these operations, 11 were bilateral and 17 were unilateral.

The overall success rate in both groups was 100%. There were no significant differences between the two groups regarding the number of interventions per patient (Mann-Whitney U test, $p > 0.05$). Therefore, each operation was analyzed as a separate case.

CT- and fluoroscopy-guided operations showed no significant differences in means of intervention side ($\chi2$ test, p = 0.343) and complications ($\chi2$ test, p = 0.622). In the CT group, only 2 patients showed subtle subcapsular hematoma and one patient showed mild subcapsular hematoma. On the other hand, no complications were observed in the fluoroscopy group. Nephrostomy replacement under fluoroscopy was completed in a shorter time than the first time nephrostomy operations under CT (CT group: 17.20 ± 8.79 minutes, Fluoroscopy group: 8.18 ± 2.93 minutes, p<0.001, two-sample t-test)

Radiation Doses in CT and Fluoroscopy Guided Nephrostomy

The median effective radiation dose was 1.18 mSv in CT-group and 1.68 mSv in the fluoroscopy group (Table 2). CT-guided nephrostomy operations were completed with radiation doses significantly lower than the fluoroscopy-guided nephrostomy operations (Mann-Whitney U test, $p < 0.001$).

DISCUSSION

Previously, PCN was performed under fluoroscopic guidance for access and subsequent manipulation, while CT was used for localization of the target before operation and verification of the results after the operation (6). The operation had the risk of damaging the adjacent tissues due to the poor delineation of the perinephric anatomy in fluoroscopy. Besides, the use of an intravenous contrast medium in the obstructed system increased the intrapelvic pressure and hence the possibility of hemorrhage and sepsis. Finally, the interventional radiology staff and the patient were exposed to a considerable amount of radiation (5,6,13).

Ultrasonography (US) has been a widely accepted alternative over fluoroscopy in PCN placement (14). It is an ideal method during pregnancy and childhood due to its radiation- and contrast-free nature (13). However, it has a lower success rate in non-dilated calyces than CT guidance (13). Additionally, it is inadequate in obese and dysmorphic patients (1).

The advantages of using CT rather than the standard fluoroscopy in nephrostomy are defined for operation conveniences such as better delineation of anatomical structures and higher manipulation success during the operation and lower radiation exposure for the interventional staff (15-17). CT-guided PCN is an alternative with operation convenience, even in obese patients, undilated calyces, and certain anatomic anomalies such as ectopic kidneys, retrorenal colon due to its competence in anatomic delineation without requiring contrast medium (5,18). The interventional radiology staff is not exposed to radiation since s/he is not present in the CT room during a scan. Furthermore, compared to fluoroscopy, CT-guided operations can be completed with lower radiation exposure for the patients as well (8, 9, 19). Our results showed that the effective radiation dose for the patient is reduced in CT compared to fluoroscopy (1.18 mSv in CT and 1.68 mSv in fluoroscopy). This finding for nephrostomy is consistent with the literature on the other interventional procedures such as lumbar puncture (8, 19) and scoliosis (9). However, it should be noted that we compared the radiation exposure in the first-time nephrostomy under CT and the nephrostomy replacement under fluoroscopy. The first-time nephrostomy differs from the nephrostomy replacement at the initial steps that first the Chiba needle and then the dilator is inserted in the former. These steps are not necessary for the nephrostomy replacement procedure. The trajectory and position of the Chiba needle are extensively controlled with imaging equipment during initial positioning. As a result, considerable radiation exposure may result in this step of the first-time nephrostomy. Stated thus, the replacement procedure is expected to be completed with a radiation exposure lower than a first-time procedure. Therefore, our results indicate PCN operations can be completed with lower radiation exposures with an ultra-low-dose capable CT device in comparison to fluoroscopy conjoined ultrasound-guided full-stage PCN.

CT-fluoroscopy and low-dose CT are alternatives to standard CT and standard fluoroscopy-guided interventions (20, 21). However, albeit the real-time guidance advantage of CT-fluoroscopy, the interventionist and accompanied staff are exposed to radiation as well as the patient. Besides, it may not improve the efficiency or the operation time, and the absorbed radiation doses may not reduce for the patient depending on the intervention type (20, 21). On the other hand, low-dose CT considerably reduces the radiation dose compared to the standard CT and CT-fluoroscopy (21). However, radiation exposure of the interventionist is still a problem. Also, devices with low-dose imaging capability are required. An experienced interventionist can place the guidewire and catheter at the target without real-time imaging by observing a few slices acquired with standard CT. This may also decrease the absorbed radiation dose by the patient while the interventionist is not exposed to radiation. Similarly, an inexperienced interventionist may need more CT scans which would also increase the absorbed radiation dose. Silverman et al. reported that as the interventional radiologist became more experienced with CT-fluoroscopy technique, radiation dose absorbed by patients decreased (20). Nephrostomy operations presented here are performed by a radiologist with 17 years of experience in CT-guided biopsy. The experience of the interventionist should also be considered while choosing the technique to be used. We should also note that we used ultra-low-dose settings on the CT device, and therefore, the absorbed radiation doses reported here might be comparable to those which may result in the low-dose CT technique mentioned by Shah et al (21).

As expected, nephrostomy replacements under fluoroscopy were completed in a shorter time than the first time nephrostomy operations under CT because exchanging any catheter from an existing tract will take a shorter time than a proper new tract puncture, dilating, and finally placement of a new catheter.

Study Limitations

Fluoroscopy-guided PCN exchange is not an exact compatible group to select as a control group. It is expected the patients to have lower radiation exposure. However, due to the advantages of CT-guided PCN as mentioned above, all the first-time nephrostomy procedures are routinely performed under CT guidance in our center. Therefore, fluoroscopy-guided nephrostomy replacement was the closest technique to compare with CT-guided nephrostomy. The study was a retrospective analysis which could have caused a possible selection bias. All the nephrostomies were done in a single-center and by the same interventional radiologist which is inferior to a multicenter randomized controlled trial.

Conclusions

Although both conjoint uses of ultrasound and fluoroscopy or computed tomography alone have been recommended for percutaneous nephrostomy, to the best of our knowledge, this is the first study comparing the respective patients' radiation dose exposure in these two techniques.

Our study showed that the patients receive less radiation in CT-guided first-time nephrostomy compared to nephrostomy replacement under fluoroscopy. Therefore, CT-guidance is a favorable alternative to fluoroscopy conjoined ultrasound guidance in nephrostomy tube placement. The experience of the interventionist is an important factor in the duration and the radiation doses, and it should be considered while choosing the guidance method in nephrostomy.

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None declared.

Author Contrubitons

Designing the study and collecting the data were done by **Yaşar Türk** and, reviewing the literature, being prepared for the ethics committee, analyzing, and reporting the data were done equally by the authors.

Conflicts of Interest

We have no conflict of interest to declare

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Ethical Approval and Informed Consent:

This study was approved by Non-Invasive Clinical Studies Ethics Board at the Faculty of Medicine at Tekirdağ Namık Kemal University Ethics Committee (Permission granted/Decision no: 2020.16.01.16).

Peer Review Process

Extremely peer-reviewed.

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