Observational Study

Comparison of Radiation Exposure Between Trident and Conventional Cannula in Genicular RF Procedures Under Fluoroscopy for Gonarthrosis

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Background: Genicular nerve radiofrequency ablation (GNRFA), including conventional, cooled, and pulsed techniques, has been used in the treatment of symptomatic knee osteoarthritis (OA).

Objectives: This study aimed to compare conventional and trident GNRFA application methods, to evaluate the characteristics of fluoroscopy use and to evaluate the differences in terms of x-ray exposure.

Study Design: Observational study and original research.

Setting: This work was conducted at Adana City Hospital, Adana, Turkey.

Methods: A 3-pronged radiofrequency ablation (RFA) cannula was pushed under C-arm fluoroscopic guidance to known sites of the superomedial genicular nerve, superolateral genicular nerve, inferomedial genicular nerve, nerve to vastus medialis, nerve to vastus lateralis and nerve to vastus intermedius shortly after suitable placement, sterile preparation, and subcutaneous anaesthesia. All patients were exposed to ablation at RF 90°C for 60 seconds.

Results: The study included 41 patients, 28 (68.3%) women and 13 (31.7%) men, with a mean age of 68.2 ± 7.0 years. Conventional and Trident™ GNRFA was performed in 22 and 19 patients, respectively. The median radioactivity exposure in the conventional GNRFA group was 0.14 (0.11/0.17) mGy, while the median radioactivity exposure in the Trident™ group was 0.11 (0.06/0.17) ($P < 0.001$). WOMAC scores between the baseline and first- and third-month post-treatment in the Trident™ group were significantly higher than in the conventional group ($P = 0.018$ and $P = 0.006$, respectively). In both treatment groups, the improvement in VAS and WOMAC scores was significant at one month and continued similarly at 3 months.

Limitation: The study's limitations include a small sample size and a lack of blinding due to the study design, which may have introduced bias.

Conclusion: GNRFA using a lateral approach and a Trident™ cannula offers significant advantages, including better improvement in WOMAC scores, shorter procedure times, fewer fluoroscopy shots, and reduced radiation exposure.

Key words: GNRFA, monopolar, Trident™, WOMAC, knee OA, radioactivity, fluoroscopy

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Chronic knee pain caused by knee osteoarthritis (OA) is a widespread problem, affecting millions of people worldwide (1). Knee pain affects approximately 45% of patients during their lifetimes and is linked to significant disability and a lower quality of life. Obesity, trauma (including from surgery), and advanced age are all risk factors for knee pain. Clinically, patients with knee OA typically complain of pain, which is frequently accompanied by a limited range of motion, stiffness, osteophytes, crepitus, and effusion. Patients suffer increasing physical harm during the disease, due to OA's progressive degenerative nature and associated pain. Despite the existence of surgical and nonsurgical treatment options for the condition, many people experience chronic knee pain and functional impairments.

Since an optimal treatment for knee OA has yet to be determined, treatment focuses on improving patients' quality of life, reducing physical impairment, and slowing disease progression through pain management (2). Conservative treatments for knee OA include weight loss, physical therapy, and pharmacological interventions, while more invasive treatments include intra-articular injections, joint-preserving surgical procedures, and total knee arthroplasty (TKA). Unfortunately, many people do not respond well to conservative treatments. Furthermore, total knee arthroplasty (TKA) often cannot be performed due to patient preference, age, or medical comorbidities considered inappropriate by orthopedic surgeons. However, up to 20% of patients continue to suffer from knee pain after TKA (3-7).

Radiofrequency ablation (RFA) of the genicular nerve is increasingly being used to treat the chronic pain caused by osteoarthritis. The treatment involves the targeted delivery of radiofrequency energy to the genicular nerves, which causes partial sensory denervation of the joint capsule, tissue heating, and neural denaturation (8), thereby reducing nociceptive signal transmission.

A range of RFA technologies has been used, including conventional monopolar, bipolar, and cooled monopolar electrodes. Although these technologies create lesions of different sizes and ablation durations, they all require proper placement of the electrodes near the target nerves. The minimally invasive conventional technique involves using a high-temperature probe to target specific nerves that innervate the affected tissue. RFA is a novel technique used to treat a wide range of cancers, cardiac arrhythmias, and other conditions, but it has recently gained popularity for relieving chronic pain in patients with musculoskeletal disorders such as OA (9). RFA for knee OA, which was first studied by Choi et al in 2010, has become increasingly popular in subsequent years (10,11). Genicular nerve radiofrequency ablation (GNRFA), including conventional, cooled, and pulsed techniques, has been used in the treatment of symptomatic knee OA. The literature has shown that GNRFA can be an effective alternative for individuals with this condition (10,12,13).

Fluoroscopic imaging is used frequently in orthopaedic and algological interventions. C-arm fluoroscopy is widely used in the operating room to determine the correct anatomical position and achieve a successful blockade during the GNRFA procedure. While fluoroscopy has a significant impact on procedural success, the primary concern for the operating room team is secondary radiation caused by x-rays that are not absorbed by the patient and are directed elsewhere, resulting in occupational exposure for the intervention team. Therefore, the number and duration of x-ray shots in procedures utilizing the beneficial effects of fluoroscopy should obviously be reduced. The importance of wearing personal protective equipment is similarly clear.

In addition to the traditional monopolar cannula approach, the use of multi-tined cannulas in GNRFA procedures has grown in recent years. The multi-tined cannula enables a more vertical approach and the formation of a relatively large lesion, thereby better capturing neural distribution areas. Multi-tined cannulas are thought to allow for a faster blockade of larger neural networks.

Because of the above developments, our study aimed to compare conventional and Trident™ GNRFA application methods. Our goal was to evaluate the characteristics of fluoroscopy use and to evaluate the differences in terms of x-ray exposure.

Methods

Patients

In our study, the results of patients who had knee OA and underwent GNRFA were evaluated retrospectively. To be included in the study, each patient had to satisfy the following inclusion criteria: (1) age >18 years; (2) Kellgren-Lawrence (KL) OA score grade > 3; and (3) knee pain persisting for more than 6 months. Patients were excluded from the study if they had a history of prior knee surgery (including arthroscopy), were diagnosed with neuropsychiatric disorders (due to their impact on pain questionnaire results), were undergoing various pain management procedures, or were receiving medical treatment for neuropathic pain.

Patient Positioning and Preparation

Patients were generally positioned on the procedure table to maximize the physicians' access to the target area while maintaining comfort and safety throughout the procedure. Patients were placed in a supine position, with their symptomatic knees flexed at a 30-degree angle (14). This procedure was carried out using standard sterile preparation techniques. To reduce discomfort during the procedure, local anesthesia was applied at the entry site and throughout the planned target area. Topically, 1 mL of 2% lidocaine was applied, enough to cause skin wheal formation (10,14,15).

GNRFA

Superolateral genicular nerve (SLGN), superomedial genicular nerve (SMGN), and inferomedial genicular nerve (IMGN) blocks target the periosteal areas that connect the femoral shaft to the bilateral epicondyles and the tibial shaft to the medial epicondyle (10,15,16). In the present study, the fluoroscopy-guided procedure was always initiated in an anteroposterior (AP) view. A correct AP view was defined by the patella in the midline, and the tibiofemoral joint was seen symmetrically and at its widest extent. The needles were applied to the point where the shaft met the epicondyle in the AP view and advanced to the midpoint of the long axis of the long bone shaft in the lateral view (17-20) (Figs. 1 and 2).

The precise placement of the conventional cannula (introducer) was determined using AP fluoroscopy pictures. Lateral images were used for determining the location of a 100-mm-long, 18-gauge 3-pronged RFA cannula (Diros Technology Inc.) with 5 mm active tips (21). The electrode was properly positioned in the intended GN by a sensory test at 50 Hz and < 0.5 V. This test generally causes the patient a sensation of pressure or mild pain.

Applying RF

A step-by-step description of the new protocol for GNRFA, as previously detailed by Koshi et al (1), has been outlined before. A 3-pronged RFA cannula (Diros Technology Inc.) was advanced under C-arm fluoroscopic guidance to known sites of the SMGN, SLGN, IMGN, nerve to vastus medialis, nerve to vastus lateralis, and nerve to vastus intermedius shortly after suitable placement, sterile preparation, and subcutaneous anesthesia. All patients were exposed to ablation at RF 90°C for 60 seconds. Sensory and motor stimulation, or patient examination, were used to determine whether the appropriate effect was achieved (Fig. 3).

Fig. 1. *Fluoroscopy-guided procedure always requires therapeutic imaging in anteroposterior (AP) view.*

Fig. 2. *Therapeutic application of GNRFA in the lateral direction under fluoroscopy.*

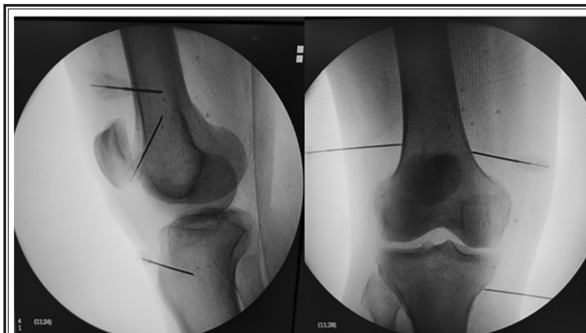

Fig. 3. *Therapeutic Trident™ GNRFA application.*

Post-Procedure Follow-Up

Patients were advised to avoid heavy lifting for the first week, refrain from submersion in water for at least 3 days, and gradually return to normal physical activity over 2 weeks. Patients were also advised not to run or climb stairs for up to one month after the procedure. The post-procedure follow-up assessed pain at rest, during activity, and at night, as well as functional status. Patients were evaluated for pain and functionality using the WOMAC and VAS indices.

Data

Patients' demographic and clinical data (age, gender) were obtained from their medical records. Each patient was called for a symptom evaluation at one and then 3 months after GNRFA (21). The WOMAC OA index was used to evaluate the patients' overall knee function in the previous 48 hours. Changes in the WOMAC total score from the baseline were assessed. The WOMAC is a self-administered 24-item questionnaire with 3 subscales: pain (5 items), stiffness (2 items), and physical function (17 items). Each item is rated on a scale of None (0) to Extreme (4). Higher scores indicate more severe pain, stiffness, and functional limitations (22). At each visit, all patients were also asked to fill out a VAS score assessment questionnaire (23).

Statistical Analysis

SPSS 25.0 (IBM Corporation) and PAleontological STatistics 3 (Hammer Ø, Harper DAT, Ryan PD) programs were used to analyze the variables. The conformity of univariate data to normal distribution was evaluated with the Shapiro-Wilk Francia test, while the homogeneity of variance was evaluated with the Levene test. While the Dornik and Hansen omnibus test was used for the conformity of multivariate data to a normal distribution, Box's M test was used for variance homogeneity. When comparing 2 independent groups with each other according to quantitative variables, the independent samples t-test was used with bootstrap results, while the Mann-Whitney U test was used with Monte Carlo results. Friedman's 2-way test was used with Monte Carlo results to compare more than 2 repeated measurements of the dependent quantitative variables, and the post hoc test was performed for the stepwise step-down comparisons test. The Pearson chi-square test was used to compare categorical variables by group, and the Monte Carlo simulation technique was used for testing. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the classification based on the cut-off value calculated from group variables were evaluated. These metrics, along with the actual classification, were analyzed and presented using receiver operating characteristic (ROC) curve analysis according to the variables we named Number of Shots and Radioactivity (Mgy). In the tables, quantitative variables were represented as mean (± SD) (minimum/maximum) and median (minimum/maximum), while categorical variables were represented as n (%). The variables were analyzed at a 95% confidence level ,and a *P*-value of less than 0.05 was considered significant.

Results

Demographic Findings

Forty-one patients, comprising 28 (68.3%) women and 13 (31.7%) men, were included in the study. The mean age of the patients was 68.2 ± 7.0 years, and the mean body mass index (BMI) was 29.4 (21.8/46.0) kg/m^2.

Conventional and Trident™ GNRFA was performed in 22 and 19 patients, respectively. There was no difference in terms of age, BMI, and Kellgren-Lawrence levels between treatment groups ($P > 0.05$) (Table 1).

Clinical Manifestations

The gonarthrosis-related VAS and WOMAC scores of the patient groups were similar to those seen during the pre-procedure period ($P > 0.05$). The mean procedure time was 548.4 ± 51.0 s in the conventional cannula group and 302.7 ± 30.9 s in the Trident™ group ($P < 0.001$). In the conventional GNRFA group, the median number of fluoroscopy pulses was 42.0 (36.0/51.0); in the trident group, it was 23.0 (20.0/28.0) ($P < 0.001$) (Table 1).

Furthermore, the median radioactivity exposure in the conventional GNRFA group was 0.14 (0.11/0.17) mGy, while the median radioactivity exposure in the trident group was 0.11 (0.06/0.17) ($P < 0.001$) (Table 1) (Fig. 4).

During the study, the patients' VAS and WOMAC scores were evaluated before the procedure, as well as one and then 3 months afterward. No significant difference in VAS changes was found between the groups ($P > 0.05$). However, the change in the Trident™ group's WOMAC score from the baseline and the first and 3rd month after treatment was significantly higher than that in the conventional group ($P = 0.018$ and $P = 0.006$, respectively) (Table 1). In both treatment groups, the improvement in VAS and WOMAC scores was signifi-

Table 1. *Demographic and clinical findings of patients who underwent trident cannula and conventional GNRFA.*

	Total (n = 41)	Cannula		*p*
		Trident™ (n = 19)	Conventional (n = 22)	
	Mean ± SD (min/max)	**Mean ± SD (min/max)**	**Mean ± SD (min/max)**	
Age	68.2 ± 7.0 (52/79)	67.2 ± 8.3 (52/79)	69.0 ± 5.9 (58/77)	0.417 [t]
	Median (min/max)	**Median (min/max)**	**Median (min/max)**	
Height	161.0 (150.0/180.0)	161.0 (154.0/179.0)	161.5 (150.0/180.0)	0.705 [u]
Weight	77.0 (57.0/109.0)	77.0 (66.0/102.0)	76.5 (57.0/109.0)	0.879 [u]
BMI	29.4 (21.8/46.0)	30.3 (21.8/39.4)	29.3 (24.4/46.0)	0.656 [u]
	n (%)	**n (%)**	**n (%)**	
Gender				0.999 [c]
Female	28 (68.3)	13 (68.4)	15 (68.2)	
Male	13 (31.7)	6 (31.6)	7 (31.8)	
Stage				0.999 [c]
III	31 (75.6)	14 (73.7)	17 (77.3)	
IV	10 (24.4)	5 (26.3)	5 (22.7)	
	Median (min/max)	**Median (min/max)**	**Median (min/max)**	
Number of Shots	36.0 (20.0/51.0)	23.0 (20.0/28.0)	42.0 (36.0/51.0)	< 0.001 [u]
Radioactivity (Mgy)	0.11 (0.06/0.17)	0.07 (0.06/0.09)	0.14 (0.11/0.17)	< 0.001 [u]
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Surgery time (sec)	434.5 ± 131.0	302.7 ± 30.9	548. 4± 51.0	< 0.001 [t]
	n (%)	**n (%)**	**n (%)**	
Number of Shots Classified for Roc curve				< 0.001 [rc]
≤ 28	19 (46.3)	19 (100) [sp (npv)]	0 (0)	AUC (Se): 1 (0)
> 28	22 (53.7)	0 (0)	22 (100) [ss (ppv)]	
Radioactivity (Mgy) Classified for Roc curve				< 0.001 [rc]
≤ 0.91	19 (46.3)	19 (100) [sp (npv)]	0 (0)	AUC (Se): 1 (0)
> 0.91	22 (53.7)	0 (0)	22 (100) [ss (ppv)]	
Surgery time (sec)				< 0.001 [rc]
≤ 352	19 (46.3)	19 (100) [sp (npv)]	0 (0)	AUC (Se): 1 (0)
> 352	22 (53.7)	0 (0)	22 (100) [ss (ppv)]	
VAS				
Preop	8.0 (6.0/10.0)	8.0 (6.0/10.0)	7.5 (6.0/10.0)	0.544 [u]
1st month	3.0 (1.0/4.0)	3.0 (1.0/4.0)	3.0 (1.0/4.0)	0.912 [u]
3rd month	3.0 (1.0/5.0)	3.0 (1.0/5.0)	2.5 (1.0/4.0)	0.052 [u]
VAS Change				
(First month-Preop)	-5.0 (-7.0/-3.0)	-5.0 (-7.0/-4.0)	-5.0 (-7.0/-3.0)	0.468 [u]
(3rd month-Preop)	-5.0 (-7.0/-3.0)	-5.0 (-7.0/-3.0)	-5.5 (-7.0/-3.0)	0.205 [u]
(First month-3rd month)	0.0 (-2.0/3.0)	0.0 (-1.0/3.0)	0.0 (-2.0/1.0)	0.059 [u]
WOMAC				
Preop	60.0 (42.0/78.0)	62.0 (42.0/78.0)	60.0 (48.0/76.0)	0.578 [u]
First month	36.0 (23.0/48.0)	35.0 (23.0/48.0)	37.0 (26.0/48.0)	0.146 [u]
3rd month	37.0 (25.0/48.0)	36.0 (25.0/48.0)	37.5 (26.0/48.0)	0.764 [u]

t: Independent samples t-test (bootstrap); u: Mann-Whitney U-test (Monte Carlo); c: Pearson chi-square test (Monte Carlo); rc: roc curve analysis (Youden index J [Honley & McNell]); AUC: area under the ROC curve; ss: sensitivity; sp: specificity; npv: negative predictivity; ppv: positive predictivity; Se: standard error

Table 1 (cont.). *Demographic and clinical findings of patients who underwent trident cannula and conventional GNRFA.*

	Total (n = 41)	Cannula		p
		Trident™ (n = 19)	Conventional (n = 22)	
WOMAC Change				
(First month-preop)	-25.0 (-45.0/-4.0)	-26.0 (-45.0/-4.0)	-22.5 (-34.0/-7.0)	0.018 [u]
(3rd month-preop)	-23.0 (-37.0/-4.0)	-25.0 (-36.0/-4.0)	-22.0 (-37.0/-7.0)	0.278 [u]
(1st month-3rd month)	1.0 (-4.0/12.0)	2.0 (-3.0/12.0)	-0.5 (-4.0/5.0)	0.006 [u]

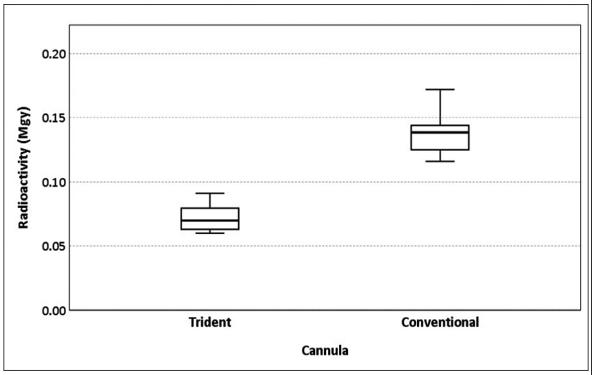

Fig. 4. *Comparison of radioactivity during the procedure of conventional and trident cannula.*

cant at one month and continued similarly at 3 months (Table 1 and Table 2).

Discussion

GNRFA has become a popular treatment for chronic pain in knee OAs (13,24-27). GNRFA is a minimally invasive percutaneous procedure that uses thermal energy to coagulate sensory nerves that innervate the anterior knee capsule, preventing nociception. Traditionally, GNRFA focuses on the superior medial (SMGN), superior lateral (SLGN), and inferior medial (IMGN) genicular nerves. However, more detailed dissections have revealed significant variability in these targets, as well as additional sensory nerves that innervate the anterior capsule (28,29). According to preliminary data, more complete sensory denervation results in greater pain reduction after GNRFA (30-32). RFA is a contemporary treatment option for chronic pain. The analgesic mechanisms of RFA include inhibiting local C-fiber stimulation to block pain pathways and disrupting the vicious cycle of inflammatory responses by suppressing the release of immune cells and pro-inflammatory cytokines (interleukin-1β and interleukin-6).

GNRFA gained popularity in recent literature following a study by Choi et al (10). The literature identifies prioritized patients for this treatment. Patients with symptomatic knee OA that is resistant to conservative treatment, severe OA (Kellgren-Lawrence grade 3 or 4), a history of failed TKA, or persistent pain in the arthroplasty region are prioritised for GNRFA. It is also a treatment option for patients, who have multiple comorbidities and do not want to undergo surgery. In our study, we included patients with stage 3-4 knee OA, who did not undergo TKA surgery.

The GNRFA procedure is carried out in the operating room using C-arm fluoroscopy guidance. The superior medial genicular nerve is targeted through a fluoroscopic anteroposterior (AP) view. A second cannula is advanced percutaneously to the correct location, approximately 1 cm anterior to the adductor tubercle and in the medial direction of the distal femoral diaphysis, until it makes contact with the bone, allowing for more accurate RFA application. X-ray emission occurs during imaging to ensure that the procedure is carried out correctly and efficiently. C-arm fluoroscopy units provide x-ray images that allow interventional procedures to visualize real-time progress and facilitate manipulation, reducing intervention time (34). Radiation exposure in the fluoroscopy environment can result from both the primary beam and the leakage of scattered x-ray beams (35).

Radiation can cause serious biological effects, such as tissue reactions, hair loss, and infertility. These stochastic effects are proportional to the long-term radiation dose received and may include negative outcomes such as cancer and genetic mutations (36,37). Numerous studies have found that fluoroscopy personnel develop adverse effects such as thyroid, gonadal, and solid organ cancers, as well as cataracts, as a result of ionizing radiation exposure (34,38-41).

Therefore, it is critical to minimize the use of fluoroscopy during GNRFA manipulation in the operating room. Our study found that the Trident™ group had shorter average procedure times, fewer fluoroscopy shots, and lower levels of radioactivity emission than did the conventional cannula group ($P < 0.001$). Lesser amounts of radiation exposure led to higher WOMAC scores ($P < 0.001$), while VAS scores remained similar.

The current recommended general limits are: (1)

Table 2. *Findings of patients who underwent Trident™ cannula and conventional GNRFA.*

	VAS			WOMAC		
	Total (n = 41)	**Trident (n = 19)**	**Conventional (n = 22)**	**Total (n = 41)**	**Trident (n = 19)**	**Conventional (n = 22)**
	Median (min/max)	**Median (min/max)**	**Median (min/max)**	**Median (min/max)**	**Median (min/max)**	**Median (min/max)**
Time						
Preop	8.0 (6.0/10.0)	8.0 (6.0/10.0)	7.5 (6.0/10.0)	60.0 (42.0/78.0)	62.0 (42.0/78.0)	60.0 (48.0/76.0)
1st m	3.0 (1.0/4.0)	3.0 (1.0/4.0)	3.0 (1.0/4.0)	36.0 (23.0/48.0)	35.0 (23.0/48.0)	37.0 (26.0/48.0)
3rd m	3.0 (1.0/5.0)	3.0 (1.0/5.0)	2.5 (1.0/4.0)	37.0 (25.0/48.0)	36.0 (25.0/48.0)	37.5 (26.0/48.0)
P-value for time	< 0.001 f	< 0.001 f	< 0.001 f	< 0.001 f	< 0.001 f	< 0.001 f
Preop vs first m	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Preop vs 3rd m	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
First m vs 3rd m	0.999	0.999	0.999	0.999	0.223	0.999

f: Friedman test (Monte Carlo); posthoc test: stepwise step-down comparisons

20 mSv per year or (2) a total of 100 mSv over 5 years without exceeding 50 mSv in one year. Most orthopedic and pain specialists are exposed to doses under 2 mSv per year. This dosage is lower than in such specialities as interventional cardiology, interventional radiology, and vascular surgery, which rely heavily on live fluoroscopy. Despite this, given the known risks, radiation-related adverse effects may occur for orthopedic and pain specialists who use fluoroscopy. The International Agency for Research on Cancer (IARC) classifies ionizing radiation as a Group I human carcinogen (42). The carcinogenic effects of high and medium levels of ionizing radiation exposure are well understood, but the effects of chronic low-level exposure are less so.

Because of the proximity of the C-arm fluoroscopy source and radiation scattering from the patient, the algologist performing the intervention receives the highest radiation dose (37-62% of the total dose), while auxiliary personnel farther away from the source receive a lower radiation dose (11-20%) (43). Therefore, personnel who use fluoroscopy frequently must be monitored with dosimeters and use protective equipment appropriately. The median radioactivity exposure in the conventional GNRFA group was 0.14 (0.11 / 0.17) mGy; in the Trident™ group, it was 0.11 (0.06 / 0.17) ($P < 0.001$). Although the risk of radiation exposure during a single procedure is relatively low, frequent GNRFA procedures can result in risky cumulative radiation exposures.

In our study, the Trident™ expandable RF cannula allowed for a more perpendicular approach and the creation of a relatively large lesion, thereby better capturing neural distribution areas (44). Additionally, no procedure-related complications were observed in the patients. The application of the Trident™ cannula using a lateral approach resulted in significantly shorter procedure times and less fluoroscopy time than did the conventional (monopolar) GNRFA procedure performed with an AP approach.

Limitations

Our study's limitations include a small sample size and a lack of blinding due to the study design, which might have introduced bias. In addition, while C-arm fluoroscopy was used in the AP axis during conventional cannula use, it was used in the lateral position for the Trident™ cannula. This difference in radiation scattering might have varying effects on the operating room staff's exposure levels. Despite those limitations, the findings obtained from this study add important data to the literature, and important data have been obtained in terms of recognizing the radiation exposure of health care workers during the application of GNRFA to patients with OA knee pain. It is worth noting that Trident™ cannulas provide a better analgesic response and emit less radiation than do conventional cannulas (45,46).

Conclusions

In conclusion, GNRFA using a lateral approach with a Trident™ cannula offers advantages, such as a greater improvement in WOMAC scores, shorter procedure times, fewer fluoroscopy shots, and reduced radiation exposure.

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