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A retrospective assessment of the effectiveness of pulsed radiofrequency ablation in the treatment of chronic pain caused by advanced knee osteoarthritis

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Abstract

Background: Patients suffering from severe chronic pain often have problems finding an appropriate combination of painkillers. We retrospectively evaluated the effectiveness and safety of pulsed radiofrequency ablation (pRFA) of the genicular nerves in 96 patients with knee osteoarthritis (KO). We hypothesized that age, sex, and body mass index (BMI) may influence the quality of the pRFA treatment.

Methods: A diagnostic blockade with total volume of 9 ml of 1% lidocaine (WZF, Poland) combined with 4 mg of dexamethasone with subsequent pRFA with a radio frequency of 300–500 kHz under ultrasound guidance was used during the procedure. The study participants were assessed during regular monthly visits until 12 months.

Results: The nerves' ultrasound identification was successful in 90.62% of the cases. According to the numeric rating scale (NRS), pain was reduced by 50% or more in 64.06% of the cases. The average pain relief period lasted just over 7 and a half months. There were no pRFA-related complications or side effects of the drugs used.

Conclusions: pRFA seems to be safe and effective for the treatment of chronic pain in KO. The outcome of the treatment may be related to the patient's age (block duration increased with patient age) and sex (in women, the therapeutic effect was more effectively prolonged) in our study group. There was also higher effectiveness of pRFA in high-BMI patients, which was close to statistical significance ($P = 0.053$).

Key words: nerve block, radiofrequency ablation, osteoarthritis, knee.

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The International Association for the Study of Pain recommends an interdisciplinary approach to pain syndromes which do not respond to standard pharmacological treatment.

The knee joint is innervated by four main nerves: the femoral nerve, the obturator nerve, the tibial nerve, and the common peroneal nerve. The articular branches reach the knee along with the vessels, and almost all of them separate from the muscular branches. Branches of the femoral nerve reach the anterior superior part of the knee. The anterior inferior part of the knee is innervated by the lateral branch of the common peroneal nerve and the medial branch of the tibial nerve. The upper posterior part of the knee joint is innervated by the sagittal branches, the tibial branches of the sciatic nerve, and by the obturator nerve. The lower posterior part is innervated by the ramuli of the tibial nerve [1].

The most common cause of knee pain is osteoarthritis, and the pooled global prevalence of this pathology is 22.9% in individuals aged 40 and over, thus adding to a global population of patients with knee osteoarthritis (KO) around 654.1 million [2]. Currently, the following treatments of this chronic disease are available: manual therapy and rehabilitation, pharmacological treatment, intra-articular injections, and surgery.

Patients with arthrosis of the knee causing chronic pain are referred for pulsed radiofrequency ablation (pRFA) after exhaustion of all invasive treatment methods and orthopaedic disqualification from reconstructive surgery. pRFA is a method of combating chronic pain using current with

a radio frequency (300–500 kHz). The treatment involves damaging nerve structures through the controlled effect of temperature. This is achieved using high-frequency wave generators to generate radio waves of a specific length, which propagate in the tissues.

The treatment procedure itself involves the insertion of a needle (electrode), under ultrasound control, close to the nerve to be subjected to RFA. The correct positioning of the electrode can be confirmed by motor stimulation, i.e., observation of motor activity after stimulation with a current of 2–5 Hz, and sensory stimulation with a current of 50–100 Hz. After the correct location of the electrode is confirmed, the neurodestruction procedure is then performed by supplying the radio frequency current for 60–120 seconds. As a result, temperature increases to 42°C. The principle of operation of RFA has not yet been fully investigated. It is likely that pain is alleviated by denervation of structures, e.g., in the knee or shoulder. However, Teixeira and Sluijter [3] observed that RFA affected the immune cells of patients with metastatic tumours. The process activated phagocytes and led to lower levels of inflammation and pain.

The main goal of this study was to assess the effectiveness and safety of pRFA applied to the knee. Pain levels were recorded before the pRFA and again three months later. Jamison *et al*. [4] listed a group of factors that may affect the result of treatment after ablation. These authors took concomitant disease of the hip joint, the degree of degeneration and the prognostic blockade effect into account. However, the topic has not been extensively analysed to date. In a systematic review and meta-analysis of ultrasound-guided RFA in KO carried out by Huang *et al*. [5] in 2020, only 8 out of 157 eligible studies of treatment efficacy and safety were taken into consideration. These authors focused on primary goals and did not consider coexisting factors influencing the efficacy and safety of the RFA procedure [5]. Old age, obesity, and female sex have previously been proposed as risk factors in the development of knee arthritis [6]. However, these factors have not been extensively studied in relation to RFA effectiveness and safety. This may be unfortunate, given that contemporary societies have become older and more obese, and females tend to prevail over males among KO patient populations. In this study, we therefore sought to assess the impact of the patients' age, body mass index (BMI) and sex on the effectiveness and duration of the clinical effect of blockades. In this paper, we present the results of an analysis of 96 treated patients. However, this is still a higher number than in any of the studies analysed by Huang *et al*. [5].

METHODS

In a retrospective study, we analysed data from the medical records of patients at the Institute of Rural Health in Lublin (Poland). The primary aim was to check the effectiveness and safety of the pRFA procedure performed in our patients. The formed a consecutive series of men and women who were admitted for thermolysis of the genicular nerves due to KO in the period from 2017 to 2019. The patients were treated by two physicians with perennial experience in thermolysis in the specialized treatment room as a one-day procedure. Before patients qualified for treatment, a detailed history of their chronic diseases and renal failure was collected. The patients were asked to use the numeric rating scale (NRS) to rate their experience of pain during the pharmacological treatment, before and immediately after the diagnostic–prognostic procedure, and before the RFA procedure. Subsequent ratings were obtained every following month up to 12 months. Detailed epidemiological anamneses about the forms of conventional and unconventional methods of pain treatment previously undergone by patients were also obtained.

If patients had received intra-articular steroid or hyaluronic acid injections due to knee pain, the RFA procedure was postponed for six months. Patients who used unconventional methods, including compresses and herbal ointments, qualified for the procedure after detailed anamneses and physical examination. The local ethics committee at the Institute of Rural Medicine in Lublin, Poland agreed to the inclusion of patients in the study (consent number: 1/04/2023/IMW, April 05, 2023). Informed consent was obtained from all subjects involved, and the study protocol determined inclusion and exclusion criteria for patient participants.

The inclusion criteria were as follows: age ≥ 18 years; knee joint pain resistant to pharmacological treatment and rehabilitation procedures applied for over six months; written consent to undergo the pRFA procedure. The exclusion criteria were as follows: age < 18 years; surgical procedures in the knee joint; previous RFA treatment, allergy to local anaesthetics applied during the procedure; pregnancy or breastfeeding; exacerbated mental illness; uncontrolled hypertension; decompensated heart failure; uncontrolled hyperglycaemia; chronic renal failure (up to 24 hours after haemodialysis); chronic liver failure with coexisting bleeding disorder; peripheral vascular disease; administration of anticoagulants and antiplatelet drugs.

In all cases, an ultrasound-guided prognostic and therapeutic block was applied before the procedure. A combination of 9 mL of 1% lidocaine (WZF, Poland) and 4 mg of dexamethasone (Demezon,

MIBE GmbH Arzneimittel, Germany) was used to block the superior lateral, the superior medial, and the inferior medial genicular nerves (up to approximately 3 mL of the local anaesthetic with steroid for one nerve). We followed the anatomical guide of a diagnostic blockade before the final thermolysis as described by McCormick *et al*. [7] in 2017. Patients qualified for RFA if, after the diagnostic/prognostic block, their pain decreased by 50% according to the NRS for a period of 2 weeks. If there was no analgesic effect after the diagnostic/prognostic block, the patients did not receive pRFA.

The procedures were performed under sterile conditions. An eZono 4000 ultrasound apparatus (eZono AG, Germany) with a linear or convex head depending on the depth of the nerve localization, a sterile adhesive cover, and sterile gel were used to visualise the needle. A 10 cm Cosman 20 G cannula with a 10 mm active tip (Cosman Medical, USA) was used for the RFA treatments. The nerves were stimulated with a current of less than 0.4 mA by the application of G4 RFA apparatus (Cosman Medical, USA) to exclude the proximity of motor fibres to ensure the pRFA of only sensor nerves. We used reusable active electrodes and disposable passive electrodes. The patients were placed in a supine position with 30° to 40° of flexion in the treated knee joint. The pRFA was performed as a fully antiseptic procedure after local anaesthesia of the skin with 1 ml of 1% lidocaine (WZF, Poland). The RFA needle was placed at three unique anatomic sites to block the superior lateral, superior medial, and inferior medial genicular nerves. The specific anatomic localization of the nerves was described by McCormick *et al*. [5]. The correct positioning was confirmed by ultrasound imaging. The patients received two pRFA cycles, each of 90 s duration. The following pRFA parameters were used: maximum temperature 42°C, voltage 45 V, pulse rate 2 Hz, pulse width 20 ms, electrode power 0.3 W. Only one joint was treated during one pRFA session. During the procedure, their heart rate, blood pressure and arterial oxygen saturation were all monitored. After the treatment, the patients were monitored for local complications (resulting from the traumatization of tissues after puncture, or in response to the toxicity of the drugs used for the diagnostic block), and any such occurrences were recorded in an additional protocol during the in-person control visit.

We defined effectiveness as a pain reduction of 50%. In the event of an insufficient nerve blockade, patients received additional pain treatment including oxycodone, buprenorphine, tramadol, and/or pregabalin. The appropriate set of medications and their dosages were individually selected according to pain treatment guidelines provided by the Polish Association for the Study of Pain.

Statistical analysis

The demographic data, as well as the efficacy of the pRFA, are presented as mean, lower, upper limit, and standard deviation (SD), standard error (SE), ±95% confidence interval. The patient population was assessed as a whole group, and in subgroups regarding age (< 60 years, 60–80 years, and > 80 years), BMI (< 25, 25–30, and > 30 kg m^{-2}), and sex.

When assessing the pRFA efficacy we used the one-sample Student's *t*-test for one trial. The mutual relationships between pRFA efficacy and the variables age, BMI, and sex were tested using Pearson's χ^2 test. If a relationship was detected, the Mann-Whitney *U* test or Kruskal-Wallis test was used to compare the groups to detect the direction of the relationship. Nonparametric tests were applied due to the lack of normality of the considered variables. A *P*-value of 0.05 was accepted as statistically significant in all tests.

The statistical analysis was performed using TIBCO Software Inc. (2017), Statistica (data analysis software system), version 13. The license is owned by the Medical University of Lublin and University of Maria Curie-Skłodowska in Lublin.

All data are presented in 10 tables.

RESULTS

The RFA procedure in the knee was applied to a group of 96 patients who met the study inclusion and exclusion criteria, underwent a physical examination, and gave informed written consent to the procedure. The most numerous age group comprised patients aged 60–80 years old (55/96, 57.29%). The patients' average BMI was 25–30 kg m^{-2} (41/96, 42.71%). Women outnumbered men in the study (70/96, 72.92%). The specific demographic data are presented in Table 1.

The initial effect of RFA was assessed immediately after the procedure. For analysis purposes, a final

TABLE 1. Patients' demographic data

	Number	%
Age (years)		
< 60	18	18.750
60–80	55	57.291
> 80	23	23.958
BMI (kg m^{-2})		
≤ 24.9	13	13.542
25–29.9	41	42.708
≥ 30	42	43.750
Sex		
Women	70	72.917
Men	26	27.083

therapeutic effect was determined to be a pain reduction of 50% or more according to the NRS, recorded directly before pRFA, and again every consecutive 1-monthly visit throughout 12 months. The ultrasound-guided identification of genicular nerves during the procedure of pRFA reached a success rate of 90.78%.

pRFA efficacy and duration in the whole group of patients

Among 96 tested cases, 87 patients presented at least 50% pain alleviation, which covers 90.625%. In the remaining 9 cases, the pRFA allowed the NRS to be reduced by 30–40%, which may be interpreted as insufficient. Mean effectiveness of the pRFA was 64.062% with SD 14.838, and when using the *t*-test, the effect was significantly higher than 60% (one sample *t*-Student's *t*-test: $t = 2.682597$, $P = 0.0043$). The pain alleviation above 50% after pRFA in 33 cases lasted at least 12 months (34.375%). The mean duration of the effective blockade was 7.57 months with SD 3.63, and after applying the *t*-test, we found it significantly longer than 6 months (one-sample Student's *t*-test: $t = 4.2427$, $P = 0.000025$).

Once completing the above-mentioned assessment we focused on further analysis regarding the possible influence of age, BMI, and sex on the pRFA effectiveness.

pRFA efficacy in selected groups

pRFA effectiveness > 50% was observed in all age subgroups of patients (Table 2).

pRFA effectiveness in BMI subgroups: we noted high mean effectiveness of pRFA among patients with various BMI, in all cases exceeding 60% (Table 3).

pRFA effectiveness in women and men subgroups: the mean pRFA effectiveness was also above 60% in both women and men groups (Table 4).

We analysed the differences among the groups by using two methods of statistical evaluation.

ANOVA and Kruskal-Wallis tests: the analysis did not reveal significant differences in pRFA effectiveness in selected subgroups ($P > 0.05$). The effectiveness did not differ among patients with different age ranges. Various BMI did not change the pRFA effectiveness. We did not note an influence of gender on pRFA efficacy.

Pearson's χ^2 test: the analysis confirmed the previous results in terms of age and gender differences. However, we noted a borderline correlation between pRFA effectiveness and BMI ($\chi = 9.31$, df = 4, $P = 0.0538$). The most pronounced pain alleviation (> 80% NRS reduction) was reported by the patients with obesity (≥ 30 kg m^{-2}) – 42.86%. Patients with the weakest effect (< 50% NRS reduction) were the least numerous – 11.11%. Detailed information regarding the decomposition of pRFA efficacy in various BMI subgroups is presented in Table 5.

Duration of pRFA in selected groups

Duration of pRFA (> 50%) in age groups: when comparing the age subgroups, the range covers a period of over 6 and a half months to just over 9 and a half months. The oldest patients presented the longest effect of the procedure (mean 9.522 months) (Table 6).

Duration of pRFA (with efficacy > 50%) in BMI groups: the duration of the effective pRFA procedure was in the range 6.854–8.615 months among the BMI subgroups (Table 7).

TABLE 2. pRFA effectiveness expressed in % of NRS pain alleviation in age subgroups

Age (years)	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
< 60	18	65.000	50.000	80.000	9.235	3.524	58.001	71.998
60–80	55	63.091	30.000	100.000	15.260	2.016	59.087	67.094
> 80	23	65.652	30.000	90.000	17.536	3.118	59.461	71.843

TABLE 3. pRFA effectiveness expressed in % of NRS pain alleviation in BMI subgroups

BMI (kg m^{-2})	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
≤ 24.9	13	63.846	30.000	80.000	18.947	1.001	6.627	10.604
25–29.9	41	61.707	30.000	90.000	15.637	0.563	5.734	7.973
≥ 30	42	66.429	30.000	10.000	12.459	0.557	6.846	9.059

TABLE 4. pRFA effectiveness expressed in % of pain relief in women and men groups

Sex	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
Women	70	63.286	30.000	100.000	16.126	0.421	7.322	8.993
Men	26	66.154	30.000	80.000	10.612	0.690	4.629	7.731

TABLE 5. Decomposition of pRFA effectiveness in various BMI subgroups

Efficacy (NRS pain reduction in %)	BMI ≤ 24.9 kg m^{-2}	BMI 25.0–29.9 kg m^{-2}	BMI ≥ 30 kg m^{-2}	Aggregated
< 50 % column % line	3 23.08 33.33	5 12.20 55.56	1 2.38 11.11	9
50–80 % column % line	5 38.46 7.58	29* 70.73 43.94	32* 76.19 48.48	66
> 80 % column % line	5 38.46 23.81	7 17.07 33.33	9 21.43 42.86	21
Aggregated	13	41	42	96

*Statistically significant result

TABLE 6. Duration of pRFA (> 50%) in age groups

Age (years)	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
< 60	18	7.667	3.000	12.000	2.990	0.820	6.037	9.296
60–80	55	6.727	1.000	12.000	3.649	0.469	5.795	7.659
> 80	23	9.522	2.000	12.000	3.409	0.726	8.080	10.963

TABLE 7. Duration of pRFA (> 50%) in BMI groups (in months)

BMI (kg m^{-2})	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
≤ 24.9	13	8.615	2.000	12.000	4.093	1.001	6.627	10.604
25–29.9	41	6.854	1.000	12.000	3.403	0.564	5.734	7.973
≥ 30	42	7.952	2.000	12.000	3.656	0.557	6.846	9.059

TABLE 8. Duration of pRFA (> 50%) in women and men groups (in months)

Sex	Number	Mean	Minimum	Maximum	SD	SE	–95%	+95%
Women	70	8.157	1.000	12.000	3.832	0.421	7.322	8.993
Men	26	6.000	3.000	12.000	2.466	0.690	4.629	7.371

Duration of pRFA (with efficacy > 50%) in women and men groups: women reported a longer period of pain alleviation than men (Table 8).

Similarly to the previous analysis, we compared the means for duration of the pRFA in age, BMI, and sex groups. We used Kruskal-Wallis and Mann-Whitney tests with additional analysis using Pearson's χ^2 test.

Age – in the oldest patients the pRFA duration was the longest. Kruskal-Wallis test: H(2, N = 96) = 10.0089; P = 0.0067).

BMI – the patients' BMI did not affect the pRFA duration. Kruskall-Wallis test (P > 0.05).

Sex – women maintained effective pain control significantly longer than men (Mann-Whitney U-test Z = 2.284, P = 0.022; when including continuity fix: Z = 2.343, P = 0.019).

Pearson's χ^2 test: the analysis confirmed the previous results in aspect of the age and gender differences.

Age: in patients > 80 years old, the therapy gave a longer clinical effect (Pearson's χ^2 10.766, P = 0.029; χ^2 NW 10.713, P = 0.030; Table 9).

We found no influence of BMI on pRFA duration in the studied subgroups (P > 0.05).

A greater long-term therapeutic effect was noted in women when compared to men (Pearson's χ^2 11.313, P = 0.003; χ^2 NW 13.374, P = 0.001; Table 10).

DISCUSSION

In this study, we analysed a wide range of knee osteoarthritis patients who underwent pRFA of the knee joint nerves. This is an important study area because KO is now a highly prevalent pathology. In the United States of America, its prevalence has doubled since the mid-20th century, and the problem may become more widespread, as increasing longevity and BMI values are known to trigger KO development [8]. In this study, we analysed 96 patients. Within this field of research, this represents quite a substantial number. In a review of 20 studies on the subject, Chou *et al.* [9] reported sample sizes of patients undergoing RFA which ranged from 7 to 76 patients. Our analysis involves a higher number

TABLE 9. Effective pRFA duration in age subgroups (duration in months)

pRFA effectiveness (duration in months)	Age < 60 y.o.	Age 60–80 y.o.	Age > 80 y.o.	Aggregated
≤ 5 % column % line	4 22.22 13.33	23* 41.82 76.67	3 13.04 10.00	30
6–11 % column % line	9 50.00 27.27	17* 30.91 51.52	7 30.43 21.21	33
≥ 12 % column % line	5 27.78 15.15	15* 27.27 45.45	13* 56.52 39.39	33
Aggregated	18	55	23	96

Statistically significant result

TABLE 10. Effective pRFA duration in the subgroups of women and men (duration in months)

Efficacy (duration in months)	Women	Men	Aggregated
≤ 5 % column % line	19* 27.14 63.33	11* 42.31 36.67	30
6–11 % column % line	20* 28.57 60.61	13* 50.00 39.39	33
≥ 12 % column % line	31* 44.29 93.94	2 7.69 6.06	33
Aggregated	70	26	96

*Statistically significant result

of patients. Most of these were women, which is a typical feature of KO patient populations. In the previously cited review of twenty studies, men predominated over women in only two. Cho *et al.* [10] provided results of a population analysis of KO occurrence in a group of 696 elderly patients. Patients in all stages of KO development, including candidates for knee arthroplasty, were predominantly women [10].

To date, clinical trials have shown that peripheral nerve block is a safe and effective technique [11]. A prior diagnostic block helps to predict the outcome of the final RFA, and one block has proved to be a reasonable solution [12]. Our choice of pRFA was based on everyday practice, although the effectiveness provided by different RFA techniques (conventional, pulsed, or cooled) seems to be comparable [9]. The application of ultrasound guidance is also safe, and its effectiveness is comparable to that of the fluoroscopy technique, without the radiation exposure required by the latter [13]. pRFA reduces pain levels and both the number and dosage levels of oral drugs needed for pain management. Among patients in our study, RFA treatments were effective in 64.062% of cases on average, which is a substantial figure, and comparable to those of other studies. In the retrospective study of Chen *et al*. [14], the effectiveness of RFA in KO was 61.1%. When comparing these rates of success, it should be noted that a primary outcome in the analysis of Chen at al. was designated as a ≥ 30% decrease in average knee pain scores which lasted at least 3 months without cointerventions. In our study, we required a much higher level of pain reduction (50%) to indicate treatment effectiveness, and this adds value to our outcome. However, it should be noted that, among most patients in our study, knee pain was not the only pain they suffered from. Typically, it was accompanied by ailments resulting from degenerative lesions in the spine, and this may have influenced the patients' rating of pain according to the numeric rating scale.

It is usually elderly patients who suffer from ailments. For this reason, the authors of this study were particularly interested in the potential influence of age on the effectiveness of RFA. Our results did not indicate statistical significance for pain alleviation after RFA. However, there was significantly longer duration of the nerve block in the oldest age group. In this regard, the ageing of the peripheral nervous system and age-related changes in pain perception should both be taken into consideration. With ageing, there is a gradual loss of both myelinated and unmyelinated nerve fibres. Peripheral nerve demyelination, remyelination and myelin balloon figures are all examples of changes which occur while ageing. Other examples can be readily stated. The expression of the main myelin proteins (P0, PMP22, MBP) changes. The functioning of cytoskeleton proteins deteriorates, causing axonal transport disturbances that finally lead to axonal atrophy. Reductions in nerve conduction velocity, muscle strength, sensory discrimination, autonomic responses, and endoneurial blood flow are all pathophysiological indicators of age-related changes. Finally, neuroregeneration is impaired due

to changes in neuronal, axonal, Schwann cell and macrophage responses [15].

Lautenbacher *et al*. [16] published an overview study with a meta-analysis of 31 studies investigating pain thresholds and 9 studies assessing pain tolerance among both young and elderly patients. The pain threshold increases with age, especially when thermal stimuli are applied, whereas pain tolerance is sustained. The authors concluded their study with the hypothesis that pain perception of low-intensity pain stimuli declines with age. El Tumi *et al*. [17] analysed 12 scientific papers and found that the pressure pain threshold was lower in older adults, but there were no differences between older and younger adults with respect to heat pain thresholds. The patients in our group exhibited a high initial level of pain. The chronicity of pain should lower its tolerance, so a more pronounced immediate therapeutic effect could be expected after the block. If narrower age ranges and larger groups of patients are studied, the results may reveal significant effects for observations that were not statistically significant in our study. However, in our study, the sense of pain relief undoubtedly lasted longer in the elderly patients. This observation has an important clinical implication. The progressive ageing of the nervous system may facilitate the eligibility of elderly patients for knee RFA in the future. Unfortunately, we could not find any study evaluating the influence of age on the effectiveness of pRFA in KO, so we were unable to compare our results with previous findings in the literature.

BMI was the second parameter analysed in our study. In general, the most pronounced pain alleviation (> 80% NRS reduction) was reported by the patients with obesity (≥ 30 kg m^{-2}). The correlation was close to but did not reach statistical significance. Also BMI was not found to exert a statistically significant influence on the duration of the RFA effect. When analysing the possible effect of high BMI on RFA effectiveness, it is necessary to consider problems arising from the difficult anatomical conditions caused by obesity. These can be partially addressed using ultrasound for nerve identification. The usefulness of ultrasound in RFA of the knee nerves was demonstrated by Wong *et al*. [18]. Another issue relates to the possibility of changes in the nerve function, which may develop with obesity. Miscio *et al.* [19] investigated nerve conduction parameters in obese patients without concomitant diabetes in motor (median, ulnar, peroneal, and tibial) and sensory (median, ulnar, and sural) aspects of nerve conduction. The results of their study showed a significantly decreased compound muscle action potential amplitude of the tibial and peroneal nerves and a decreased sensory nerve action potential amplitude of all nerves in the obese group. Most of the sensory thresholds were lowered in the obese patients [19]. These authors suggested that metabolic alterations may be responsible for the development of this phenomenon. The functional changes of the nerves may reduce the precision of nerve location and the effectiveness of the block itself despite the use of ultrasound. If the block was effective, the BMI did not influence the duration of the RFA effect, which may be a positive clinical impact. This conclusion can be stated with some confidence because studies analysing the interrelation between the occurrence of neuropathic pain and BMI have shown that neuropathic pain is higher in high-BMI patients [20, 21].

Our results are partly consistent with the conclusions drawn by Chen *et al*. [14], who gave obesity a positive role in predicting a good outcome after RFA of genicular nerves (but only in multivariate logistic analysis, OR 3.68, 95% CI 1.66 to 8.19, $P = 0.001$). As the authors stated in their discussion, this factor "fell shy of statistical significance", and was treated as an "unusual trend". They did not consider further the possible nature of this phenomenon. In addition, their analysis concluded that neither age nor gender was an influential factor, which stands in contrast to our results. However, these differences in study conclusions may arise from the previously mentioned difference in the definition of a positive outcome [14].

The sex of the patients was the last variable under analysis. Our results showed that RFA was more effective in women. There were more women in our study. This was not intended but resulted from the population profile of the patients reporting to the Pain Clinic. Previous research has revealed higher levels of pain and lower functional status in women with KO. Therefore, a higher percentage of women can be expected among patients presenting at clinics [22]. A similar predominance of women has been observed in other studies assessing the effectiveness of RFA in cases of KO. In eight analysed studies, only one showed a predominance of men, and this was a study of only eight patients, so the sample size was extremely low [4]. Future studies should consider the effectiveness of RFA in comparable groups of men and women. The possibility of sex differences affecting pathophysiological changes and the development of pathologies in the peripheral nervous system should also be investigated further. Al-Salmi *et al*. [23] conducted a neurophysiological study and found that sex had a significant influence on distal latencies and conduction velocities of some peripheral nerves in healthy Omani adult subjects. They suggested that different cut-off values for the two sexes could

be useful to interpret such findings. Sexual differences could be related to anatomical (differences between men and women in the height and length of the limbs) and/or physiological factors [23]. The study cited above is of particular importance because it involved examinations of the peroneal and tibial nerves, which innervate the lower limbs. Men with diabetes, which aggravates peripheral neuropathy, may have more frequent problems maintaining correct posture [24, 25]. On the other hand, females are at higher risk of polyneuropathy during alcoholism [26]. In short, the differences between men and women with respect to pathological changes in neural transmission are a complicated area of study. Further research on this issue is necessary.

In our study, patients experienced no serious complications after their treatment procedures. This is a noteworthy finding, since Kim *et al*. [27] reported vascular complications such as pseudoaneurysm, arteriovenous fistula, hemarthrosis and/or osteonecrosis of the patella. We also found no side effects of the drugs used for the diagnostic block. Comparably, Konya *et al*. [28] did not record any such complications in their group of 48 patients. However, Mather *et al*. [29] found that the administration of a local anaesthetic after the peripheral nerve block resulted in systemic toxicity in 7.5/10,000 cases and a mortality rate of 0.023/100,000 cases. However, such low rates of complications may not be detectable in studies of small patient groups.

To sum up the results of our research, we conclude that the treatment used was effective and safe, and the variables analysed in the study can be considered in terms of potential benefits for patients in the future. However, further research on the effectiveness and safety of RFA should be conducted on specific subgroups of patients to allow for the presence of additional diseases, especially diseases of the nervous and metabolic systems. In addition, the optimal timing of pRFA in patients suffering from chronic pain due to KO has yet to be determined. A holistic attitude towards KO patients should not only cover invasive methods, but also involve a full spectrum of rehabilitative exercises whose effectiveness in terms of pain relief and functioning (with good adherence to the exercise programme) was described by de Sire *et al*. [30]. Despite numerous reports advocating complex lifestyle and psychological intervention systems for the treatment of KO, future studies should seek to identify prognostic social factors, and consider stratified care models, transdisciplinary care delivery and technology augmented interventions, as Tan *et al*. [31] concluded in their review analysis. When analysing the material reported in this study, we are inclined to suggest that the method of pRFA should be applied to patients suffering from chronic pain due to KO, especially to older women with higher BMI, who seem to benefit especially from this technique.

LIMITATIONS OF THE STUDY

The study was retrospective. There was not a comparable number of men and women in the study. In addition, we did not apply functional, physical, and emotional parameters in the follow-up period. These data were incomplete and we were not able to include them in the study. We did not take into consideration other factors that could influence the RFA effect, e.g., history of drugs used, including opioids. Comparisons of duration of the pRFA between men and women may be considered biased due to the uneven number of participants in those groups.

CONCLUSIONS

pRFA of the nerves responsible for sensing in the knee joint seems to be a safe and effective method of treatment of chronic pain caused by degenerative lesions in this area. The factors age and sex influenced the effectiveness and duration of RFA treatment in patients analysed in our study. There was also interesting (though not significant) higher effectiveness of pRFA in high-BMI patients, worth further exploration.

Future studies may focus on larger groups of patients and pay special attention to prognostic factors captured in scales, enabling patients and clinicians to determine the most effective and safe RFA procedure.

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