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Influence of ultrasound therapy on volume of the synovial fluid in knee joint arthrosis (gonarthrosis)-initial reports

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SUMMARY

Aim of the paper: Aim of the study was impact assessment of the ultrasonic wave on production of synovial fluid in suprapatellar pouch, pain symptoms, and knee movement range.

Material and methods: The study group consisted of 23 patients that were diagnoses with excess of synovial fluid in suprapatellar pouch. The measurement of the fluid volume was made using ultrasound examination. Volume of the fluid < 4 mm is considered as positive result of the study. The data was collected with usage of a self-made study protocol. In assessment of pain symptom, the VAS scale was used.

Results: Statistically significant reduction of the synovial fluid volume in suprapatellar pouch ($p<0.0001$) was obtained. Worse result was notice in older patients ($p=0.2807$), and with greater body mass ($p=0.3346$). Statistically significant reduction of pain symptoms of knee joint at night ($p=0.0002$), and during walk on stairs ($p<0.0001$) was noted. In variable

assessment, “walk on the flat ground” had the strongest result (p=0.0001). After the therapy, knee mobility has improved. Improvement of flexion mobility is considered as a statistically strong result (p=0.0013).
Conclusions: Formed during the therapy, endogenous heat reduces the volume of synovial fluid in suprapatellar pouch. The result of the thermal therapy increases joint movement and decreases pain symptoms.

Keywords: ultrasound therapy, knee joint, suprapatellar pouch, arthrosis (gonarthrosis).

INTRODUCTION

Gonarthrosis is a chronic disorder which is accompanied by constant or periodic pain. Pain results from an acute or chronic inflammation process. The process is always accompanied by the synovial membrane. A histopathological image of membrane consists of overgrowth, infiltration, neoangiogenesis and stranding. Persisting inflammation of membrane leads to faster degradation of cartilage and soft tissues forming a joint [1,2]. Clinical symptoms of the membrane inflammation are pain, limited movement, and joint effusion resulting from overproduction of synovial fluid [1,2].
In knee joint, the synovial membrane develops multiple synovial bursae. Under the quadriceps muscle, 2-3 cm over the knee cap, there is articular cavity bounded with large suprapatellar bursa that creates suprapatellar pouch. Allocation of the synovial fluid in articular cavity is variable and conditioned by the position of the knee. In normal condition, it migrates to suprapatellar pouch performing its function. The main role of the synovial membrane is production and absorption of synovial fluid and selective transportation of joint blood-fluid [3].
Ultrasounds is a method used in a therapy to treat pain symptoms and degenerative changes of musculoskeletal system [4]. Range of therapeutic frequency wave is from 800 kHz to 3 MHz. Energy absorption depends on frequency, wave amplitude and acoustic impedance of a tissue. The thermal effect created in the tissue stimulates tissue metabolism, stimulates repair processes, diffusion of ions through the cell membrane, accelerates the analgesic and relaxing effect [4,5,6].
The aim of the study is evaluation of the impact of the ultrasonic wave on fluid volume of suprapatellar pouch, joint movement and pain symptoms in patients with gonarthrosis.

MATERIAL AND METHODS

Gathered data relates to 23 patients (9 males and 14 females). In case of two patients, both knees undergone a procedure (the number of studied knees: 25).
Average age of patients was equal to 65.7±12.3 years old, and among half of them the age were less than 66 years old (interquartile range IQR: 55-77) The youngest patient was 46 years old and the oldest was 84 years old.
The average value of the body mass index (BMI) was 27.7±4.8 kg/m^2 (min–max: 18.4-36). Among half of studied subjects, the scope of BMI was less than 27.5 (IQR: 24.6-31.20) kg/m^2. 8 patients (34.8%) weight was normal, 5 patients (21.7%) were diagnosed with overweight, and 10 patients (43.5%) with obesity.
10 studied subjects (43.5%) consisted of seniors, 5 patients declared that they work sedentary (21.7%), and 8 patients declared mixed type of work (34.8%).
The data was collected twice – before the therapy and right after it – in own study protocol. Criterion for inclusion was osteoarthritis of the knee (gonarthrosis) with overproduction of synovial fluid located in a suprapatellar pouch. Criterion for study exclusion was report of acute inflammation of the knee joint.

The Bioethics Committee of the Medical University of Łódz consent no. RNN/333/18/KE was obtained. The patients were informed about the study goal, they signed a written consent for conducting the studies. All patients were examined in accordance to the pre-set test protocol. In the study protocol, the patients were asked about their age, height, weight, kind of physical activity, and pain symptoms during rest, walk on the flat ground and on stairs. The subjective VAS scale was used to assess the pain. Ultrasound scan was performed with Echoson apparatus, linear head 5-12 MHz in the longitudinal position of the head at the base of the patella. During the study, patient took dorsal decubitus position with studied knee joint in 30° flexion. The first and second study was performed by the same person. The volume of fluid above 4 mm is considered as a positive result of the study.
Ultrasound therapy was performed with BTL apparatus, head with surface 4 cm², 1 MHz frequency and 3.5 W 0.8W/cm² power with 100% duty cycle and labile technique, making slow circular movement in suprapatellar pouch area with speed 4 s for full circular movement of the head. Duration of the procedure: 5 min. The test subject took dorsal decubitus position with half-roller beneath knee joint. The therapies were performed in series of 10 procedures, every day at the same time with Saturday-Sunday break. The obtained data underwent statistical analysis.

STATISTICAL ANALYSIS

The statistical package STATISTICA PL 13.3 was used for the calculations.
Variables measured on at least interval scale described by providing measures of location, median (Me) and interquartile range (IQR), and minimum and maximum (Min-Max). In case of variables with normal distribution, arithmetic mean and standard deviation (SD) were additionally given. Normality of variables was verified with Shapiro-Wilk normality test. For qualitative variables, the number of observations with a given feature variant (N) and corresponding percentage (%) were given.
To compare analyzed variables with inclusion of repeated measurements (before and after the therapy), due to the nature of studied variables, the non-parametric Wilcoxon signed-rank test was used. In addition, the size of the obtained effect was calculated (effect size) using measure of effect size for the Wilcoxon signed-rank test: $r = Z/\sqrt{N}$ (where Z stands for the value of the statistics Z in the Wilcoxon signed-rank test, and N stands for a sample size). The effect is considered as poor when $r \in (0.10\text{-}0.40)$, average when $r \in [0.40\text{-}0.60)$, and strong when $r \geq 0.60$ (these values were accepted after Salvatore S. Mangiafico, 2016, *Summary and Analysis of Extension Program Evaluation in R*, http://rcompanion.org/handbook/F_06.html).
For evaluation of correlation between qualitative variables the chi-square independence test was used, and where variables measured on at least ordinal scale calculated Spearman's rank correlation coefficients.
Statistical results were considered statistically significant at $p<0.05$.

RESULTS

In tab. 1 and fig. 1 presented results of the assessment of pain symptoms according to VAS scale at night, during walk on the flat ground and on stairs, before and after the therapy.

Tab. 1. The assessment of pain symptoms according to VAS scale at night, during walk on the flat ground and on stairs, before and after the therapy

Variable		Me (IQR)	Min-Max	p-value	Effect size
VAS (at night)	before therapy	2 (1-4)	0-8	0.0002	0.7406
	after therapy	2 (0-2)	0-5		
VAS (during walk on the flat ground)	before therapy	4 (2-6)	0-9	<0.0001	0.8178
	after therapy	3 (1-4)	0-8		
VAS (during walk on stairs)	before therapy	5 (3-8)	0-9	0.0001	0.7898
	after therapy	3 (1-5)	0-7		

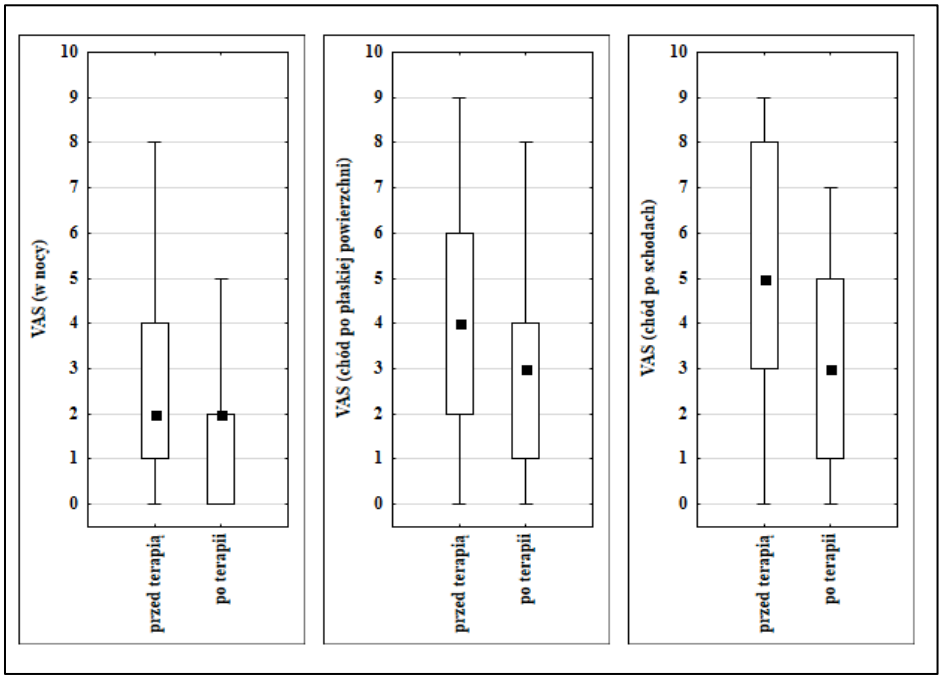

Fig. 1. The assessment of pain symptoms according to VAS scale at night, during walk on the flat ground and on stairs, before and after the therapy (Median/IQR/Min-Max)

Statistically significant reduction of pain symptoms (measured in VAS scale) has been observed after the therapy, both at night (p=0.0002) and during walk on the flat ground (p<0.0001) and on stairs (p=0.0001). In each case, the effect obtained should be considered as strong, while the improvement is most noticeable during walk on the flat ground (Me (IQR) accordingly: 4 (2-6) before the therapy vs 3 (1-4) after the therapy), and during walk on stairs (accordingly before and after the therapy: Me (IQR): 5 (3-8) vs 3 (1-5)).

No statistically significant dependence was noted between reduction of pain symptoms (measured in VAS scale) and patients' gender, type of occupation, range of body mass index and age.

In tab. 2 and fig. 2 the assessment results of flexion movement range before and after the therapy in studied group of patients. Statistically significant (p=0,0013) improvement of flexion movement range after therapy has been observed.

Tab. 2. Assessment of flexion movement range before and after the therapy

Variable		Me (IQR)	Min-Max	p-value	Effect size
Flexion	before therapy	100 (90-110)	60-120	0.0013	0.6424
	after therapy	110 (100-120)	60-120		

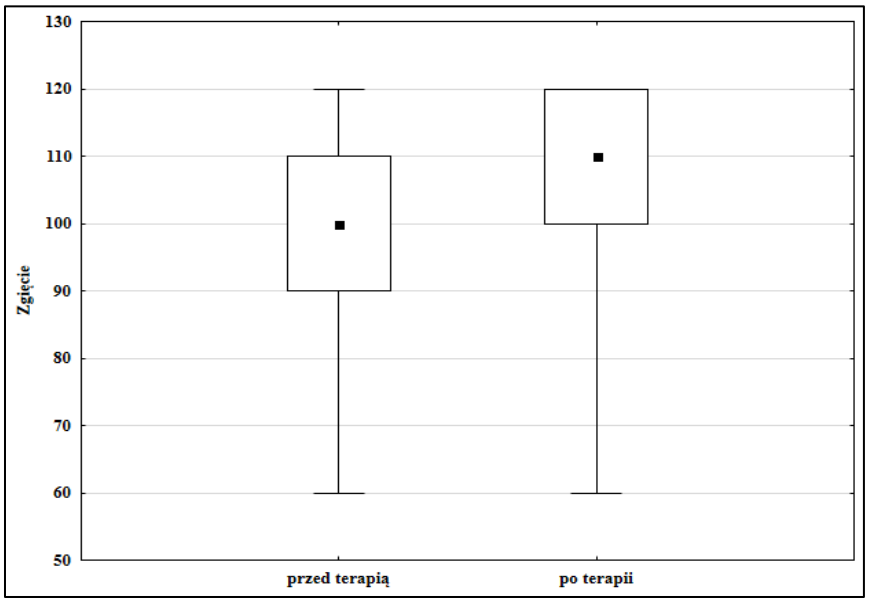

Fig. 2. Assessment of flexion movement range before and after the therapy (Median/IQR/Min-Max)

Before the therapy, among the half of patients the flexion movement range it did not exceed 100° (IQR: 90°-110°); after the therapy the improvement of movement range was noted to (on average) 110° (IQR: 100°-120°). The obtained effect should be considered strong.
No statistically significant dependence was noted between improvement of flexion movement range and patients' gender, type of occupation, range of body mass index and age.
In tab. 3 and fig. 3 the assessment results of changes in fluid volume in knee joint before and after the therapy. Before the therapy, among the half of patients the volume was less than 7.7 mm (IQR: 6.5-12.1 mm). After the therapy, statistically significant ($p<0.0001$) reduction of fluid volume was noted – Me (IQR): 5.5 (4.2-8.6) mm. The obtained effect is very strong.

Tab. 3. Assessment of fluid volume before and after the therapy

Variable		Me (IQR)	Min-Max	p-value	Effect size
Fluid volume (mm)	before therapy	7.7 (6.5-12.1)	5.4-21.7	<0.0001	0.8746
	after therapy	5.5 (4.2-8.6)	2.9-13.2		

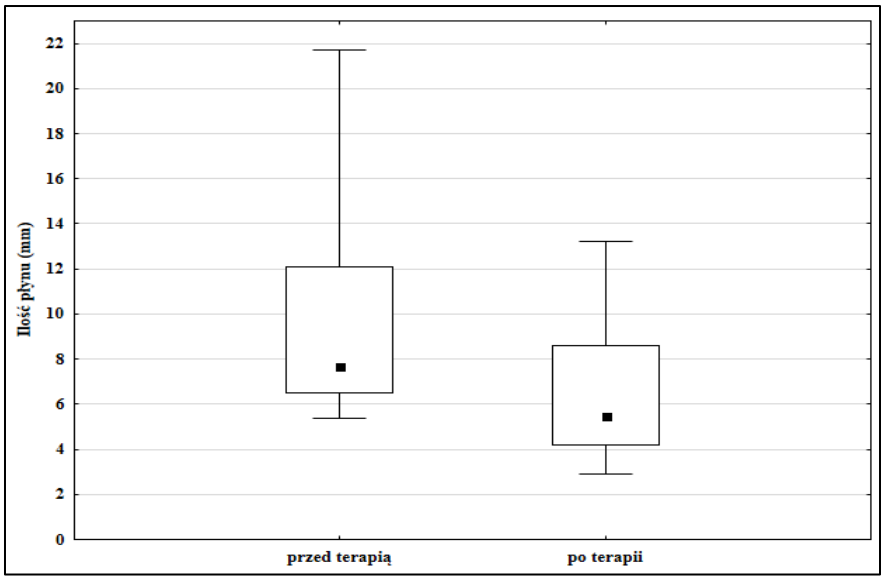

Fig. 3. Assessment of fluid volume before and after the therapy (Median/IQR/Min-Max)

It is important to notice that the reduction of the fluid was noted in patients after the therapy. In addition, the percentage of the fluid volume change was calculated after the therapy, the results were presented in fig. 4. The half of patients showed the reduction of fluid volume at most 29.7% (IQR: 19.4-45.6%).

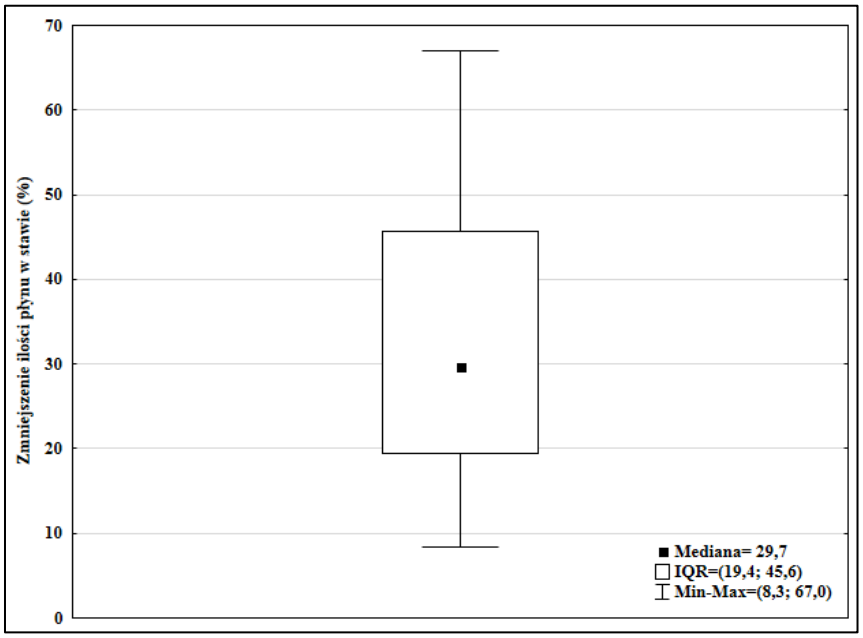

Fig. 4. Assessment of fluid volume changes after the therapy (in %)

No statistically significant dependences were noted between reduction of the knee effusion (knee joint fluid) patients' gender, type of occupation, range of body mass index and age. However, it can be noted that treatment results are worse in older and with larger body mass patients (Spearman's rank correlation coefficient R=-0.2245; p=0.2807 for age, and R=-0.2013; p=0.3346).

DISCUSSION

Ultrasounds are commonly used method used in a therapy of degenerative changes of a knee joint [6,7,8,9]. The results of the therapy depend on energy intensity, duration and the tissue property. Produced endogenous heat is the basis to initiate biophysical and biochemical changes in tissue [5]. The most important biological effects are improvement of blood circulation and stimulation of cellular metabolism.

Gonarthrosis is a chronic disease and impacts the life quality of a patient [10]. Accompanying pain relates to every fourth person in the population over 55 years old [11]. Eitner et al. reviewed the mechanisms associated with degenerative pain. The authors pointed out three areas of pain genesis: processes occurring in the knee joint, neural mechanism and coexistent diseases [12]. Chojnacki et al. indicate a multifaceted and complex etiology of degenerative disease of local inflammatory nature [10]. In the pain etiology analysis of progressive degenerative changes of knee, many authors emphasize role of the synovial membrane [1,2]. Sarmanaowa et al., Hall et al. agree that locally ongoing inflammation of the synovial membrane is the cause of pain symptoms, overproduction of synovial fluid and limited movement of the joint [11,13].

Rodriguez-Grande et al. by studying the impact of ultrasonic wave on pain symptoms, joint movement, muscle strength and life quality of persons that suffers from gonarthrosis, confirm the effectiveness of the therapy [6]. Ciosek et al. obtained similar effects by assessing the impact of ultrasounds on pain symptoms and movement range of the joint. Zhang et al. in randomized, double-blind analysis of clinical study positively assessed the impact of pulsed and continuous ultrasonic waves on the pain symptoms and mobility of the joint. Draper et al. obtained similar results. As a result of the analysis of their clinical studies, they propose ultrasound as a non-invasive treatment method of gonarthrosis [9,14,15]. In own studies, the reductions of pain symptoms and increase of movement range, also was obtained($p=0.0013$). Statistically significant results were noted in the assessment of each variable related to pain symptoms, whereby, the strongest positive change was noted during “walk on the flat ground” ($p<0.0001$).

Thermal therapy on the joint with synovial fluid pathology is an effective method [16]. Anand et al. by studying the impact of short-wave diathermy on pain symptoms and thickness of the knee joint synovial membrane, they noticed that it is a sensitive marker correlating with joint pain. After three therapeutic sessions, authors obtained reduction of the membrane thickness by 20.58% [8]. In own study, which is a pilot study of extensive research work, the effect of ultrasound on synovial hypertrophy was not assessed, but on the amount of synovial fluid accumulated in suprapatellar pouch. Statistically analyzed data allows stating initially that the applied ultrasonic wave with a thermal effect reduces synovial fluid volume in suprapatellar pouch. The difference after the therapy was noted in each patient. The half of patients showed the reduction of fluid volume at most 29.7% However, it can be noted that treatment results are worse in older $p=0.2807$ and with larger BMI $p=0.3346$ patients.

Aim of the conducted study was preliminary assessment of the ultrasound therapy impact on the volume of synovial fluid and pain symptoms resulting from gonarthrosis. Collected clinical material is insufficient and require further studies. In case of obtaining permanent effect of the therapy with usage of ultrasounds, it can be an alternative tool for evacuating excess amount of synovial fluid.

CONCLUSIONS

1. Ultrasonic wave impacts the reduction of pain symptoms and increases movement range of the knee joint.
2. The endogenous heat resulting from the application of the ultrasonic wave reduces the volume of synovial fluid in the knee.

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