Research Paper: Neuromuscular Electric Stimulation Versus Traditional Treatment on Harris Hip Score in Cases of Avascular Necrosis of Femoral Head After Kidney Transplantation

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Citation Youssef M. Neuromuscular Electric Stimulation Versus Traditional Treatment on Harris Hip Score in Cases of Avascular Necrosis of Femoral Head After Kidney Transplantation. Physical Treatments. 2021; 11(3):181-188. http://dx.doi.org/10.32598/ptj.11.3.439.3

doi: http://dx.doi.org/10.32598/ptj.11.3.439.3

Article info:
Received: 03 Jul 2020
Accepted: 20 Apr 2021
Available Online: 01 Jul 2021

Keywords:
Avascular necrosis, Femoral head, Physical activity, Neuromuscular electric stimulation, Exercise, Infrared

ABSTRACT

Purpose: Usually, about 25% of the patients treated with corticosteroids after kidney transplantation suffer from the complication of Avascular Necrosis (AVN) of the femoral head.

This study aims to compare the effect of Neuromuscular Electric Stimulation (NMES) and traditional treatment (infrared and decrease weight-bearing) on Harris hip score.

Methods: Twenty patients who developed AVN of the femoral head after kidney transplantation were divided into two groups. The first group was treated by NMES and stretching and strengthening exercises 3 sessions a week for 3 months. The second group was treated by Traditional Treatment (TT) and stretching and strengthening exercises 3 sessions a week for 3 months.

Results: Harris hip score component was measured before the intervention and then three months after the intervention using the t-test. After the intervention, significant differences were found between both groups in pain, support, distance walked, limping, putting on shoes and socks, climbing stairs, sitting, flexion (all P<0.001), external rotation (P=0.014), abduction (P=0.030), adduction (P<0.001), public transportation (P=0.010), and total hip score (P<0.001).

Conclusion: TT exercises accompanied by NMES were more effective than TT alone for AVN of femoral head patients and could stop the progressive worsening of hip joint mobility.

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Highlights

- Avascular necrosis is ischemic bone necrosis affect the femoral condyles, tibial plateau, talus, and humeral head.
- The prevalence is typically 6% to 15% but may be as high as 52% in patients treated with high-dose of corticosteroids.
- In renal transplant patients, the ischemia occurs very early, often within 12 weeks of transplantation.
- Patient experience pain, limitation of ROM and limping during activity of the hip. By activity insidious onset of pain will appear and with disease progression, pain occur at rest and affect ROM and function.

Plain Language Summary

After transplantation, inactivity and postoperative malnutrition lead to BMI and muscle atrophy, pre-exciting metabolic bone disease or mass accompanied by treatment by immunosuppressive therapy such as high doses of corticosteroids, lead to cellular hypertrophy and toxicity. Fat embolism is formed due to elevated lipid levels lead to micro emboli and endothelial cell changes causing venous stasis, an increased intra-osseous pressure and bone necrosis. Once osteonecrosis begins, 80% of the femoral heads will collapse, if not treated. Conservative treatment options including bed rest, reduced weight bearing, analgesics, deep heat modalities, braces, and ROM exercises but unfortunately, pain des not relieved 100%. AVN characterized by inflammatory changes and ischemia which occur in the first stage and lead to pain and edema. Using of NMES during early stage increase cell membrane adenosine receptors which have an anti-inflammatory effect accompanied by decrease the production of free radicles and this lead to decrease the pain. The anti-inflammatory effect reduced by NMES, decrease the breakdown of the cartilage and increase angiogenesis and improve bone formation through increase osteoblasts and decrease the osteoclasts.

1. Introduction

Avascular Necrosis (AVN) is also called aseptic necrosis of bone, ischemic bone necrosis, osteochondritis dessecans, and osteonecrosis [1]. Femoral condyles, tibial plateau, talus, and humeral head may be affected. Its prevalence is 6% to 15% and rises by 52% in patients under high-dose corticosteroids. Also, AVN is seen in 85% of cases [2, 3].

After transplantation, inactivity and postoperative malnutrition result in low Body Mass Index (BMI) and muscle atrophy. There is a history of metabolic bone disease, mass accompanied by immunosuppressive medication such as high dosages of corticosteroids, cellular hypertrophy, and toxicity. Elevated lipid levels cause microemboli, and along with endothelial cell changes, venous stasis occurs. These changes lead to increased intra-osseous pressure and bone necrosis [4].

The ischemia occurs very soon in renal transplant patients, often within 12 weeks of transplantation. Symptoms may not appear that soon, but within two years, most patients are diagnosed [5, 6]. This disease mainly affects the femoral head. Once osteonecrosis begins, 80% of the femoral head will ruin if not treated [7].

The patients started to complain in the third, fourth, and fifth decade of their life; men are more affected than women with a ratio of 4:1. At the beginning of femoral head AVN, it is asymptomatic, but with the progression of the disease, patients experience pain, reduced Range Of Motion (ROM), and limping during the hip joint activity [1, 8]. By activity, the pain will appear insidiously, and with disease progression, pain occurs at rest and affect ROM and function [9].

In the latter stages, as joint deformity and muscle wasting develop, active and passive ROM is lost, most frequently in abduction, flexion, and internal rotation of the affected hip. Positive Trendelenburg sign and click is heard when the patient is asked to rise from a seat or after external rotation of the abducted hip [10].

Conservative treatment options include bed rest, reduced weight-bearing, analgesics, deep heat modalities, braces, and ROM exercises. Unfortunately, pain is not entirely relieved [11]. Hip MRI is the most reliable tool in the diagnosis of AVN and also helps to determine its stage [12].

2. Materials and Methods

All study procedures were done following the ethical standards of the 2000 revision of the Helsinki Declaration. All patients were asked to sign an informed consent for study participation after a full explanation of the procedures.

Study subjects

This study was conducted on 20 patients (13 men and 7 women) admitted to Cairo University Hospitals. All patients had kidney transplantation surgery 1-4 years ago and were under immunosuppressive corticosteroid treatment after surgery. They were 37 to 45 years old. The patients were diagnosed according to their clinical manifestations and confirmed by MRI. All patients had AVN of femoral head grades from II to IV. The patients were randomly divided into two groups: the first group was treated by Neuromuscular Electric Stimulation (NMES) along with stretching and strengthening exercises, and the second group by Traditional Treatment (TT) with stretching and strengthening exercises. The exclusion criteria were diabetic patients, extensive destruction of the femoral head and joint, and obese patients with a BMI of ≥35 kg/m^2.

Evaluative procedures:

ROM (Range of Motion): By goniometer, we compared the range of motion of the affected hip with the normal side to detect subtle limitations or painful movements [13].

Muscle Testing: Manual muscle test was used to assess the strength of hip flexors, extensors, internal and external rotators of the hip joint, and particular muscle groups that are the source of pain [14].

Harris Hip Score (HHS): It is a pain scale and assesses sitting, limping, ascending stairs, support, putting on shoes and socks, enter public transportation, distance walked, range of motion, absence of deformity, total HHS. The evaluation was used before and after the application of treatment of both groups [15, 16].

Treatment procedures

Group 1: The patients received a 30-min session of NMES around their hip joints. One electrode is placed on the greater trochanter of the femoral head and the other on the gluteus maximus muscle for 30 min using the Healthtronic three channels model (BM 1006). The electrode size is 10×9.4 cm. Electric stimulation is the process of using an electrical impulse to contract and relax the gluteus maximus muscle. The current intensity was adjusted according to the patient's tolerability. The device was set for 20 s of stimulation followed by 4 s relaxation.

The session was followed by another 30 min of stretching and strengthening exercises of the affected lower limb and active exercise for the normal limb. Strengthening exercises involve hip joint muscles, knee flexors and extensors, ankle dorsiflexors, and plantar flexors. Each exercise was done in 5 sets, with 10 repetitions in each set [17]. The patient can relax whenever they want. The resting period between each exercise is 1-2 min. The stretching exercise for external rotators and abductors are done with 30 repetitions interrupted with a resting period when the patient wants. Stretching positions are taught to do at home, too. The intervention was done 3 sessions a week for 3 months.

Group 2: TT consists of infrared and exercises. Infrared as a method of heating improves circulation by providing vasodilatation so that it can relieve pain. It is applied on the hip joint for 20 min at 0.45 to 0.60 cm, according to the patient's sensation of warmth [11].

Statistical analysis

All the obtained data are presented as the Mean±SD. They were analyzed using the independent t-test. The statistical significance was set at a confidence level of 95% ($P<0.05$). Pre- and post-treatment analyses were done in Minitab version 13.1.

3. Results

A total of 20 patients consisting of 13 men (65%) and 7 women (35%) participated in this study. They were between 37 and 45 years old. Before treatment, no significant differences were found between study groups regarding pain (P=0.343), support (P=0.727), distance walked (P=0.591), limping (P=0.591), putting on shoes and socks (P=0.104), climbing stairs (P=0.193), public transportation (P=0.343), sitting (P=0.343), flexion, (P=0.6420), abduction, (P=0.193), external rotation (P=0.678), adduction (P=0.343), and total Harris hip score (P=0.074).

However, after treatment, significant differences were found between the two groups regarding pain ($P< 0.001$), support ($P<0.001$), distance walked ($P<0.001$), limping ($P<0.001$), putting on shoes and socks, ($P<0.001$), climbing stairs ($P<0.001$), sitting ($P<0.001$), flexion, ($P<0.001$), external rotation ($P<0.001$), public transportation (P=0.010), abduction, (P=0.030), adduction ($P<0.001$), and total hip score (P=0.016).

Table 1. Pre- and post-treatment for neuromuscular electric stimulation (group 1) and traditional treatment (group 2)

Variables	Mean±SD		P	Mean±SD		P
	Per-treatment			Post-treatment		
	Group 1	Group 2		Group 1	Group 2	
Pain	4.7±0.67	5.00±0.82	0.343	2.2±0.79	4.7±0.95	≤0.001
Support	5±0.82	4.9±0.74	0.726	2.2±0.79	4.5±0.85	≤0.001
Distance walked	4.5±0.53	4.6±0.52	0.591	4.6±0.51	4.1±0.74	≤0.001
Limping	3.89±0.33	3.8±0.42	0.591	2.33±0.5	3.6±0.51	≤0.001
Putting on shoes, socks	2.4±0.52	2.8±0.42	0.104	1.4±0.51	2.7±0.48	≤0.001
Climbing Stairs	1.4±0.51	3.2±0.42	0.193	2.7±0.48	3.1±0.57	≤0.001
Public transportation	1.9±0.32	2.0±0.00	0.343	1.2±0.42	1.7±0.48	=0.010
Sitting	2.7±0.48	2.9±0.32	0.343	1.7±0.48	3.00±0.00	≤0.001
Hip flexion	3.4±1.17	2.2±0.92	0.642	10.00±1.49	4.7±1.05	≤0.001
Abduction	1.7±0.48	1.4±0.52	0.193	3.9±0.57	3.0±0.94	=0.030
External rotation	1.3±0.48	1.4±0.52	0.678	3.2±0.42	3.2±0.42	≤0.001
Adduction	1.2±0.42	1.3±0.48	0.343	3.2±0.42	2.6±0.70	≤0.001
Total hip score	63.6±22.7	62.4±1.58	0.074	64.4±2.17	72.1±2.42	≤0.001

PHYSICAL TREATMENTS

P≤0.001 is highly significant, P≤0.005 significant.

4. Discussion

To the best of our knowledge, this is the first study that compares TT of physical therapy with new methods like NMES. Also, it is the first study that measures the effect of different Physical Therapy (PT) modalities on HHS. There are no significant differences between the groups in the component of HHS before the treatment in pain, support, distance walked, limping, putting on shoes and socks, climbing stairs, abduction, adduction, external rotation, hip flexion, public transportation, sitting, and total hip score. However, after three months of treatments, there were significant differences in all components of HHS in the NMES group and non-significant differences in the TT group (Table 1).

Premkumar et al. [6] conducted a meta-analysis to find the effect of TT for AVN of the femoral head. They reported that 80% of 819 patients had a negative outcome followed for 34 months without weight-bearing. So, they concluded that the TT is ineffective in the treatment of AVN of the femoral head. Unfortunately, traditional drugs and PT methods continue to be used despite their ineffectiveness.

Kaushik et al. [18] found that preventing the weight-bearing (with a cane, crutches, or walker), with the modification of activity, and traditional PT is ineffective in treating late-stage AVN (the third and fourth stage). Also, it failed to prevent disease progression, even in the early stages (Steinberg stage I and II).

Bogdan et al. [8] found that conservative treatment of 30 sessions of hyperbaric oxygen therapy, using non-steroidal anti-inflammatory drugs, cold packs, ROM exercises, and bed rest cannot relieve pain. However, in some early cases (Steinberg Stage-I, II), low weight-bearing, restricting activities, or using crutches can stop the damage due to AVN and allow natural healing. Still, these patients have an 85% risk of femoral head collapse. When the involved segment is smaller than 15%, the protected weight-bearing may be effective and located far from the weight-bearing region. ROM and strengthening exercises can maintain joint function as it prevents muscle weakness and keeps joint mobility, but it did not prevent disease progression. This finding agrees with the present study TT has increased only 1 point in Harris hip score,

which indicates the improvement of patient's activity of daily living as presented in Table 1.

Several studies documented the effect of NMES in reducing pain in spinal cord injury [19, 20], neck pain [21], patellofemoral pain [22], shoulder pain [23], and pain associated with endometriosis [24]. AVN is characterized by inflammatory changes and ischemia, which occur in the first stage and progresses to pain and edema. During the early stage, NMES increases cell membrane adenosine receptors which have an anti-inflammatory effect accompanied by a decrease in the production of free radicles and consequently lowering the pain [25]. NMES reduces the anti-inflammatory effect, thereby decreasing the breakdown of the cartilage, increasing angiogenesis, and improving bone formation through an increase in osteoblasts and decrease in the osteoclasts [26, 27].

Stimulation of the femoral head anteriorly and posteriorly for a long period induces the recovery of bone ischemia through 1) increase in the production of growth factors and increase osteoblasts activity, 2) formation of new vessels that stop the extension of necrosis to another area, and 3) decrease in the parathyroid hormones leading to decrease the activity of the osteoclasts [28]. So NMES may be an excellent tool that helps in treating patients with AVN of the femoral head. Some studies stated that physical therapy could be used in combination with core decompression and even replace it. A study compared core compression and bone grafting associated with PT with core compression and bone graft alone. The results revealed hip progression 70% with 5 points improvement in HHS compared to 79% progression and 3 points improvement in Harris score in decompression group. This finding supports the present study results, as HHS increased 8 points in the NMES group and 1 point in the TT group.

Marchese et al. [14] conducted a study on 38 patients with sickle cell disease (17 received hip core decompression with physical therapy and 21 received physical therapy alone). The physical therapy protocol comprises the weight-bearing limitation of toe-touch weight bearing on the affected hip for the initial 6 weeks of the study. If the patient's one hip has osteonecrosis, he or she was asked to use a crutch or a walker. And if both hips were affected, the patient was asked to use a wheelchair during mobility. The researchers stated the relation between pain, ROM, and functional mobility. Also, stretching and strengthening exercises were administered once or twice a week to assist with the home exercise program for 3 months. That study reported that PT alone seems to be as effective as hip core decompression followed by PT. In the NMES group, there is a decrease in pain scale accompanied by an increase in the ROM and activity of daily living (Table 1). However, the TT group showed no significant difference in any component of HHS.

Neumayr et al. [29] compared the results of core decompression followed by a PT program with a physical therapy program alone on 38 patients (46 hips) with sickle cell disease and Steinberg Stage-I, -II, or -III. No intraoperative and postoperative complications occurred in 17 patients who received decompression combined with PT and 21 patients who received PT alone. After three years of follow-up, the hip survival rate was 82%, with 18.1 points improvement in HHS in the group treated with decompression and physical therapy and 86% hip survival and 15.7 points improvement in HHS in the group treated with PT alone. These findings support and explain the results of the present study. NMES created a significant difference in all evaluation parameters (Table 1); in other words, total HHS increased 8 points in the NMES group while only 1 point in the TT group.

5. Conclusion

The study revealed that NMES is more effective than TT in relieving pain and empowering the muscles around the hip. These effects improved Harris hip score and activity of daily living in patients treated with NMES.

Ethical Considerations

Compliance with ethical guidelines

All the participants were informed about the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975. Informed consent was obtained from all patients.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Conflict of interest

The author declared no conflict of interest.

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