
THE EFFECT OF HYPERBARIC OXYGEN (HBO) ON PERIPHERAL PERFUSION OF GANGRENIC WOUNDS IN DM PATIENTS AT Dr. RAMELAN NAVAL HOSPITAL SURABAYA

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ABSTRACT

Introduction

As a result of development in Indonesia, disease patterns have undergone a significant shift. This shift in disease patterns is thought to be related to changing lifestyles, for example, dietary patterns. These changes are evident in the consumption of foods that are high in carbohydrates, protein, fat, sugar, salt, and low in fiber. This increases the risk of several diseases, including diabetes mellitus (DM).

Method

This quasi experimental research with non equivalent control group design pre-post test approach, aim to identify HBO influence against peripheral perfusion of gangrene Diabetes mellitus patients in Dr. Ramelan Hospital, Surabaya

Result

The results of research on 40 respondents which were taken by consecutive sampling, showed there was a significant difference in peripheral perfusion after giving HBO group intervention and control ($p=0.001$). a significant difference on peripheral perfusion before and after given HBO intervention and control group ($p=0.005$)

Conclusion

Concluded by Hyperbaric oxygen has an effect on peripheral perfusion of gangrene in diabetic mellitus patients from finger tips, CRT and oxygen saturation .

INTRODUCTION

As a result of development in Indonesia, disease patterns have undergone a significant shift. This shift in disease patterns is thought to be related to changing lifestyles , for example, dietary patterns. These changes are evident in the increased consumption of foods containing excessive amounts of carbohydrates, protein, fat, sugar, salt, and low levels of fiber. This

increases the risk of several diseases, including diabetes mellitus (DM) (Suyono, 2006). In diabetic patients with gangrenous wounds, improving perfusion is absolutely essential because it significantly aids in the transport of oxygen and blood to damaged tissue. Good peripheral perfusion in the wound will also improve the wound healing process, and vice versa. Perfusion is closely related to the adequate transport or

distribution of oxygen to all cell layers and is a crucial element in the wound healing process (Smeltzer & Bare, 2002). Adequate perfusion provides oxygenation and nutrition to body tissues and cells. Good perfusion is characterized by the presence of good clinical signs in the wound, namely warmth, a normal capillary refill time (CRT), and normal oxygen saturation.

HBO therapy can theoretically increase the amount of dissolved oxygen in such a way that it will be more easily accepted by the

tissue. The use of HBO will increase vascularization and tissue perfusion, so that it will be able to supply the oxygen needs of injured tissue. This is the basis for this therapy to be used to improve perfusion in wound tissue that experiences hypoxia, because the presence of hypoxia in the tissue will cause a long wound healing process (Guritno, 2005). The purpose of this study was to identify the effect of HBO on peripheral perfusion of gangrenous wounds in patients with diabetes mellitus at Dr. Ramelan Naval Hospital Surabaya.

MATERIALS AND METHODS

This research method is quasi-experimental, with a Nonequivalent Control Group Pre-post test Design approach. The sample size is 40 respondents taken by consecutive sampling at RSAL Dr. Ramelan Surabaya. Data analysis uses the T-test for numerical data and Chi-square for categorical data, with a confidence level of 95%.

Inclusion criteria

- a. DM patients with _angrene
- b. First time receiving HBO therapy
- c. Get wound care every day
- d. Willing to be a respondent

RESULT

Table 1. Differences in peripheral perfusion between the intervention and control groups before HBO was performed.

Perfusion before HBO					
		Bum	Good	Total	P
		n	n	N	
klpk	Inter	18 (90%)	2 (10%)	20 (100%)	1.00
	cont	18 (90%)	2 (10%)	20 (100%)	
amount		36	4	40	

The results of the analysis above can be illustrated that peripheral perfusion before HBO was performed in the intervention and control groups was that 18 (90%) respondents had poor perfusion, while only 2 (10%) respondents had good perfusion.

The results of the statistical test obtained a p value = 1.00 which means there was no significant difference between the intervention and control groups before HBO was performed.

Table 2. Differences in peripheral perfusion between the intervention and control groups after HBO

		Perfusion after HBO			p
		Bum	Good	Total	
		n	n	N	
kl pk	Inter	6 (30%)	14 (70%)	20	0.001
	control	17 (85%)	3 (15%)	20	
Amount		23	17	40	

The results of the analysis above can be seen that peripheral perfusion after HBO in the intervention group was poor in 6 (30%) respondents, and good perfusion in 14 (70%) respondents. Meanwhile, in the control group, 17 (85%) respondents had

poor perfusion and 3 (15%) respondents had good perfusion. The results of the statistical test obtained a p value = 0.001, which means there was a significant difference in the intervention and control groups after HBO.

Table 3. Differences in peripheral perfusion before and after HBO in the intervention group

		Post HBO perfusion			
		Bum	Good	total	p
Pre HBO perfusion	Bum	6 (33.3%)	12 (66.7%)	18 (90%)	0.001
	Good	0 (0.0%)	2 (14.3%)	2 (10%)	
amount		6	14	20	

The results of the analysis above can be seen that peripheral perfusion before HBO was administered in the intervention group was 18 (90.0%) respondents whose

perfusion was not good, then given HBO it became 12 (66.7%) respondents who were good and the remaining 6 (33.3%) respondents were still not good. While good

perfusion before being given HBO was 2 (10.0%) respondents, after being given HBO it remained good in 2 (14.3%) respondents. The results of the statistical test obtained a

p value = 0.001 which means there was a significant difference between before and after HBO was administered in the intervention group.

Table 4. Differences in peripheral perfusion before and after HBO group control

		Post HBO perfusion			
		Bum	Good	total	p
Pre HBO perfusion	Bum	16 (88.9%)	2 (11.1%)	18 (90%)	1,000
	Good	1 (50%)	1 (50%)	2 (10%)	
amount		6	14	20	

The results of the analysis above can be seen that peripheral perfusion in the control group in the first measurement was 18 (90.0%) respondents whose perfusion was not good, then in the second measurement it became 16 (88.9%) respondents who remained not good and 2 (11.1%) respondents who became good. While good perfusion in the first measurement was 2

(10.0 %) respondents, in the second measurement it became 1 (50.0%) respondents who were not good and 1 (50.0%) respondents who remained good. The results of the statistical test obtained a p value = 1,000 which means there was no significant difference in the control before and after HBO was administered.

DISCUSSION

The results of the study showed that there was no difference in peripheral perfusion in the intervention and control groups before HBO was performed. In the intervention group, 18 (90%) respondents had poor perfusion, while only 2 (10%) respondents had good perfusion. Meanwhile, in the control group , 18 (90%) respondents had poor perfusion and 2 (10%) respondents had good perfusion. The statistical test results obtained a p value of 1.000, so it can be concluded that there was no significant difference in peripheral perfusion before

HBO was performed in the intervention and control groups.

Based on the acral values, 5 respondents in the intervention group had warm acral and 15 respondents with non-warm acral. Meanwhile, in the control group, 2 respondents had warm acral and 18 respondents with non-warm acral. The statistical test results showed a p value of 0.375, indicating no significant difference in acral values before HBO between the intervention and control groups .

In addition to acral, another sign that supports the absence of differences in peripheral perfusion before HBO is the CRT. The average CRT of the intervention group before HBO was 6.25 seconds, while the average CRT of the control group before HBO was 7.05 seconds, the difference before and after HBO was 0.80 seconds. The statistical test results obtained a p value = 0.478, so it can be concluded that there is no significant difference between CRT before HBO in the intervention and control groups.

In addition to the two assessments above, perfusion was also assessed based on the oxygen saturation value contained in the blood. The average oxygen saturation in the intervention group was 95.65 % , while in the control group the average oxygen saturation was 95.50%. The statistical test results obtained a p-value of 0.511, indicating no significant difference in oxygen saturation between the intervention and control groups.

According to Clayton & Tom (2009) , CRT disorders were found in DM patients with gangrene. This is caused by the presence of several damaged blood vessels and the possibility of peripheral vascular insufficiency, which affects the amount of blood flow to the periphery. Falanga and colleagues demonstrated in their study that

6 (30%) respondents had poor perfusion . Meanwhile, in the control group, 17 people (85%) had poor perfusion while the remaining 3 people (15%) had good perfusion. The results of the statistical test obtained a p value = 0.001, which means there was a significant difference in the intervention and control groups after HBO.

hypoxia increases TGF- β synthesis and secretion by fibroblasts in vitro and reduces pro-collagen 1 expression. Siddiqui and colleagues also demonstrated that acute hypoxia increases fibroblast proliferation, collagen synthesis, and TGF- β 1 mRNA expression. Chronic hypoxic conditions reduce these activities , but this reduction is reversible when the cells are returned to a higher oxygen environment. In addition, ROS (radical oxygen species) generated from oxidative stress also induce fibroblast growth factors.

According to Guyton & Hall (2006), the process of oxygen transport and tissue oxygenation is directly influenced by the cardiovascular and hematological systems. Oxygen saturation is determined by the chemical process of oxyhemoglobin in the body. SaO₂ examination with pulse oximetry is an examination to determine oxygenation capacity. Although pulse oximetry cannot replace arterial blood gas analysis, it is an effective way to monitor patient oxygenation. A decrease in blood flow to the peripheral area causes a decrease in oxygen saturation. This is supported by the results of research that found a decrease in oxygen saturation in the examination of the distal part of the toes that have gangrenous wounds (Smeltzer, et al, 2008).

According to the results of Efrati's research in his research on the effects of HBO in non-healing vasculitis, it was stated that administering HBO would increase the number of vasculatures, increase fibroblasts and osteoblasts, and also increase angiogenesis, 80% of wound healing was good, increased capillary diffusion in tissue

ischemia and oxygen saturation became better.

Niinikoski (1999) stated that administering HBO 2.5 ATA for 90 minutes every 7 days has an impact on increasing tissue oxygen, initially increasing vasoconstriction, then vasodilation, increasing the body's antibiotic effect, and helping wound healing. The HBO method in principle is started with the administration of 100% O₂, a pressure of 2-3 Atm, followed by decompression sickness treatment. This will cause tissue damage, wound healing, hypoxia around the wound. This condition will trigger an increase in fibroblasts, collagen synthesis, increased leukocyte killing, and angiogenesis which causes neovascularization of the wound tissue. Then there will be an increase and improvement in microvascular blood flow. Increased capillary density causes the ischemic area to experience reperfusion. In response, there will be an increase in NO up to 4-5 times accompanied by the administration of hyperbaric oxygen 2-3 ATA for 2 hours. This therapy is most often performed on patients with diabetes mellitus who have wounds that are difficult to heal due to poor peripheral perfusion and tissue oxygenation in the distal area. So it can be said that the acral change from not warm to warm is caused by the effect of administering HBO (Mathieu, 2006).

In this study, administering HBO to patients with gangrene had a positive impact on perfusion, helping to increase perfusion in the area affected by gangrene. Changes in capillaries are passive and influenced by changes in the construction of the blood vessels that carry blood to and from the capillaries. Capillary diameter also changes with chemical stimuli. Some capillary beds,

such as those at the fingertips, have arteriovenous anastomoses, allowing blood to pass directly from the arterial system to the veins. These vessels are believed to regulate heat transfer between the body and the external environment. The distribution of capillaries throughout the tissue varies depending on the tissue type. Capillaries merge into large blood vessels called venules, which in turn merge to form veins. Therefore, the venous system is analogous to the arterial system (Black & Hawk, 2005).

According to Guritno (2005), one of the effects of HBO related to the partial pressure of oxygen in plasma is modulating the oxygen pressure production of nitric oxide (NO). The synthesis of nitric oxide (NO) by the vascular endothelium is responsible for vasodilator tone, which is important for blood pressure regulation. In the periphery, there is a widespread network of nerves, previously known as nonadrenergic and noncholinergic. Some forms of neurogenic vasodilation in the peripheral nervous system are mediated through NO-dependent mechanisms. Furthermore, exposure of endothelial cells to hyperglycemia will increase the formation of superoxide which can dampen the activity of NO. NO is a powerful endothelial-derived vasodilator and has an important role in hemostasis of the blood vessel system. HBO has a mechanism by modulating nitric oxide (NO) in endothelial cells. In these endothelial cells, HBO also increases vascular endothelial growth factor (VEGF). Through the Krebs cycle, there is an increase in nucleotide acid dihydroxy (NADH) which triggers the increase in fibroblasts. Fibroblasts are needed for proteoglycan synthesis and together with VEGF will stimulate collagen

synthesis in the remodeling process, one of the stages in wound healing (Lakesla, 2009).

Oxygen in the blood is transported in dissolved form in plasma fluid and bound to hemoglobin. The largest portion is bound to hemoglobin, with only a small portion found in soluble form. In HBO, soluble oxygen is very important because soluble oxygen is more easily consumed by tissues through direct diffusion than oxygen bound to hemoglobin (Guritno, 2005).

Experimental evidence suggests that increased oxygen pressure at the wound site can result in faster and more efficient healing. Therefore, oxygen therapy has been used to aid in the healing of both acute and chronic wounds. Hyperbaric oxygen therapy is one method of supplemental oxygen delivery and is primarily used for chronic wounds. HBO is defined as the administration of 100% oxygen at increased pressure.

According to Richard (2002), in his research, administering HBO to experimental animals can increase the amount of arterial oxygen and also accelerate the wound healing process. So far, evidence for efficacy in chronic wounds, animal studies and cultured cells show that HBO actually increases the proliferation of fibroblasts and endothelial cells, thereby helping granulation tissue and wound contraction. HBO also increases keratinocyte differentiation and keratinocyte migration in a human skin equivalent model.

Clinical evidence includes an analysis of studies of HBO and diabetic lower extremity ulcers, which concluded that HBO reduced amputations in diabetic foot

ulcers and reduced venous ulcer size at 6 weeks, but not after 18 weeks. A controlled study of diabetic foot ulcers found HBO resulted in a significant reduction in ulcer size at Day 15, but not after 30 days of treatment, although a smaller review found that HBO actually increased the trend towards reduced ulcer size. A controlled study found that HBO reduced the incidence of bacterial colonization in diabetic ulcers, but did not reduce the length of hospital stay (Niinikoski, 2006).

In the intervention group before HBO, the results showed that 18 (90%) respondents experienced poor perfusion and 2 (10%) respondents had good perfusion. After receiving HBO in this group of 18 respondents, 12 (66.7 %) had good perfusion and 6 (33.3%) respondents had poor perfusion, while 2 respondents who were previously good after receiving HBO had good perfusion. From the statistical test, $p = 0.005$ was obtained, which means there was a significant difference in perfusion after receiving HBO in the intervention group.

The data above shows that 6 respondents still have poor perfusion, possibly due to a vascular defect suffered by the patient. Supporting data for this condition is the respondents' acral condition. Before receiving HBO, 15 (75%) respondents had non-warm acral and 5 respondents had warm acral. This is different after respondents received additional HBO therapy for 10 times, in this study, the results were that 18 people experienced improvement in their acral to warm. Meanwhile, 2 were still found to be in a non-warm condition. From the statistical test, the results obtained were $p = 0.001$,

meaning there was a significant difference in acral between before and after HBO.

Furthermore, the CRT before HBO therapy showed an average value of 6.25 seconds . This was different after the respondents received HBO therapy. After HBO therapy, the average CRT value was 2.55 seconds . The statistical test showed a p-value of 0.001, indicating a significant difference between the CRT before and after HBO therapy.

Furthermore, the average oxygen saturation before HBO therapy was 95.85 % , indicating that diabetic patients with gangrene experienced decreased peripheral blood flow. The average oxygen saturation after HBO therapy was 97.65 % . Statistical analysis showed a p-value of 0.001, indicating a significant difference in In this intervention group, respondents not only received HBO, but also received continuous wound care every day after HBO was administered. So this also affected the respondents' wound healing process. Although the method used was still conventional, it also had an important meaning in the wound healing process, namely. Wound care carried out was no different from the treatment method in the control group. In the intervention group, the treatment method was carried out by removing the dressing, then washing using 0.9% isotonic NaCl solution, if necrotic tissue was found or could obstruct the discharge of pus, a necrotomy would be performed, if pus was found, massage was performed around the tissue to remove it. Then, rinsing was carried out again and then dressing with gauze.

Sheikh and colleagues demonstrated increased VEGF levels in wound fluid from mice treated with HBO. While evidence for

oxygen saturation before and after HBO therapy.

According to research by Uhl, Sirja & Nilson (1994), administration of HBO for 2-9 days every day with 2.5 ATA before and after HBO obtained significant results $p < 0.001$. It was also stated that administration of HBO in ischemic conditions will be able to increase micro blood flow, increase re-epithelialization and increase tissue perfusion. The same opinion was also expressed by Vrounreats at all, in his research on the physiological implications of HBO in leg perfusion, the results showed that administration of HBO can increase oxygen supply and perfusion in the injured leg area.

its efficacy in chronic wounds remains limited, animal studies and cultured cells suggest that HBO significantly increases the proliferation of fibroblasts and endothelial cells, thus promoting granulation tissue formation and wound contraction. HBO also enhances keratinocyte differentiation and migration in a human skin equivalent model.

In this study, it can be said that the administration of HBO 2.4 ATA with 100% O₂ 3x30 minutes for 10 times and added daily wound care, obtained significant improvements in perfusion, so that it will be very helpful in the subsequent wound healing process. Related to the role of nurses in administering HBO, nurses play a very important role in the entire process of administering HBO. Before undergoing HBO therapy, a nurse is required to carry out the nursing care process , during HBO and after HBO.

Comparison of perfusion before and after in the control group showed no significant difference between before and after with a p-value of 1.000. This means that the control group did not experience any significant changes in perfusion.

This is supported by the average measurement of components in perfusion, namely acral, CRT and oxygen saturation. In the first acral measurement, 18 respondents (90%) had poor acral and only 2 respondents had good acral, while in the second measurement, 15 respondents (75%) had poor acral and 5 (25%) respondents had good acral. From the results of the statistical test, a p value of 0.375 was obtained, which means there was no difference in acral between the first and second measurements.

When viewed from the CRT, the average value in the first measurement was 7.05 seconds with a standard deviation of 3.351. Meanwhile, in the second measurement, the average CRT value was 6.10 with a standard deviation of 4.038. With an average difference of 0.950. This can indicate there is no difference. From the results of the statistical test, the p value = 0.496 was obtained, this means there was no significant difference in the first and second measurements in the control group.

In addition, oxygen saturation in the control group also did not experience significant changes, from the results of the study, the average value of the first measurement was 95.50% and in the second measurement was 95.60%, the average difference in the first and second measurements was 0.10. The

results of the statistical test obtained a p value = 0.853, which means there is no significant difference when viewed from oxygen saturation.

According to Grim et al (2006), a lack of blood volume will cause vasoconstriction and decreased oxygen availability, resulting in decreased perfusion. Peripheral perfusion will also decrease if the foot damage becomes more extensive, even if the foot damage penetrates deeper tissue, then peripheral perfusion in that area will be further lost, which can result in tissue necrosis.

According to the research results of Hermanto & Taufiqurrahman (2009), it was stated that the healing time for wounds before being given HBO for 50 days of treatment had only reached 66.7% healing from the initial wound, after being given HBO for 40 days, the wound healing process was 90% better than the initial wound condition.

Respondents in the control group only received treatment according to the hospital's SOP, without being given HBO therapy so that the results of the first and second measurements did not show statistically significant differences. The treatment carried out was still conventional so it took a long time for perfusion to be good, the foot care method provided was the same as the foot care in the intervention group, namely opening the bandage, then washing with 0.9% NaCl, after that if necrotic tissue was found, a necrotomy was performed, and re-rinsing was carried out and then closed.

CONCLUSION

There was no significant difference between peripheral perfusion in DM patients with gangrenous wounds before HBO was performed in the intervention and control groups at Dr. Ramelan Hospital Surabaya . There was a significant difference between peripheral perfusion in DM patients with gangrenous wounds after HBO was performed in the intervention and control groups at Dr. Ramelan Hospital Surabaya . There was a significant

difference between peripheral perfusion in DM patients with gangrenous wounds before and after HBO was performed in the intervention group at Dr. Ramelan Hospital Surabaya . There was no significant difference between peripheral perfusion in DM patients with gangrenous wounds before and after HBO was performed in the control group at Dr. Ramelan Hospital Surabaya .

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