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Non-traditional Topical Negative Pressure Applications

Geleneksel Olmayan Topikal Negatif Basınç Uygulamaları

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Non-traditional Topical Negative Pressure Applications

ABSTRACT

Topical negative pressure is one of the first treatment methods that comes to mind for chronic wound closure in recent years, and especially in reconstructive surgery, topical negative pressure therapy is a definitive treatment method that is frequently used. The purpose of this article is to compile non-traditional applications in the literature and to prompt scientists to form thoughts on the usability of this method in different areas. Considering the experimental and clinical research conducted for non-traditional topical negative pressure applications, although positive results were obtained in many of them, it is understood that more comprehensive research is required since there are not enough subjects or patients. We think that it can be applied to clinical practice, especially in the experimentally proven hypothermia-induced myocardial infarction and flap delay issues.

Keywords: Negative pressure, Plastic surgery, Topical, Vacuum.

ÖZET

Topikal negatif basınç, son yıllarda kronik yara kapanmasında akla gelen ilk tedavi yöntemlerinden biri olup, özellikle rekonstrüktif cerrahide topikal negatif basınç tedavisi sıklıkla kullanılan kesin bir tedavi yöntemidir. Bu makalenin amacı literatürdeki geleneksel olmayan uygulamaları derlemek ve bilim insanlarını bu yöntemin farklı alanlarda kullanılabilirliği konusunda düşünce oluşturmaya teşvik etmektir. Geleneksel olmayan topikal negatif basınç uygulamaları için yapılan deneysel ve klinik araştırmalar göz önüne alındığında, birçoğunda olumlu sonuçlar elde edilmesine rağmen, yeterli sayıda denek veya hasta olmadığından daha kapsamlı araştırmalara ihtiyaç duyulduğu anlaşılmaktadır. Özellikle deneysel olarak kanıtlanmış hipotermi kaynaklı miyokard enfarktüsü ve flep gecikmesi sorunlarında klinik pratiğe uygulanabileceğini düşünmekteyiz.

Anahtar Sözcükler: Negatif Basınç, Plastik cerrahi, Topikal, Vakum.

Introduction

Wound healing is one of the most important factors affecting patient comfort, hospitalization, and survival. While clean wounds formed after surgery can heal faster and easier within days, chronic wounds may not close for weeks, months, or even years. Topical Negative Pressure (TNP) is one of the first treatment methods that comes to mind for chronic wound closure in recent years, and especially in reconstructive surgery, TNP therapy is a definitive treatment method that is frequently used. Voinchet and Magalon used the term negative pressure-assisted wound and named it vacuum-assisted closure (VAC) (1). Morykwas and Argenta investigated the most comprehensive experimental and clinical applications in the literature regarding TNP (2,3). They proved that TNP increases local blood circulation, accelerates granulation tissue formation, increases survival of random patterned flaps, and reduces the level of bacteria in the wound (2). Since then, TNP has been used frequently in the closure of complicated wounds in plastic surgery, general surgery, orthopedics, and cardiovascular surgery (4–11). These complicated wounds are usually pressure sores, open bone fractures, extremity injuries, wounds with poor circulation, and defects that occur after surgery or trauma. The success of TNP in complicated wounds is known, but scientists have been investigating the beneficial effects of TNP on the body regions and systems for many years. The purpose of this article is to compile Non-Traditional TNP applications in the literature and to prompt scientists to form thoughts on the usability of this method in different areas. Non-traditional TNP applications are summarized in Table I.

Topical Negative Pressure History

Alexander Graham Bell's first son was born prematurely and died several weeks later. He developed the vacuum jacket or Baby Life Saver, aimed to assist breathing in weak or immature babies, and took one of the first steps in neonatal asphyxia. The working principle of this device was to ensure the expansion and contraction of the chest cage in small babies. It was successful in the formation of inspiration and expiration movements. However, since the device was not successful in the study he conducted on a drowning cat, it was not used clinically (12).

In 1928, Drinker and Shaw invented a device called the Iron Lung, which enclosed the entire body except the head and did not leak air to the outside. The Iron Lung was frequently used in polio epidemics in the 20th century. After the 1950s, respiratory ventilation devices were used more frequently instead of this device (13,14).

Table I. Non-traditional topical negative pressure applications

Author	Year	Application	Type
Bell	1989	Chest	Experimental
Drinker	1928	Polio	Clinical
Spalding	1950's	Chest	Clinical
Münster	1999	Cardiovascular Perfusion	Clinical
Greco and Schlenz	2002-2007	Breast Enlargement	Clinical
Kamolz	2004	Burn	Clinical
Lindstedt	2007	Myocardial Infarction	Experimental
Sciortino	2009	Subcutaneous Emphysema	Clinical
Seyfried and Newton	2013-2017	Gastrointestinal Leak	Clinical
Kajihara	2013	Systemic Sclerosis	Clinical
Menezes	2014	Photodynamic Therapy	Clinical
Lee	2015	Fat Graft Survival	Experimental
Aydin	2017	Flap Survival	Experimental
Brown	2021	Flap Survival	Clinical
Liang	2024	Vascular Erectile Dysfunction	Clinical

Non-Conventional Applications of the Topical Negative Pressure

1. Vacuum Assisted Venous Drainage "Hamlet Box"

One of the most common problems with cardiopulmonary bypass is insufficient venous drainage. This problem can contribute to interstitial edema and multiorgan failure, creating serious problems for both the surgeon and the perfusionist. Vacuum-assisted drainage is a system called a "Hamlet Box" with a vacuum regulator. Tested in 54 patients, this system demonstrated effective drainage with smaller catheters, reduced fluid addition, and prevented complications such as hemolysis. Tested both in the laboratory and clinically, it showed no side effects and performed uneventful surgeries. All patients in the study survived and recovered well (15).

2. Non-surgical Vacuum Assisted Breast Augmentation "BRAVA"

A device called BRAVA, which increases breast volume and works with the help of negative pressure, has been described (16). This device has been used in clinical studies by Greco et al. (17). Later, Schlenz and Kaider conducted a detailed study on breast augmentation patients who did not want surgery (18). In this study, the requirement for at least 10 hours of use per day for at least 10 weeks was explained to patients with a body mass index over 18. Standard photographs, breast examination, measurements of breast circumference at nipple height and inframammary fold, and volume measurements of the breasts with the Grossman-Roudner device were obtained periodically at the beginning of treatment, after 6 weeks of use, and up to 14 months after the end of treatment. 40 of the 50 registered women could be evaluated. Ten dropped out of the study for the following reasons: loss of interest and failure to comply with the treatment protocol (n=6), reluctance to attend minimum required follow-up visits (n=3), and greater than 5% weight change (n=1). The median observed volume gain was 155 cc, with a range of 95 to 300 cc. Satisfaction levels varied; 75% of users were satisfied or very satisfied with the results. However, negative situations such as the BRAVA device restricting social life, not being used comfortably while sleeping, patients comparing the results with breast augmentation surgery, and high expectations for it were noted.

3. Use in Superficial Burns

As wound care and treatment for burns improve, morbidity and mortality rates decrease. The most important factor that is a source of infection in a burn wound is exudate. Therefore, methods that can reduce exudate have been continuously investigated. TNP devices have been used as exudate collection containers, and healing has been accelerated, infection rates have decreased, and hospitalization has been shortened (19). TNP is safe and effective for accelerating healing and reducing infection rates in burn wounds (20). TNP has also been used to reduce swelling and increase perfusion in non-full-thickness and superficial burn injuries (21). However, no statistically significant results were found in these studies. Furthermore, high-quality research, including well-designed, adequately powered multicenter trials, is needed to evaluate the effects of TNP on healing times, costs, and patient quality of life (22).

4. Use in Hypothermia-Induced Myocardial Infarction

It is known that hypothermia limits myocardial infarction. Interesting results were found in a study investigating the effects of different levels of TNP on microvascular blood flow in the myocardium reperfused during hypothermia (23). The study used a porcine model, specifically seven domestic terrier pigs, to investigate the effects of TNP on microvascular blood flow during hypothermia. Median sternotomy was performed, and cardiopulmonary bypass (CPB) was established to facilitate the measurement of microvascular blood flow using laser Doppler velocimetry. After hypothermia was induced to 31°C, microvascular blood flow was recorded before and after application of various levels of TNP (50, 75-, 100-, 125-, and 150-mm Hg). Following a 40-minute occlusion of the left anterior descending artery, measurements were made at depths of 6 to 8 mm in the epicardium and myocardium. The study concluded that a TNP of -50 mm Hg significantly increased microvascular blood flow in both the epicardium and myocardium of reperfused hypothermic myocardium. However, TNP levels of -75 mm Hg and above did not significantly alter microvascular blood flow, and pressures of -100 mm Hg to -150 mm Hg resulted in a significant decrease in blood flow. These findings may have implications for improving outcomes in the treatment of myocardial infarction by optimizing TNP administration.

5. Use for Subcutaneous Emphysema

Intrathoracic infection is a serious life-threatening condition. TNP has been successfully applied for a variety of severe intrathoracic infections, including postresectional empyema, necrotizing lung, intrathoracic esophageal leaking empyema, and mediastinitis. It has been stated that it may be an alternative to open thoracostomy for severe infections (24). A 70-year-old man with a history of bullous emphysema developed severe subcutaneous emphysema due to repeated needle decompression

attempts. A chest tube was placed, and a "vent" incision was made to relieve subcutaneous air. TNP was applied because of the ongoing subcutaneous emphysema. After 48 weeks of this treatment, the subcutaneous emphysema was found to have significantly decreased, and the results were supported by computed tomography (25).

6. Use of Gastrointestinal Surgery Leaks

Gastric leaks after bariatric surgery, such as Roux-en-Y gastric bypass, are serious complications that require expert management. Traditional surgical reinterventions are often ineffective due to the inflamed and damaged tissue surrounding the leak, making closure difficult. In a 41-year-old woman who developed a large gastric leak after Roux-en-Y gastric bypass surgery, previous attempts to close the leak with covered metal stents had failed due to stent migration (26). Endoluminal negative pressure therapy successfully sealed the leak within a week, and the patient showed complete recovery without stenosis on follow-up.

A review of the literature on esophageal perforations found that 163 out of 179 patients recovered, with a mortality rate of 12.8% (27). Although sample sizes are small, TNP results are better than traditional treatments, with most patients recovering in an average of four weeks, compared to the typical 6-8 weeks for stents.

Rectal resection is an important treatment for rectal cancer. Anastomotic leakage may lead to decreased long-term survival and increased tumor recurrence. Endoscopic Vacuum Therapy (EVT) shows 79.7-100% success rates in various surgeries (28).

7. Use in Systemic Sclerosis

Systemic sclerosis is a condition characterized by vascular involvement, such as skin ulcers, gangrene, and fissures, that are often resistant to conventional medical treatments and can significantly impact patients' quality of life, leading to long treatment periods and, in severe cases, amputation. TNP therapy supplemented with split-thickness grafts (STSG) was applied to two patients, aged 64 and 73, who had a history of amputation and fistula. The combination of TNP and STSG was effective in both patients, leading to complete wound healing and preventing the need for further amputation (29).

8. Optimization of Photodynamic Therapy

To treat and diagnose various cancers and skin diseases, it is important to increase the formation of protoporphyrin IX (PPIX), and for this purpose, Photodynamic therapy (PDT) with 5-Aminolevulinic acid (5-ALA) is used. However, the penetration of 5-ALA through the skin is limited, which affects its efficacy. Menenez et al. aimed to improve topical photodynamic therapy using TNP with 5-ALA cream (30). The study applied 20% 5-ALA cream to a 9 cm^2 skin area and then applied an occlusive dressing to protect from light. They used fluorescence spectroscopy and wide-field fluorescence imaging to measure PPIX production on the skin surface after 7 and 24 hours. A vacuum device was used to induce negative pressure, which is assumed to increase PPIX production and distribution. They applied 200 mmHg for 4 minutes, using alternating continuous and pulsed modes, while monitoring skin temperature changes hourly with an infrared thermometer. TNP therapy was found to significantly increase PPIX production, distribution, and elimination compared to the control group. PPIX formation was approximately 30% greater in the deeper skin layers and 20% greater in the surface layers. The therapy also accelerated the elimination of PPIX by reducing skin photosensitivity, which is beneficial for PDT treatment.

9. Use to Improve Fat Graft Survival

Fat grafting is widely used for soft tissue augmentation, but due to the low ischemic tolerance of fat tissues, early revascularization is crucial for graft survival. An experimental study was conducted using 20 New Zealand male white rabbits that were subjected to negative pressure of -125 mm Hg on the left or right dorsal ear for one week before fat grafting (31). Fat was grafted onto the dorsal perichondrium, and various parameters such as fat weight, microvessel density, and glycerol release were measured one week and three months after grafting. Microvessel density in the study was evaluated using a standard immunohistochemical method and Laser Doppler Flow measurement

for tissue perfusion. The experimental group that received negative pressure preconditioning showed significantly higher microvessel density in both skin and fat tissues compared to the control group. Skin perfusion and fat survival rates were also significantly higher in the experimental group, indicating improved vascularity and graft viability. The study proved that TNP therapy increased angiogenesis, which is crucial for the survival of transplanted fat tissues.

10. Use for Flap Survival

As an alternative to the traditional surgical flap delay method, the effectiveness of non-invasive TNP-assisted flap delay was investigated experimentally (32). 3 groups were formed as the Control group, the Surgical delay group, and the TNP-assisted group. A total of 30 experimental animals were used, 10 New Zealand breed rabbits in each group. The experiment was performed using a 25x5 cm random flap in the lateral thoracic region. In the TNP-assisted group, flaps were lifted after applying 80 mmHg pressure for one week. The obtained parameters, total flap area and necrotic flap areas, necrosis rate, vascular density, and neovascularization markers (CD31/CD34), were measured with Laser Doppler flowmeter images and contrast-enhanced Computed Tomography. In all measured parameters, the TNP-assisted group showed equivalent results to surgical delay and was superior to the control group. The necrosis rate was significantly lower in the TNP group (19.58%) compared to the control group (65.56%) and the surgical delay group (37.31%). This result proved that TNP-assisted flap delay is a good alternative to surgical flap delay. Thus, reconstructive surgeons have the opportunity to reduce surgeries to a single operation by using TNP-assisted methods instead of a two-stage surgical flap delay. However, this study needs to be reinforced with clinical studies. In a related clinical study in the literature, Brown et al. applied a free anterolateral tight flap to two patients and applied -125 mmHg TNP to the donor area for 6 days. Although the flaps were huge, approximately 22x9 cm, the flaps survived completely, and no partial or complete necrosis was reported (33). Postoperative flap survival is also one of the most important issues for reconstructive surgery. In a large-scale systematic review, flap survival with TNP was as high as 97.1% and complications were found to be as low as 5.7% (34).

11. Use for Vascular Erectile Dysfunction

The clinical effects of Traditional Chinese Medicine topical irrigation combined with TNP irrigation and tadalafil for the treatment of vascular erectile dysfunction (ED) have been investigated (35). Arterial ED means there is a problem with blood flow to the penis, while intravenous ED means there is a problem with blood flow from the penis. There were 43 patients in total in the observation group. This group included 22 arterial ED patients and 21 intravenous ED patients. There were also 43 patients in the control group, including 21 arterial ED patients and 22 intravenous ED patients. The observation group received oral tadalafil along with traditional Chinese medicine TNP irrigation for four weeks. The control group received only oral tadalafil for the same period. Significant improvements were observed in the observation group in terms of IIEF-5 (International Index of Erectile Function-5), EHS (Erection Hardness Score), GAD (Generalized Anxiety Disorder) scores, PSV (Peak Systolic Velocity), EDV (End Diastolic Volume), and RI (Resistance Index) compared to before treatment. Although the results in this study are positive, larger groups and more detailed studies are needed since there is no control group that did not receive Tadalafil.

12. Recent Studies of the TNP

Recent studies have shown that this method not only serves drainage purposes but also provides regenerative, hemostatic, and vascular modulatory effects. Tan et al. reported that the application of TNP combined with fish skin-derived acellular dermal matrix in diabetic foot ulcers significantly reduced infection rates and healing time. This study demonstrates that TNP can be considered not only a mechanical drainage tool but also a platform that supports biological regeneration (10). Currie et al. reported that complications such as seroma and skin necrosis, which may occur after lymphadenectomy, were significantly reduced with the combination of topical tranexamic acid, TNP, and long-term drainage. This finding suggests that TNP can be considered a proactive tool in preventing surgical complications

by supporting vascular stability and tissue integrity (36). Pelham et al. reported that TNP both provides infection control and helps protect the implant in the treatment of infected and exposed orthopedic implants. This study demonstrates that TNP may support regenerative processes by increasing antibiotic penetration at the bone-implant interface (37). TNP has been frequently reported in head and neck surgery, infected and exposed implants, intrathoracic surgery, cardiac surgery, spinal surgery, gynecological problems, burns, congenital problems, donor site closure, lymphadenectomy, and extremity salvage (36–40).

Conclusion

This study emphasized rare applications, as opposed to TNP therapy, which has traditionally been used for wound closure in clinics. Considering the experimental and clinical research conducted for non-traditional TNP applications, although positive results were obtained in many of them, it is understood that more comprehensive research is required since there are not enough subjects or patients. We think that it can be applied to clinical practice, especially in the experimentally proven hypothermia-induced myocardial infarction and flap delay issues.

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