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Research Article

Efficacy of Negative Pressure Wound Treatment Using Vacuum Assisted Closure Technique Combined with Nano-Silver Medical Antibacterial Dressing and Recombinant Bovine Fibroblast Growth Factor Gel for Management of Acute Auricular Chondritis

Rongtao Cui[1,2], Lihui Han[1,3], Ran Zhao[2], Qiuchen Li[2], Zhang Feng[2], Hu Xiao[2], Zhanjie Yang[2], Mingqing Wang[2], Wenjun Xue[2], Ran Huo[2*]

[1]School of medicine, Shandong University, Wenhuaxi Rd, Jinan, China

[2]Department of Burn and Plastic Surgery, Shandong Provincial Hospital affiliated to Shandong University, Jingwuweiqi Rd, Jinan, China

[3]Surgical Intensive Care Unit, Shandong Provincial Hospital affiliated to Shandong University, Jingwuweiqi Rd, Jinan, China

These authors of Rongtao Cui and Lihui Han were contributed equally to this study.

[*]**Corresponding author:** Ran Huo, Department of Burn and Plastic Surgery, Shandong Provincial Hospital affiliated to Shandong University, 324 Jingwuweiqi Rd, Jinan, 250021, P.R. China. Tel: +86-15168889001; Emails: huoran@medmail.com.cn

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Abstract

Objective: We aim to explore the effective treatment and repair methods for Acute Auricular Chondritis (AAC) caused by non-burn injuries in its early stage and alleviate the great pain caused by diseases including cartilage infection and necrosis in the auricular while improving the quality of the patients' lives as well as reducing the incidence of small ear malformation.

Methods: In the experimental group, 12 cases of AAC from 10 patients caused by external ear no-burn injuries were treated in our hospital since January 2015, all of the patients had no diabetes and rheumatoid immune related diseases. Vacuum Assisted Closure (VAC) technique with Nano-silver Medical Antibacterial Dressing (MAD, Acasin®) and Rb-FGF (Beifuxin®) gel was applied to the wound, and the auricle was shaped during the dressing process. We adjusted the negative pressure range of the VAC in the process of normalization (Details of the process can be seen in the Method of the article). In the control group, there were 6 patients (6 ears) that had non-burn AAC. Since these patients required conservative treatment, full course of antibiotic treatment of adequate dose were given while regular dressing changes were given to the ulcerated wound on time.

Results: 12 cases of AAC from 10 patients were healed thoroughly through leveraging standardized VAC technique combined with Nano-silver MAD and Rb-FGF gel treatment. Concurrently, the external ear structure was preserved completely and there was no major ear defect or ear cauliflower like deformity occurred in the auricle. The outer auricle was only slightly invaginated in the outer upper ear wheel, and the rest of the auricle was in normal shape. In control group, only 1 patient was healed with no recurrence after 3 months of follow-up visit. This patient's auricle anatomy was normal and the cartilage elasticity was good while no related complications and sequel appeared. Conservative treatment was effective for 2 of the patients. After 3 months of follow-up visit, both of their left auricles contracted locally. For the rest 3 patients, the auricle contracture was relatively obvious, and the appearance of the ear was thickened. To note that, the overall effective rate of the control group was 50%.

Conclusion: Traditional incision and drainage for AAC caused by non-burn injuries often result in different degree of external ear deformities. Ear defects or cauliflower-like deformities not only make it difficult to reconstruct the external ear but also cause serious psychological injury to the patients. The novel standardized treatment prescription can treat AAC early and effectively, reduce the physiological and psychological pain of patients, and decrease the traditional treatment of external ear malformation caused by AAC significantly.

Keywords: Acute auricular chondritis; Non-burn; Nano-silver medical antibacterial dressing; Rb-FGF; VAC

Introduction

Acute Auricular Chondritis (AAC), which is often caused by mechanical trauma, frostbite, auricle hematoma secondary tissue necrosis, is a non-suppurative inflammation of the perichondrium and cartilage of the auricle. It is a stubborn and painful external ear disease, which is progressive cartilage necrosis. As a result of cartilage necrosis, the auricle loses its support, and eventually, deformity occurs because of scar contraction, which not only affects appearance but also physiological function. There are plenty of causes of non-suppurative auricular chondritis and various treatment methods. The common treatment methods include the following procedures: expelling inflammatory pus, promoting wound healing, preventing the recurrence of chondritis, restoring the normal anatomy of the auricle to the greatest extent, and avoiding complications and sequelae [1].

Negative pressure Vacuum Assisted Closure (VAC) refers to placing a drainage tube connected to a special vacuum negative pressure pump into the wound, wrapping it with a polyurethane sponge, sealing the wound with a transparent film, and treating it within a negative pressure environment. By significantly increasing blood flow in and around the wound, treatments with VAC can reduce edema and inflammation, and promote repairing cell proliferation and granulation by eliminating bacteria. They can also regulate the levels of the extracellular matrix such as MMPS and hyaluronic acid bi-directionally, inhibit the degradation of extracellular matrix, and remove the resistance of cell migration [2]. Hu and others reported that using VAC technology could induce large amount of blood flow to the wound, significantly promote wound vascularization, and shorten the wound healing time at last [3].

Nano-silver Medical Antibacterial Dressing (MAD) (Acasin® dressing) is a new type of antibacterial dressing developed for the treatment of various infectious wounds using Nano-silver materials with a particle size of 4-8 nm. After contacting with the wound, it would instantly and permanently release the silver Nanoparticles to efficiently and effectively exterminate various pathogens that invade the wound, thereby reduce inflammation and relieve pain and promote the effectiveness of wound healing. Nano-silver is highly active, small particle size and large surface area, which is of strong antibacterial effect and superior to traditional Ag+ bacteriostatic agents. It could be bond to the ribonucleic acid in the bacteria and lead to the death of bacteria [4]. The recombinant bovine fibroblast growth factor (Rb-FGF) gel (Beifuxin®) is a multifunctional growth factor that could promote cell division, which is a polypeptide substance composing of 53 amino acid residues. It may combine with the corresponding receptors on the cell surface to form a complex that binds to lysosomes after entering the cytoplasm, stimulates cell nuclear DNA formation, promote cell proliferation and division, and accelerate bacterial death [5]. Due to the excellent moisturizing efficacy, it can reduce the thickness of the wound dressing and the utilization of excipients while reducing the patients' financial burdens. Above all, the combination of the two materials can accelerate cell division, promote wound healing, and alleviate patients' pain.

Materials and Methods

Patient Data

From January 2015 to January 2019, 10 patients (12 ears included) of non-burn AAC were admitted to the department of Burn and Plastic Surgery in Shandong Provincial Hospital, 8 of those were unilateral ear diseases, and 2 of those were bilateral ear diseases. There were 9 males (11 ears) and 1 female (1 ear), aged from 58 to 71 years old. The onset time ranged from 1 week to 2 months. The locations of the chondritis included upper front of the auricle, navicular fossa, and triangle nest. The cases in the control group were 6 patients (6 ears) with non-burn AAC admitted to the department of Burn and Plastic Surgery in Shandong Provincial Hospital. All of them were unilateral ear, all male, aged from 62 to 70 years old (all shown in Table 1). These patients required conservative treatment, so full course of antibiotic treatment of adequate dose were given, and regular dressing changes were given on time to ulcerated wound. All patients had no history of previous ear surgery, auricular trauma and ear infection, or diabetes and rheumatoid immune-related diseases. All patients denied scar physique, completed the relevant preoperative examination after admission, and had no surgical contraindications.

Table 1 Basic characteristics of the subjects (number)

	Males	Females	Age(years)
VAC+Acasin® dressing + Beifuxin®	9	1	64(58,71)
Conservative treatment	6	0	65(62,70)

Note: Data are presented as median with boundary value.

Table 1: Basic characteristics of the subjects (number).

Treatment Planning

The patient was placed in a supine position. After given general anesthesia and routinely sterilized and draped, debridement surgery was given. After cutting the skin along the edge of the auricle, all the inflammatory exudates were taken out, the visible necrotic tissue and necrotic cartilage were completely debrided, and the mucus-like secretion on the surface of the ear cartilage was scraped. The wound was completely hemostasis, and the skin was reset after repeated washing with hydrogen peroxide and normal saline. VAC technique with Nano-silver MAD (Acasin®) and Rb-FGF (Beifuxin®) gel was applied in the wound, and the auricle was shaped during the dressing process. Notable that the negative pressure range of the VAC was adjusted as follows: Firstly, negative pressure range was set at 100 mmHg in the first 3 days, and then modified into 75 mmHg, continuous vacuum sealing suction was conducted in the next 4 days.

Secondly, the VAC dressing was removed after the first 7 days of treatment and debridement again, then clear necrotic

tissue and cartilage were both cleared away, the VAC covered area containing Nano-silver MAD and Rb-FGF gel was applied in the wound, negative pressure range was set at 100 mmHg in the first 3 days, then 75 mmHg, continuous vacuum sealing suction was conducted in the next 4 days; Thirdly, the VAC dressing after the second 7 days was removed again if the wound was clean and fresh, wound was sutured with bandage, dressing need to be changed regularly and the suture must be taken out after the third 7 days. The 6 patients (6 ears) with non-burn AAC in the control group were admitted to Burn and Plastic Surgery in Shandong Provincial Hospital. All of the patients were male, aged from 62 to 70 years old and had unilateral ears. They were given conservative treatment, in which full course of antibiotic treatment of adequate dose were provided while regular dressing changes were given punctually to the ulcerated wound (All shown as Figure 1-3).

Figure 1: Wound condition before, during and after surgery.

Figure 2: Vacuum Assisted Closure (VAC).

Figure 3: Materials used during surgery. The recombinant bovine fibroblast growth factor (Rb-FGF) gel (Beifuxin®, left) and Nano-silver medical antibacterial dressing (Acasin® dressing, right).

Plan Evaluation

- **Healed:** After 3 months of treatment, the auricle anatomy was normal with no apparent contracture deformity, no auricle incrassation.
- **Effective:** After 3 months of treatment, the auricle left locally contracture, however the vertical distance from the most depressed part of the contracture to the posterior auricular sulcus was shortened but no more than 1/3 of the contralateral normal ear, or the remaining auricle area (with the back of the auricle) was no less than 2/3 of the contralateral normal ear, and auricle incrassation could be detected by palpation.
- **Improved:** After 3 months of treatment, the auricle contracture was more evident. The vertical distance from the most depressed part of the contracture to the posterior auricular sulcus was shorter than that of the contralateral normal ear by more than 1/3 and no more than 2/3, or the remaining auricle area (according to the back of the auricle) was larger than that of the contralateral normal ear by no less than 1/3 and less than 2/3 of the normal ear, and the appearance of the ear was thickened.
- **Invalid:** After 3 months of treatment, the auricle contracture was obvious, and the vertical distance from the most depressed part of the contracture to the posterior auricular sulcus was shorter than that of the contralateral normal ear by more than 2/3, or the remaining auricle area (with the back of the auricle) was less than 1/3 of the contralateral normal ear, might require a second operation to heal (Figure 4) [6].

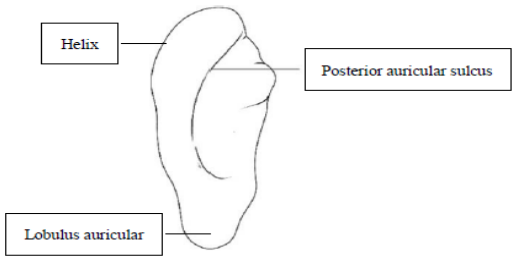

Figure 4: Back of the auricle.

Data Analysis

All statistical analysis was conducted using SPSS version 18.0. The count data were expressed as n/%, and the Chi-square (χ^2) test was used for comparison between the experimental and control groups, $p<0.05$ was considered statistically significant.

Results

Comparison between the treatment methods of non-burn AAC

10 patients (12 ears) with non-burn caused AAC were treated with standardized treatment combining with VAC, Acasin® dressing,

and Beifuxin® gel. All of them were cured in 14-21 days after their surgeries, and the incision healing conformed to the first stage and grade A healing. After 3 months of follow-up visit, there was no recurrence, the auricle anatomy was normal, the cartilage elasticity was good, and none of the related complications or sequel arised. In general, the total effective rate was 100%. 6 cases (6 ears) of patients with non-burn caused AAC were conservatively treated and given full course of antibiotic treatment of adequate doses and local regular wound dressing changes. Only 1 patient of them was healed, recurrence did not emerge after 3 months of follow-up visit, the auricle anatomy was normal, the cartilage elasticity was good, no related complications and sequel appeared. 2 of them were effective. After 3 months of follow-up visit, the left auricle locally contracted, the vertical distance from the most depressed part of the contracture to the posterior auricular sulcus was shortened but no more than 1/3 of the contralateral normal ear, auricle incrassation was observed with palpation. For the other 3 patients, the auricle contracture was more obvious, the vertical distance from the most depressed part of the contracture to the posterior auricular sulcus was shorter than that of the contralateral normal ear by more than 1/3 and no more than 2/3, and the appearance of the ear was thickened. The total effective rate was 50%. The comparison between the therapeutic effects of the two treatment methods was shown in Table 2. The results were evaluated by using χ^2 test ($p<0.05$) and the corresponding difference was statistically significant.

Table 2 Comparison of the effects of the two treatments for non-burn acute auricular chondritis (n/%)

	Healed	Effective	Improved	Invalid	Total efficiency	*P*
VAC+Acasin® dressing + Beifuxin® (n=12)	12/100%	0/0.00	0/0.00	0/0.00	100%	
Conservative treatment (n=6)	1/16.67%	2/33.33%	3/50%	0/0.00	50%	<0.05

P is the value of χ^2 test from comparison of the effects of the two treatments for non-burn acute auricular chondritis.
P<0.05 was considered statistically significant.

Table 2: Comparing of the effects of the treatments for non-burn acute auricular chondriris (n/%).

Comparison between the two treatment courses for non-burn AAC

10 patients (12 ears) with non-burn caused AAC were treated with standardized treatment combining VAC, Acasin® dressing, and Beifuxin® gel. All of them were cured in 14-21 days after surgery; 6 cases (6 ears) of patients with non-burn caused AAC were conservatively treated and given full course of antibiotic treatments of adequate doses as well as local regular wound dressing changes. 2 patients recovered within 28-35 days, 3 patients recovered within 35-42 days, and 1 patient had a healing time of more than 42 days due to recurrence during treatment. The comparison between the therapeutic effects of the two treatment methods was shown in Table 3. The results were evaluated by using χ^2 test ($p<0.05$) and the difference was also statistically significant.

Table 3. Comparison of two courses of treatment for non-burn acute auricular chondritis (day)

	14-21d	21-28d	28-35d	35-42d	>42d	Total	*P*
VAC+ Acasin® dressing + Beifuxin® (n=12)	12	0	0	0	0	12	<0.05
Conservative treatment (n=6)	0	0	2	3	1	6	<0.05

P is the value of χ^2 test from comparison of two courses of treatment for non-burn acute auricular chondritis.
P<0.05 was considered statistically significant.

Table 3: Comparison of two courses of the non-burn acute auricular chondritis (day).

- **Comparison of preoperative performance, intraoperative status and postoperative recovery of non-burn acute auricular chondritis (Figure 1 shown as followed).**
- **The materials used during the operation and the wound shaping solution during surgery (Figure 2 and 3 shown as followed).**

Discussion

The auricle is exposed to the outside, lacking subcutaneous tissue, especially the anterolateral side, which is relatively dense and has limited buffering effect on inflammatory exudation. Once an infection occurs after injury, the treatment is not timely and in place simultaneously, the infection might spread to the perichondrium and lead to local blood supply disorders, cartilage degeneration and necrosis while producing a series of following rejection actions. Once the treatment was delayed and the damaged area of ear cartilage would enlarge gradually and result in auricular deformity apparently. Once infection develops into auricle suppurative auricular chondritis, usually it would be a hardship to cure even if the incidence range were limited [7,8].

Trauma and infection are the two triggers of suppurative auricular chondritis while trauma is ahead of infection and trauma is widely accepted as the inducement of secondary infection [1]. This type of suppurative inflammation caused by trauma and infection and marked by auricular cartilage necrosis is named after suppurative auricular chondritis. Early manifestations include local redness, swelling, fever and pain; in the late stage, there would be a sense of fluctuation in the tactile expression or self-breaking pyorrhea, and the destruction of the auricle tissue should not be underestimated. Patients with explicit ear trauma history and typical clinical manifestations could be diagnosed as suppurative auricular chondritis. While abscess is forming, it should be actively treated by surgery with systemic antibiotics and local physical therapy, which may promote the regression of inflammation and wound healing [9,10].

For those infected patients that are inappropriately treated with suppurative auricular chondritis, the influence of antibiotic therapy alone is limited, thus a local treatment would be necessary. Most of the cases are treated by skin incision along the scaphoid. Necrotizing cartilage and granulation are removed by opening the purulent cavity. After the wound cavity are cleanse with normal

saline, it would be soaked with antibiotics or external disinfectant for a moment and drainage skin be placed. The incision would not be sutured or stitched 1-2 needles at most, and external dressing bandage, daily dressing is used until incision closes up [11]. But what matters most in the debridement method is that the early drainage might not be enough, and after debridement the fresh wounds are hard to attach due to the already attached blood clots. Since the incision contracture to both sides at the late stage and even the edge of the cartilage is exposed, it is difficult to realize primary healing.

In the proposed method, all of the inflammatory exudates would be drained out along the edge of the auricle, the necrotic tissue and cartilage were removed completely, the mucinous secretion on the surface of the ear cartilage was scraped, the hemostasis was terminated, the skin was repositioned after repeated washing with hydrogen peroxide and normal saline, and the clamp was applied in the wound. The negative pressure VAC with Nano-silver Acasin® dressing and Beifuxin® gel, while shaping the auricle at the same time, adjusting the VAC negative pressure in 100 mmHg in the first 3 days, after that setted in 75 mmHg, continuous vacuum sealing attracts in the next 4 days, remove the VAC dressing after the first 7 days treatment and debridement again, remove clear necrotic tissue and cartilage, the VAC covered area containing Nano-silver Acasin® dressing and Beifuxin® gel was applied in the wound, negative pressure range is set at 100 mmHg in the first 3 days, than at 75 mmHg, continuous vacuum sealing suctions were conducted in the next 4 days while removing the VAC dressing after the second 7 days once the wound clean and fresh, wound suture bandage was executed.

As a result of negative pressure, the pressure between tissues would be reduced, and the oxygen tension around the wound would also be decreased while stimulating the start-up signal of repair, which is beneficial to the clearance of necrotic tissue timely and could promote the secretion of fibrinolytic protein activator as well as other types of enzymes. Notable that the fibrinolysis might occur in the wound, which could improve the growth of collagen tissue and create an environment that may speed up fibrinolysis and performs autolytic debridement. Chen Shaozong found that negative pressure drainage could improve the velocity of microcirculation blood flow and dilate the micro-vascular, thus would enhance the circulation of wound blood flow. Continuous high negative pressure suction can thoroughly remove the exudate from the wound and lacuna, avoid the accumulation of local exudate, shrink the wound and invaginate the cavity walls, and finally close the cavity wall to prevent the formation of residual abscess and dead space. To ensure the wound clean, accelerate tissue detumescence, improve local circulation, promote the repair of damaged tissue, is conducive to the early healing of infected wounds. The greatest advantage of turning traditional open drainage into closed drainage is that the wound cavity can be sufficiently drained to avoid hemorrhage and effusion, and to eliminate tissue edema. Therefore, the incision can be healed in the first class to reduce unnecessary dressing changes and avoid mixed or repeated infections caused by bacterial pollution, which is conducive to local infection control [12-16].

Nano-silver medical antimicrobial dressing was made by Nano-silver technology and Nano-silver ultrafine particles are made of medical aseptic gauze as the carrier to enhance its function. In comparison with traditional silver sulfadiazine, Nano-silver medical antimicrobial dressing retains the advantages of high-efficiency anti-infection of silver ions and eliminates the disadvantages of sulfonamide composition allergy and excessive deposition of silver ions [17]. When it is applied to the wound surface, there is an extremely high degree of dissolubility, antibacterial and bactericidal effect. After the release of silver ions, it would bind the negatively charged bacterial protein and deform the silver to combine with the sulfhydryl of the enzyme simultaneously, thus forming stable sulfate and inhibiting the enzyme activity of series of sulfhydryl, blocking the bacterial respiratory enzyme system, interfering with the bacterial metabolism, and resulting in the death of bacteria, then effective bacteriostasis and sterilization would be achieved [18,19].

The sterilizing mechanism of silver differs from chemical antibacterial agent, and it is implemented through using leveraging heavy metal ions to affect the transgenic of the bacterial proteins, which can be very difficult to resist, and it can be widely used to sterilize the bacteria. The chemical properties of the Nano-silver dressings are stable, could be bind to the DNA of the fungi and bacteria, allow the change of the structure and the inhibition for the activity of fungal and bacterial [20]. In the process of healing, the expression of local endogenous EGF and EGF receptors has increased in varying degrees. However, the content of EGF in tissues is usually low, which could not meet the needs of cell proliferation and the development of granulation tissue. Therefore, Rb-FGF is locally applied to the wound surface to supplement the deficiency of endogenous EGF, contributing to the initiation and regulation of the cell proliferation as well as the acceleration of wound repair [21,22]. Rb-FGF acts as a cell promoting division with strong biological activity, could stimulate fibroblasts, epithelial cells, vascular endothelial cells, dermal cells and other cells to regenerate and repair. Drugs can promote the division of endothelial cells, induce secrete certain proteases, dissolve and invade the surrounding matrix, form fiber cells and capillaries, establish collateral circulation, promote the formation of new capillary network, increase blood flow and number of capillaries in granulation tissue, and effectively improve wound microcirculation. Rb-FGF gel could promote the synthesis of DNA, RNA and hydroxyproline acid in the process of human skin and mucosal wound tissue repairing, accelerate the production of wound granulation tissue and the proliferation of epithelial cells and fibroblasts, thus shorten the time of wound healing [23-25].

Conclusion

All of the 12 patients in the experimental group were cured in the first stage after the standardized treatment, which significantly shortened the treatment course, perfectly preserved the natural

shape of the external auricle, and obtained better curative effect than the conservative treatment taken by the control group. Combined with Nano-silver antibacterial dressing and Rb-FGF gel, VAC can effectively treat AAC at its early stage, relieve the patients' physical and psychological pain, and reduce the external ear healing deformity caused by acute chondritis treated with traditional methods significantly.

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