# Evaluation of Wound Healing Efficacy of an Antimicrobial Spray Dressing at Skin Donor Sites

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**Abstract:** *Introduction.* Autologous skin transplantation is a common treatment for patients with full-thickness burns. Postoperative wound care is essential for skin graft donor and recipient sites, but traditional wound dressings such as cotton and gauze do not form an effective barrier to bacteria, and patients can feel uncomfortable when replacing dressings. *Materials and Methods.* The goal of this study was to evaluate the use of an antimicrobial spray dressing (JUC Spray Dressing, NMS Technologies Co Ltd, Nanjing, China), with respect to its antimicrobial efficiency and the degree of pain experienced by patients. *Results.* The authors found the antimicrobial spray can reduce pain during the recovery period, while providing equivalent antibacterial protection to the control treatment (AQUACEL Hydrofiber Wound Dressing, ConvaTec, Bridgewater, NJ) based on skin culture tests. The spray did not adversely affect the wound site recovery. No significant side effects were present during the treatment period. *Conclusion.* This antimicrobial spray could potentially be used in wound dressing applications.

**Key words:** full-thickness burn, antimicrobial spray, wound dressing, antimicrobial efficiency, pain

The process of wound recovery is continuous, complex, dynamic, and sophisticated, and is affected by both internal factors and the external environment. Internally, extracellular matrix (ECM) deposition and reepithelialization play an important role because they produce a barrier to resist microbial invasion. With respect to external factors, the ability to control infection determines whether the wound site will continue to deteriorate. Tissue can often no longer regenerate after a deep injury; therefore, the wound area requires a dressing to assist recovery.[1] A temporary dressing is a useful and commonly used treatment to provide a suitable environment for wound healing.

Burns are painful and severe injuries that have a radical impact on the human body. Grafting and excision have been the backbone of burn

treatment for 100 years.[2] Burn wounds often require a skin autograft to provide a suitable environment for healing. However, procedural pain from repeated treatment such as skin debridement and prolonged dressing changes can be severe.[3,4] Conventional wound dressings such as plaster, gauze, and advanced wound dressings could protect the wound, although the application and removal of these dressing materials may cause pain.[5]

An antimicrobial spray dressing (JUC Spray, NMS Technologies Co. Ltd, Nanjing, China) includes quaternary ammonium salts that have been widely used as antimicrobial agents. Their antimicrobial activity may be related to the negatively charged cell surfaces of bacteria that attract the positively charged salts and allow them to disrupt the cell membrane.[6] Therefore, once the antimicrobial spray is applied to the skin surface, it forms a positive charge film to kill and isolate bacteria. The antimicrobial properties of these salts could be altered to fit different applications by changing their functional groups.[7,8]

Some areas of the body are difficult to protect from microbial infection using traditional wound dressings, and the broad-spectrum antimicrobial spray could be a useful alternative in these cases. Unlike chemical-based treatment, antimicrobial barriers will not produce bacterial resistance. This dressing spray was used in a study to control oral infection after an operation in the oral cavity, and was shown to significantly improve healing in all patients without any obvious side effects.[9] In the current study, the authors investigated the efficacy of the antimicrobial spray in preventing infection at a skin donor site.

## Materials and Methods

The antimicrobial spray was provided by NMS Technologies Co Ltd, Nanjing, China for the purposes of this study, and polyurethane film (Tegaderm, 3M, St. Paul, MN) was purchased for use as a cover film. An advanced wound dressing (AQUACEL Hydrofiber Wound Dressing, ConvaTec, Bridgewater, NJ) was provided by the company for use as a control treatment.

*Clinical case criteria*. One hundred patients undergoing skin autografting were recruited for this study from the Tri-Service General Hospital, National Defense Medical Center, Taiwan, Republic of China, between July 30, 2012 and June 30, 2013. A skin graft donor site of both thigh areas measuring less than 10% total body surface area was tested, and the wound was treated within 24 hours. Patients were randomly divided into an antimicrobial spray group and a control-treated group. The patients consisted of 35 men and 23 women between 34 and 50 years old. This study protocol was registered and approved by the National Defense Medical Center (TSGHIRB No.: 1-101-03-001). The inclusion criteria were patients with burns undergoing autologous skin surgery who had donor site exudate; no obvious signs of infection (ie, redness or fever); and were able to self-assess. The exclusion criteria were significant donor site infection or systemic manifestations of infection, a dry donor site or one with very little exudate; existing skin diseases; severe cardiopulmonary dysfunction; and any other reason (eg, severe diseases such as liver and kidney dysfunction that may have seriously interfered with wound repair) determined by the study investigator.

**Keypoints**

- One hundred patients undergoing skin autografting were recruited for this study from the Tri-Service General Hospital, National Defense Medical Center, Taiwan, Republic of China, between July 30, 2012 and June 30, 2013.
- A skin graft donor site of both thigh areas measuring less than 10% total body surface area was tested, and the wound was treated within 24 hours.
- Patients were randomly divided into an antimicrobial spray group and a control-treated group.

*Treatment and evaluation standard*. After surgery, the donor sites underwent conventional iodine disinfection, wound tissue was taken for culture, and the color of the wound site was recorded. For the experimental group, the antimicrobial spray was applied uniformly to the wound site, where it solidified immediately to produce an invisible protective layer. This layer contains quaternary ammonium salts that have antibacterial properties. The wound site was protected with polyurethane film that was replaced every 2-3 days as required. Patients in the control group were subject to routine disinfection using only hydrocolloid dressings. Pain was measured using the Visual Analogue Scale (VAS), where 0 indicated no pain and 10 indicated extreme pain. Samples were taken from the donor site at 0, 4, 8, and 12 days for evaluation of infection and morphology, and the estimated time needed for healing, based on the clinician's assessment, was recorded.

*Tissue culture at wound sites*. A cotton swab was used to collect bacteria from the wound area, and then

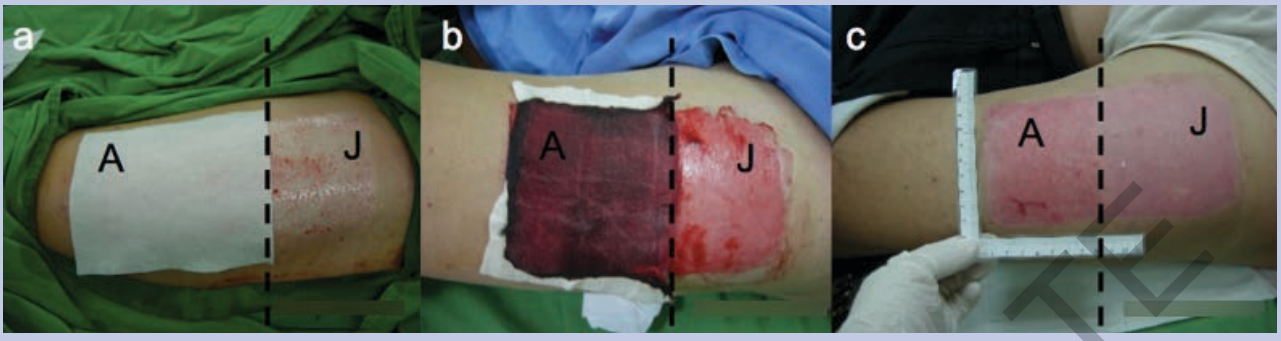


**Figure 1.** The photograph of wound closure at different time points: (a) initial treatment; (b) 3 days of treatment; and (c) 15 days after surgery and treatment with either the control dressing (A) or the antimicrobial spray (J).

**KEYPOINTS**

- The wound healing times when in the antimicrobial spray group were 16.74 ± 4.76 days, and 16.13 ± 4.84 days in the control group (Table 1), but the difference was not statistically significant.
- The number of cultures positive for bacteria increased to 0.18% in the control group and 0.17% in the antimicrobial spray group after 7 to 8 days of treatment (Table 1); however, none of these differences were statistically significant.
- The Visual Analog Scale score for pain exponentially decreased during treatment for both groups; however, the pain scores of the antimicrobial spray group at any of the time intervals were less than those of the control group (Table 1).

delivered to the Division of Clinical Pathology, Tri-Service General Hospital for analysis with a wound and pus culture. Microbes detected in the tissue cultures included diptheroids, *Staphylcoccus epidermidis*, and *Proionbacterium acnes*. If no colonies, or very few colonies, were present on the culture plate, the result was recorded as negative; otherwise, the result was recorded as positive.

*Statistical analysis*. Except for tissue culture results expressed as a percentage of the population, results are presented as the mean ± standard deviation. Statistical differences were analyzed using Student's *t* test, and differences were considered to be significant for $P$ values < 0.05.

## Results

*Wound healing time and morphology*. A visual respresentation of the wound sites is presented in Figure 1. Compared with the control dressing, the antimicrobial spray allowed a clear view of the wound site at the beginning of treatment (Figure 1a). Three days later, the control dressing had absorbed a great quantity of exudate, but because the antimicrobial spray forms only a thin film, the exudate could evaporate. In addition, the wound was easier to clean, so the wound surface was drier than when using the control (Figure 1b). After 15 days, the wound pictured had almost healed, and the wound sites of both groups showed no significant differences (Figure 1c).

The wound healing times in the antimicrobial spray group were 16.74 ± 4.76 days, and 16.13 ± 4.84 days in the control group (Table 1), but the difference was not statistically significant. This indicates the protective film from the antimicrobial spray did not adversely affect the wound site recovery. None of the patients showed any side effects during the study period.

*Wound culture*. Before wound treatment, culture tests showed no obvious bacteria from the donor area in either group. After 3 days of treatment, 0.03% of the antimicrobial spray group, but none in the control group, had a positive culture test. The number of cultures positive for bacteria increased to 0.18% in the control group and 0.17% in the antimicrobial spray group after 7 to 8 days of treatment (Table 1); however, none of these differences were statistically significant.

*Visual analog score*. The VAS score exponentially decreased during treatment for both groups; however, the pain scores of the antimicrobial spray group at any of the time intervals were less than those of the control group (Table 1). No patient in either treatment arm reported a VAS score greater than 4, and before treatment and 3 days postoperation there were statistical differences ($P$ < 0.05) between the antimicrobial spray and control groups with respect to the VAS score.

**Table 1.** The results of treatment with a control dressing or an antimicrobial spray after surgery.

| Parameters | Measurement time point | Antimicrobial spray dressing (n = 30) | Control dressing (n = 28) | *P* |
|---|---|---|---|---|
| Positive wound wulture (Percentage of population) | Preoperation | 0 (0.00%) | 0 (0.00%) | |
| | 3 days postoperation | 1 (0.03%) | 0 (0.00%) | |
| | 7~8 days postoperation | 5 (0.17%) | 5 (0.18%) | |
| Visual analog score (0-10) | | | | |
| | Preoperation | 2.87 ± 0.22 | 3.71 ± 0.27 | 0.004497 |
| | 7~8 days postoperation | 1.87 ± 0.20 | 3.00 ± 0.29 | 0.001533 |
| | 11~12 days postoperation | 1.43 ± 0.19 | 2.11 ± 0.33 | 0.033734 |
| | 15~16 days postoperation | 0.67 ± 0.17 | 1.21 ± 0.28 | 0.087392 |
| Wound healing time (day) | Complete wound healing | 16.43 ± 0.78 | 16.14 ± 0.91 | 0.752814 |

## Discussion

Burn treatment and healing are complex processes. Burn wounds are prone to bacterial infections that may delay healing. Thus, good autograft wound recovery is essential to prevent fluid and nutrient loss and promote healing.[10]

The main ingredients of the antimicrobial spray used in this study are water and quaternary ammonium salts, which act as cation particles. As an aerosol, the antimicrobial spray can uniformly cover wound sites and form a thin antimicrobial layer. This layer provides a barrier between the wound and the external environment, thus preventing disease transmission. Unlike conventional dressings, this method can be used for any part of the body and can reduce the risk of wound-dressing detachment, which results from physical activity. Microorganisms such as bacteria carry a net negative charge. When bacteria are close to wound sites, the electrostatic force leads the cation particles to absorb negatively charged bacteria. This disrupts bacterial cell membranes and leads to a loss of structure and cellular activity.[11] In this clinical study, the spray showed efficient antimicrobial activity. There were a few infections after treatment with the antimicrobial spray, but this may have been caused by sweat from physical activity that could have caused a loss of the protective film. To enable widespread use of the antimicrobial spray, the timing of changing wound dressings that have been placed over skin treated with the antimicrobial spray should be researched and discussed to test for limits of adherence.

Autograft is a common and useful way to treat burn wounds, but recovery depends heavily on postoperative care; for most patients, this is a huge challenge. Pruritus and pain at the wound site is a serious problem, especially for burn patients with comorbities, and represents both a psychological and physiological burden during treatment. Pain control is essential to improve the patient's quality of life. Currently, long-term pain control using medications like methadone or morphine reduces background pain and promotes recovery,[12] but the associated side effects such as respiratory depression, sedation, nausea, or constipation could prove problematic. Antimicrobial spray can reduce pain at the donor site by forming a physical barrier and can reduce pain significantly ($P < 0.05$), especially in the initial recovery period. The authors found that, even when the donor site had almost healed, the VAS score of the antimicrobial spray group was lower than that of the control group, suggesting antimicrobial spray is useful for reducing pain throughout recovery. In addition, no significant side effects were observed during the treatment period, indicating that the antimicrobial spray can be used as a treatment tool to improve the quality of life of burn patients.

## Conclusion

The objective of this study was to determine whether an antimicrobial spray is superior to conventional wound dressings. Burns are an accidental injury that can result in long-term pain during recovery. The antimicrobial spray is an ideal wound dressing, because it could effectively reduce pain while being suitable for wounds in areas difficult to fit with a conventional

dressing. The wound healing times are comparable between the control dressing and the antimicrobial spray. In addition, none of the patients had any side effects after surgery. Therefore, antimicrobial spray may be useful in a variety of postoperative applications.

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# 抗微生物喷雾敷料在皮肤供体部位的伤口愈合效果评价

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**摘要：**

简介：自体皮肤移植是治疗全层烧伤患者的常见方法。术后伤口护理对于皮肤移植供体和受体部位至关重要，但传统的伤口敷料如棉花和纱布不能形成有效的细菌屏障，且更换敷料时患者会感到不适。

材料和方法：本研究的目的是评估一种抗微生物喷雾敷料（JUC 喷雾敷料，南京神奇科技开发有限公司）的使用效果，重点是其抗微生物效率和患者的疼痛程度。

结果：研究作者发现，抗微生物喷雾剂在恢复期间可以减轻疼痛，同时根据皮肤培养测试，提供与对照治疗（AQUACEL Hydrofiber 伤口敷料，ConvaTec 公司，布里奇沃特，新泽西州）相当的抗微生物保护。喷雾对伤口部位的恢复没有不良影响。在治疗期间没有出现显著的副作用。

结论：这种抗微生物喷雾剂有潜力用于伤口敷料的应用。

关键词：全厚度烧伤，抗微生物喷剂，伤口敷料，抗微生物效率，疼痛

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伤口恢复的过程是连续的、复杂的、动态的和精密的，并受到内部因素和外部环境的影响。内部来说，细胞外基质（ECM）的沉积和再上皮化起着重要作用，因为它们形成了一个抵抗微生物侵入的屏障。关于外部因素，控制感染的能力决定了伤口部位是否会继续恶化。深层伤害后，组织往往无法再生，因此伤口区域需要敷料来辅助恢复。临时敷料是一种有用且常用的治疗方法，可以提供适合伤口愈合的环境。

烧伤是一种痛苦而严重的伤害，对人体有重大影响。移植和切除手术成为烧伤治疗的基础已有 100 年。烧伤伤口通常需要自体皮肤移植以提供适合愈合的环境。然而，反复治疗如皮肤清创和长期更换敷料引起的程序性疼痛可能非常严重。传统的伤口敷料如石膏、纱布和高级伤口敷料可以保护伤口，但这些敷料材料的应用和移除可能会引起疼痛。

一种抗微生物喷雾敷料（JUC 喷雾，南京神奇科技开发有限公司）包含季铵盐，季铵盐已被广泛用作抗微生物剂。它们的抗微生物活性可能与细菌的带负电细胞表面吸引带正电的盐分子，从而破坏细胞膜有关。因此，一旦将抗微生物喷雾剂应用于皮肤表面，它会形成一个带正电的薄膜来杀死并隔离细菌。这些盐的抗微生物特性可以通过改变它们的功能基团来适应不同的应用。

传统伤口敷料难以保护身体某些部位免受微生物感染，广谱抗微生物喷雾剂在这些情况下可能是有用的替代品。与化学治疗不同，抗微生物屏障不会产生细菌抗药性。这种敷料喷雾在一项研究中用于控制口腔手术后的感染，结果显示在所有患者中显著改善了愈合，没有明显的副作用。在本研究中，作者研究了抗微生物喷雾剂在防止皮肤供体部位感染方面的效果。

## 材料和方法

本研究使用的抗微生物喷雾剂由南京神奇科技开发有限公司提供，聚氨酯薄膜（Tegaderm，3M 公司，圣保罗，明尼苏达州）作为覆盖膜购买。高级伤口敷料（AQUACEL Hydrofiber 伤口敷料，ConvaTec 公司，布里奇沃特，新泽西州）作为对照治疗使用。

临床病例标准：从 2012 年 7 月 30 日至 2013 年 6 月 30 日，从中华民国台湾国防医学院三军总医院招募了一百名进行自体皮肤移植的患者。测试了双大腿面积小于 10%总身体表面积的皮肤移植供体部位，并在 24 小时内处理伤口。患者被随机分为抗微生物喷雾剂组和对照治疗组。患者包括 35 名男性和 23 名女性，年龄在 34 至 50 岁之间。该研究方案已在国防医学院注册并获得批准（TSGHIRB 编号：1-101-03-001）。纳入标准为接受自体皮肤手术且供体部位有渗出液的烧伤患者；无明显感染迹象（如红肿或发热）；能够自我评估。排除标准为显著的供体部位感染或全身感染表现，干燥或渗出液很少的供体部位；已有皮肤病；严重的心肺功能障碍；以及研究者认为可能严重干扰伤口修复的其他原因（如肝肾功能障碍等严重疾病）。

治疗和评估标准：手术后，供体部位进行了常规碘消毒，取伤口组织进行培养，并记录伤口部位的颜色。实验组均匀地在伤口部位应用抗微生物喷雾剂，喷雾立即固化形成一个无形的保护层，该层含有具有抗微生物特性的季铵盐。用聚氨酯薄膜保护伤口部位，根据需要每 2-3 天更换一次。对照组患者仅接受常规消毒和水胶体敷料。使用视觉模拟评分（VAS）测量疼痛，0 表示无痛，10 表示极度疼痛。从供体部位在第 0、4、8 和 12 天采样以评估感染和形态，并根据临床医生的评估记录愈合所需的预计时间。在伤口处进行组织培养。使用棉签从伤口区域收集

细菌，然后送至三军总医院临床病理学部进行伤口和脓液培养分析。在组织培养中检测到的微生物包括假鼻疽杆菌、表皮葡萄球菌和痤疮丙酸杆菌。如果培养皿上没有菌落，或者菌落非常少，结果被记录为阴性；否则，结果被记录为阳性。

统计分析。除了以人口百分比表示的组织培养结果外，结果以均值±标准差的形式呈现。使用学生 t 检验分析统计差异，P 值<0.05 的差异被认为是显著的。

**结果**

伤口愈合时间和形态。图 1 展示了伤口部位的视觉表示。与对照敷料相比，抗微生物喷雾剂在治疗开始时允许清晰地查看伤口部位（图 1a）。三天后，对照敷料吸收了大量的渗出物，但由于抗微生物喷雾剂只形成了薄薄的一层，渗出物可以蒸发。此外，伤口更容易清洁，所以伤口表面比使用对照敷料时更干燥（图 1b）。15 天后，图片中的伤口几乎已经愈合，两组的伤口部位没有显著差异（图 1c）。

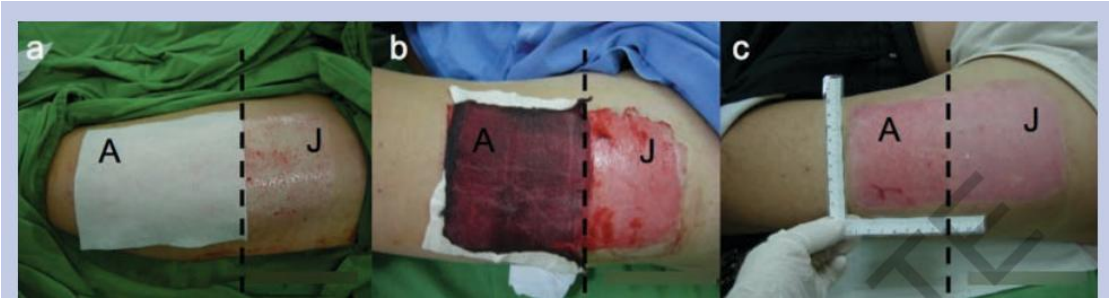


图 1。伤口闭合在不同时间点的照片：（a）初始治疗；（b） 治疗 3 天；和（c）手术后 15 天，并用对照敷料（A）或抗微生物喷雾剂（J）治疗

抗微生物喷雾剂组的伤口愈合时间为 16.74 ± 4.76 天，对照组为 16.13 ± 4.84 天（表 1），但差异不具有统计学意义。这表明抗微生物喷雾剂的保护膜并未对伤口部位的恢复产生不利影响。在研究期间，所有患者都没有显示出任何副作用。

伤口培养。在伤口治疗前，培养试验显示，两组的供体区域都没有明显的细菌。治疗 3 天后，抗微生物喷雾剂组的 0.03%，但对照组没有阳性培养试验。治疗 7 到 8 天后，对照组细菌阳性培养的数量增加到 0.18%，抗微生物喷雾剂组为 0.17%（表 1）；然而，这些差异都不具有统计学意义。

视觉模拟评分。两组的 VAS 评分在治疗过程中呈指数下降；然而，抗微生物喷雾剂组在任何时间间隔的疼痛评分都低于对照组（表 1）。两组的患者都没有报告 VAS 评分大于 4，治疗前和术后 3 天，抗微生物喷雾剂组和对照组在 VAS 评分方面存在统计学差异（P < 0.05）。

表 1 手术后用对照敷料或抗菌喷雾剂治疗的结果

| 参数 | 测量时间点 | 抗微生物喷雾敷料（n=30） | 对照敷料（n=28） | P |
|---|---|---|---|---|
| 阳性伤口（人口百分比） | 术前 | 0 (0.00%) | 0 (0.00%) | |

| | | | | |
|---|---|---|---|---|
| | 术后 3 天 | 1 (0.03%) | 0 (0.00%) | |
| | 术后 7～8 天 | 5 (0.17%) | 5 (0.18%) | |
| 视觉模拟评分（0-10） | | | | |
| | 术前 | 2.87 ± 0.22 | 3.71 ± 0.27 | 0.004497 |
| | 术后 7～8 天 | 1.87 ± 0.20 | 3.00 ± 0.29 | 0.001533 |
| | 术后 11～12 天 | 1.43 ± 0.19 | 2.11 ± 0.33 | 0.033734 |
| | 术后 15～16 天 | 0.67 ± 0.17 | 1.21 ± 0.28 | 0.087392 |
| 伤口愈合时间（天） | 伤口完全愈合 | 16.43 ± 0.78 | 16.14 ± 0.91 | 0.752814 |

## 讨论

烧伤的治疗和愈合是复杂的过程。烧伤伤口容易受到细菌感染，可能会延迟愈合。因此，良好的自体移植伤口恢复对于防止液体和营养物质的丧失以及促进愈合至关重要。10

本研究中使用的抗微生物喷雾剂的主要成分是水和季铵盐，它们作为阳离子颗粒。作为喷雾剂，抗微生物喷雾剂可以均匀地覆盖伤口部位，并形成一个薄薄的抗微生物层。这层提供了伤口和外部环境之间的屏障，从而防止疾病传播。与传统的敷料不同，这种方法可以用于身体的任何部位，并可以减少由于身体活动导致的伤口敷料脱落的风险。像细菌这样的微生物带有净负电荷。当细菌靠近伤口部位时，静电力使阳离子颗粒吸附负电荷的细菌。这会破坏细菌的细胞膜，导致结构和细胞活性的丧失。11 在这项临床研究中，喷雾显示出有效的抗微生物活性。使用抗微生物喷雾剂治疗后有少数感染，但这可能是由于身体活动的汗液可能导致保护膜的丧失。为了使抗微生物喷雾剂得到广泛使用，应研究和讨论更换已经用抗微生物喷雾剂处理过的皮肤上的伤口敷料的时间，以测试粘附的限制。

自体移植是治疗烧伤伤口的一种常见且有用的方法，但恢复严重依赖于术后护理；对于大多数患者来说，这是一个巨大的挑战。伤口部位的瘙痒和疼痛是一个严重的问题，尤其是对于有合并症的烧伤患者，在治疗过程中，这既是心理上的也是生理上的负担。疼痛控制对于提高患者的生活质量至关重要。目前，使用像美沙酮或吗啡这样的药物进行长期疼痛控制可以减少背景疼痛并促进恢复，12 但相关的副作用如呼吸抑制、嗜睡、恶心或便秘可能会带来问题。抗微生物喷雾剂可以通过形成物理屏障来减少供体部位的疼痛，并可以显著减少疼痛（$P < 0.05$），尤其是在初始恢复期。作者发现，即使供体部位几乎已经愈合，抗微生物喷雾剂组的 VAS 评分也低于对照组，这表明抗微生物喷雾剂对于在恢复过程中减少疼痛是有用的。此外，在治疗期间没有观察到任何显著的副作用，表明抗微生物喷雾剂可以作为一种改善烧伤患者生活质量的治疗工具。

## 结论

本研究的目标是确定抗微生物喷雾剂是否优于传统的伤口敷料。烧伤是一种意外伤害，可能导致恢复期间长期疼痛。抗微生物喷雾剂是理想的伤口敷料，因为它可以有效地减少疼痛，同时，它适用于传统敷料难以覆盖的伤口区域。抗微生物喷雾剂组和对照敷料组的伤口愈合时间相当。此外，手术后的患者都没有任何副作用。因此，抗微生物喷雾剂可能在各种术后应用中有用。

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