СРПСКИ АРХИВ
ЗА ЦЕЛОКУПНО ЛЕКАРСТВО
SERBIAN ARCHIVES
OF MEDICINE

Address: 1 Kraljice Natalije Street, Belgrade 11000, Serbia
☏ +381 11 4092 776, Fax: +381 11 3348 653
E-mail: office@srpskiarhiv.rs, Web address: www.srpskiarhiv.rs

**Paper Accepted*** **ISSN Online 2406-0895**

**Case Report / Приказ болесника**

Predrag T. Kovačević♣

# Effective local treatment of necrotizing fasciitis using a chlorine solution obtained by electrolysis

Ефикасан локални третман некротичног фасциитиса раствором хлора добијеног електролизом

University Clinical Center of Niš, Faculty of Medicine, Clinic for Plastic and Reconstructive Surgery, Niš, Serbia

**Received: September 21, 2024**
**Revised: November 3, 2024**
**Accepted: November 4, 2024**
**Online First: November 6, 2024**
**DOI: https://doi.org/10.2298/SARH240921083K**



*__Accepted papers__ are articles in press that have gone through due peer review process and have been accepted for publication by the Editorial Board of the *Serbian Archives of Medicine*. They have not yet been copy-edited and/or formatted in the publication house style, and the text may be changed before the final publication.
Although accepted papers do not yet have all the accompanying bibliographic details available, they can already be cited using the year of online publication and the DOI, as follows: the author's last name and initial of the first name, article title, journal title, online first publication month and year, and the DOI; e.g.: Petrović P, Jovanović J. The title of the article. Srp Arh Celok Lek. Online First, February 2017.
When the final article is assigned to volumes/issues of the journal, the Article in Press version will be removed and the final version will appear in the associated published volumes/issues of the journal. The date the article was made available online first will be carried over.

♣**Correspondence to:**
Predrag T. KOVAČEVIĆ
Faculty of Medicine, Bulevar Zorana Đinđića 81, 18000 Niš, Serbia
Email: drpredrag.kovacevic@gmail.com

# Effective local treatment of necrotizing fasciitis using a chlorine solution obtained by electrolysis

## Ефикасан локални третман некротичног фасциитиса раствором хлора добијеног електролизом

**SUMMARY**

**Introduction** Severe surgical wound infection as necrotizing fasciitis is one of the leading causes of death in the postoperative period. Large wounds affecting the skin and soft tissues are a particular problem, as such wounds are difficult to heal, especially in immunocompromised patients. Local treatment is important, and different antiseptics are in clinical use.

**Case outline** A 45-year-old woman with terminal kidney failure, with hypothyroidism and iodine allergy was admitted to the hospital with multiple abscess formation in abdominal wall. After first surgery necrotic fasciitis and sepsis were diagnosed. Complete parenteral therapy, including antibiotics, other supportive therapy and hemodialysis was performed. Successive debridement and local treatment with chlorine solution obtained by electrolysis as irrigation solution and wet wound dressing used daily lead to complete healing. Delayed wound closure was performed. She was discharged in good general condition, and the wound was healed completely.

**Conclusion** The application of a chlorine solution obtained by electrolysis (Aqualor H 200, Serbia) in a concentration of 0.2 mg/l is effective for local treatment of wounds by washing and applying wet dressing in the wound on skin and soft tissue, especially necrotizing fasciitis as wound with mixed bacterial infection.

**Keywords**: antiseptics; electrolysis; chlorine-based antiseptic; wound infection; necrotizing fasciitis

**САЖЕТАК**

**Увод** Тешка инфекција хируршке ране као што је некротични фасциитис је један од водећих узрока смртног исхода у постоперативном периоду. Опсежне ране које захватају кожу и мека ткива су значајан проблем, посебно ране које тешко зарастају код имунокомппромитованих болесника. Посебно је важан локални третман применом различитих антисептичних раствора у клиничкој пракси.

**Приказ случаја** Болесница стара 45 година која има терминалну бубрезну слабост, хипотироидизам и алергију на јод је примљена у болницу због мултиплих абсцеса у трбушном зиду. После прве операције развио се некротични фасциитис и сепса. Примењена је комплетна парентерална терапија укључујући антибиотике и другу супортивну терапију и рађене су хемодијализе. Рађена је свакодневно серија дебридмана и локални третман раствором хлора који је добијен електролизом, у виду испирања ране и као влажни завој газама натопљеним овим антисептиком до комплетног зарастања ране. Рана је секундарно сутурирана. Болесница је отпуштена кући у добром општем стању, а рана је комплетно зарасла.

**Закључак** Примена раствора хлора добијеног електролизом (Aqualor H 200, Србија) у концентрацији 0.2 mg/l је ефикасна за локални третман рана испирањем и применом влажног завоја у рани на кожи и поткожном ткиву посебно за некротични фасциитис, као ране са мешовитом бактеријском инфекцијом.

**Кључне речи:** електролиза; хлорни антисептици; инфекција ране; некротизирајући фасциитис

## INTRODUCTION

Surgical wound infection is one of the leading causes of death in the postoperative period. In developed countries, surgical site infection occurs in 16% of patients receiving hospital treatment and 38% of all surgical patients [1]. The bacterial burden in the wound can lead to infection, subclinical or clinically evident and this continuous process of the inflammation in the wound is divided into five stages:



 

1. Contamination

2. Colonization

3. Local infection

4. Spread of infection beyond 2 cm from the edge of the wound or to regional lymph nodes.

5. Systemic infection- sepsis [1–4].

The treatment of each wound must be individual (holistic), adequate, and continuous in order to ensure the goal of healing, in a clinical and economic point of view [5]. Hemodialysis patients belong to the group of immunocompromised patients. Infections in those patients could have a fatal course. Large wounds with necrotizing fasciitis are difficult to heal. Targeted antibiotic therapy is mandatory according to the findings of the wound swab, and local treatment of the wound has key importance. Various antiseptic solutions are used for wound washing as iodine solution or solution of boric acid 3%. Sodium hypochlorite solution has been used for wound treatment known as Dakin's solution used in the First World War [6].

An electrolytic solution of sodium chloride contains hypochlorite, which is formed when an aqueous solution of sodium chloride is subjected to the action of current. The concentration of chlorine oxidants in that solution is sufficient as an antiseptic and acts on a large number of microorganisms. Hypochlorite is identified as an endogenous substance in the human cells. It is produced by leukocytes in open wound on the skin [7]. There are a number of advantages of antiseptics based on chlorine oxidants:

1. Hypochlorous acid (HOCl) can be applied to the skin.



 

2. HOCl produced by leukocytes is the first line of defense against microorganisms in oxidative stress that converts $O_2$ into $H_2O_2$. and it reacts with the chlorine ion $Cl^-$ from the cells to form HOCl.

3. 0.05% HOCl is used to treat atopic dermatitis,

4. HOCl is bactericidal for most microorganisms. [8].

Active chlorine released by electrolysis from sodium chloride is molecular chlorine $Cl_2$. Molecular chlorine is rapidly hydrolyzed into a number of different chlorine compounds: hypochlorous acid (HOCl), chloride ions $Cl^-$ and hypochlorite ion ($OCl^-$) (Figure 1). [8].

By contacting the electrolytic solution with the wound, the pH of the solution is lowered, releasing hypochlorous acid, NaClO, OCl- ion, which all have a bactericidal effect [9]. That highlight the special advantage of applying chlorine solution due to its low price [10]. Wound healing is a complex morphological and pathophysiological process that is influenced by a number of factors, such as the degree of tissue damage, the strains of bacteria present in the wound, the intensity of the inflammatory process, the capacity for tissue regeneration, the general state of health and the presence of accompanying diseases [3].

Chlorine solutions obtained by electrolysis have a high necrolytic activity, antimicrobial and local immunomodulatory effect. It has an effect on gram-positive and gram-negative microorganisms, including muti-resistant microorganisms, and also exhibits fungicidal effects [11, 12]. For difficult-to-heal wounds with biofilm formation, hypochlorous acid is recommended [11, 13]. Hypochlorous acid solution has low cytotoxicity [13]. In the study conducted by Serena et al. [14], 82% of wounds that are difficult to heal were found to be contaminated with different microorganisms. Despite a series of proven facts about the effect of various antiseptics in vitro and in experiments, a more extensive clinical examination of the



 

effectiveness of antiseptic solutions in clinical studies is necessary, especially for wounds that are difficult to heal [14]. One of such infections is necrotic fasciitis, which is presented in this paper. The aim of the work is to demonstrate the effectiveness of the chlorine solution obtained with electrolysis (Aqualor H200, Serbia) for the treatment of deep infected wounds.

## CASE REPORT

A 45-year-old female patient has been on a hemodialysis program for five years due to end-stage renal failure. She suffers from hypothyroidism and is allergic to iodine.

She was admitted due to multiple subcutaneous abscesses of the abdominal wall. In the first surgery, excision of the skin and subcutaneous tissue was performed, and the wound was closed (Figure 2).

In the postoperative course, antibiotics were administered according to biogram. In the first swab, *Staphylococcus aureus* was isolated. Biochemical parameters were corrected in accordance with the laboratory results. Wound dehiscence occurs and necrotic fasciitis is noted on the anterior abdominal wall. *Staphylococcus aureus*, *Proteus mirabiliss*, *Pseudomonas aeruginosa* and *Enterococcus faecalis* were isolated in wound swabs. The patient was transferred to the intensive care unit with developed sepsis.

The wound extends transversely across the entire hypogastrium. Infection *with Proteus mirabilis*, *Pseudomonas aeruginosa* and *Enterococcus faecium* was recorded. Clinically, there is a biofilm and pyogenic membrane on the wound without signs of granulation tissue formation. Further, *Proteus mirabiliss*, *Corynebacterium* and *Pseudomonas aeruginosa* are proven in wound. The parameters of sepsis were elevated, reaching very high values (white blood cells $30 \times 10^9$/L, C-reactive protein 248.1 mg/L and procalcitonin 99 ng/L). The wound



 

is treated daily, successive necrectomies are performed and generous washing with a chlorine solution obtained by electrolysis. Strips soaked in chlorine solution remain in the wound (moist dressing). The wound shows abundant purulent discharge and has an unpleasant odor. Signs of wound secretion are progressively reduced. After two weeks, granulations appeared on the walls of the wound. Additional necrectomy of devitalized tissue was performed. Temporary sutures were placed (Figure 3 and 4).

Wound was gradually sutured. The general condition has stabilized. Throughout the hospital stay caloric intake was corrected after each dialysis, which significantly improved wound healing capacity.

On discharge, the wound was completely healed and the patient was discharged. Figure 5.

This research was approved by the Ethical Committee of the University Clinic Center of Niš, Serbia, no. 39906/3 dated on December 22, 2023 and written consent form was obtained from the patient.



## DISCUSSION

Treatment of severe infections of the skin and subcutaneous tissue is a great challenge even in the modern era. Necrotic fasciitis with mixed bacterial colonization was especially distinguished [15]. The most common causative agents are *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus* (MRSA) [16]. Colonization of *Staphylococcus aureus*, *Proteus mirabiliss*, *Pseudomonas aeruginosa* and *Enterococcus faecalis* was found in this patient. Adequate local treatment of that wound is particularly important. Although most antiseptics were introduced a long time ago, their importance is relevant nowadays, as iodine solution, hydrogen peroxide, boric-acid solution and chlorine antiseptics. The treatment of

 

immunocompromised patients receiving hemodialysis, patients receiving chronic corticosteroid therapy or diabetic patients is particularly specific. Wound healing is a very complex process. The phases of healing are hemostasis, inflammation, proliferation and the remodeling phase. Wound healing is also influenced by the systemic factors as the state of nutrition, hypoxia, infection, immunosuppression, chronic diseases, the age of the patient, and genetic factors [16]. The patient presented in this paper suffers from hypothyroidism and terminal renal failure and has a proven allergy to iodine. In the wound, active chlorine solution containing chlorine, hypochlorite ion and hypochlorous acid, disrupt cellular homeostasis by acting on the dissolution of the biofilm formed by Pseudomonas. Although some authors state that the effect of chlorine preparations on breaking biofilms in in vivo and clinical studies has not yet been clarified [16], in our patient, biofilm was present, without signs of granulation tissue formation and *Pseudomonas aeruginosa* infection present. During treatment with restricted debridement, washing the wound and applying wet bandages with chlorine, the biofilm was effectively removed.

The effectiveness of chlorine preparations for local wound treatment has been shown to be significant in reducing bacterial burden of the wound and accelerating the healing [16]. Chlorine produced by electrolysis has beneficial effects on the healing of infected wounds. The pH of the wound environment is of great importance in the control of wound healing by increasing antimicrobial activity, modulating the activities of proteases, of which matrix metalloproteases and tissue inhibitors of metalloproteases are significant, reducing the toxicity of bacterial products and accelerating epithelialization and angiogenesis [17]. Acidified electrolytic water is a synonym for chlorine solution obtained by electrolysis. It is effective in inactivating microorganisms, and Dunnill et al. [18] proved its effectiveness on *Staphylococcus aureus* and *Pseudomonas aeruginosa*. The immune response and the response to oxidative stress in wound healing, which is shortened by the effect of acidified water, were also

investigated. During wound healing, a certain amount of reactive oxygen species (ROS) is produced, which plays a significant role in normal wound healing by affecting phagocytosis processes or are secondary messengers in immune cells and regulate angiogenesis. [18]. Free radicals oxidize chemical groups containing nitrogen and sulfur on the surface of the bacterial cell and thus block membrane functions [19, 20, 21]. The chlorine solution obtained by electrolysis can be used as an antiseptic solution both for washing wounds and as a wet wound dressing. The price is very low, and its effectiveness is proven, so the price-efficiency ratio is extremely favorable. In several clinical studies, it has been proven that 0.05% sodium hypochlorite electrolytic solution shows safe effects in the treatment of infected skin wounds and can be recommended as the agent of first choice for wound treatment [12]. The application of a chlorine solution obtained by electrolysis (Aqualor H 200, Serbia) in a concentration of 0.02 mg/dl is effective for local treatment of wounds (washing and wet dressing), especially for wound with mixed bacterial infection. Treatment with chlorine solution led to the complete healing of the wound, despite of severe sepsis and necrotizing fasciitis.



**Conflict of interest:** None declared.

 

## REFERENCES


1. Onyekwelu I, Yakkanti R, Protzer L, Pinkston CM, Tucker C, Seligson D. Surgical Wound Classification and Surgical Site Infections in the Orthopaedic Patient. JAAOS Glob Res Rev 2017;1:e022. [DOI: 10.5435/ JAAOSGlobal-D-17-00022] [PMID: 30211353]
2. Haesler E, Swanson T, Ousey K, Larsen D, Carville K, Bjarnsholt T, et al. Establishing a consensus on wound infection definitions. J Wound Care 2022;31(Sup12):S48-S59. [DOI: 10.12968/jowc.2022.31] [PMID: 36475847]
3. Sganga G, Pea F, Aloj D, Corcione S, Pierangeli M, Stefani S, et al. Acute wound infections management: the 'Don'ts' from a multidisciplinary expert panel. Expert Rev Anti Infect Ther 2020;18(3):231–40. [DOI: 10.1080/14787210.2020.1726740] [PMID: 32022606]
4. Khaldoon AM, Sture H. Developing chlorine-based antiseptic by electrolysis. Sci Total Environ 2020;709:136108. [DOI: 10.1016/j.scitotenv.2019.136108] [PMID: 31905555]
5. Swanson T, Ousey K, Haesler E, Bjarnsholt T, Carville K, Idensohn P, et al. IWII Wound Infection in Clinical Practice consensus document: 2022 update. J Wound Care 2022;31(Sup12):S10-S21. [DOI: 10.12968/jowc.2022.31.Sup12.S10] [PMID: 36475844]
6. Ottesen TD, Qudsi RA, Kahaanu AK, Baptiste BJ, Woolley PM, Socci AR, et al. The Continued Utility and Viability of Dakin's Solution in Both High- and Low-resource Settings. Arch Bone Jt Surg 2020; 8(2): 198–203. [DOI: 10.22038/abjs.2019.34372.1906] [PMID: 32490051]
7. Ulfig A, Leichert LI. The effects of neutrophil-generated hypochlorous acid and other hypohalous acids on host and pathogens. Cell Mol Life Sci 2021;78(2):385-414. [DOI: 10.1007/s00018-020-03591-y] [PMID: 32661559]
8. He Z, Fan X, Jin W, Gao Sh, Yan B, Chen Ch, et al. Chlorine-resistant bacteria in drinking water: Generation, identification and inactivation using ozone-based technologies. Journal of Water Process Engineering 2023; 53: 103772. [DOI: 10.1016/j.jwpe.2023.103772]
9. Muddemann T, Bulan A, Sievers M, Kunz U. Avoidance of Chlorine Formation during Electrolysis at Boron-Doped Diamond Anodes in Highly Sodium Chloride Containing and Organic-Polluted Wastewater. Journal of The Electrochemical Society 2018;165(15): J3281-J3287. [DOI: 10.1149/2.0371815jes]
10. Ottesen TD, Qudsi RA, Kahanu AK, Baptiste BJ, Woolley PM, Socci AR et al. The Continued Utility and Viability of Dakin's Solution in Both High- and Low-resource Settings. Arch Bone Jt Surg 2020; 8(2): 198–203. [DOI: 10.22038/abjs.2019.34372.1906đ [PMID: 32490051]
11. Murphy Ch, Atkin L, Swanson T, Tachi M, Tan YK, Vega de Ceniga M, et al. Defying hard-to-heal wounds with an early antibiofilm intervention strategy: wound hygiene. J Wound Care 2020;29(Sup3b):S1-S26. [DOI: 10.12968/jowc.2020.29.Sup3b.S1] [PMID: 32160083]
12. Scalise A. The new formulation of the 0.05% sodium hypochlorite electrolytic solution for cutaneous use: reasons and advantages. AboutOpen 2021; 8(1):14–22. [DOI 10.33393/ao.2021.2221]
13. Jull A, Wadham A, Bullen C, Parag V, Parsons JGM, Laking G, et al. Prescribed exercise regimen versus usual care and hypochlorous acid wound solution versus placebo for treating venous leg ulcers: study protocol for a randomised controlled trial (Factorial4VLU). BMJ Open 2021;11:e043420. [DOI:10.1136/ bmjopen-2020-043420] [PMID: 33602710]
14. Serena TE, Serena L, Al-Jalodi O, Patel K, Breisinger K. The efficacy of sodium hypochlorite antiseptic: a double-blind, randomised controlled pilot study. J Wound Care 2022;31(Sup2):S32-S35. [DOI: 10.12968/jowc.2022.31.Sup2.S32] [PMID: 35148643]
15. Kojić M, Mikić D, Nožić D, Rakonjac B. Streptococcal Necrotizing Fasciitis with Toxic Shock Syndrome and Rapid Fatal Outcome. Srp Arh Celok Lek 2015;143(7–8):476–79. [DOI:10.2298/SARH1508476K] [PMID: 26506762]
16. Rembe JD, Huelsboemer L, Plattfaut I, Besser M, Stuermer EK. Antimicrobial Hypochlorous Wound Irrigation Solutions Demonstrate Lower Anti-biofilm Efficacy Against Bacterial Biofilm in a Complex in-vitro Human Plasma Biofilm Model (hpBIOM) Than Common Wound Antimicrobials. Front Microbiol 2020;11:564513. [DOI: 10.3389/fmicb.2020.564513] [PMID: 33162949]
17. Sim P, Strudwick XL, Song Y, Cowin AJ, Garg S. Influence of Acidic pH on Wound Healing In Vivo: A Novel Perspective for Wound Treatment. Int J Mol Sci 2022;23(21):13655. [DOI: 10.3390/ijms232113655] [PMID: 36362441]
18. Dunnill C, Patton T, Brennan J, Barrett J, Dryden M, Cooke J, et al. Reactive oxygen species (ROS) and wound healing: the functional role of ROS and emerging ROS-modulating technologies for augmentation of the healing process. Int Wound J 2017;14 (1):89–96. [DOI: 10.1111/iwj.12557] [PMID: 26688157]
19. Fadriquela A, Sajo MEJ, Bajgai J, Kim DH, Kim CS, Kim SK, et al. Effects of Strong Acidic Electrolyzed Water in Wound Healing via Inflammatory and Oxidative Stress Response. Oxid Med Cell Longev 2020:2459826. [DOI: 10.1155/2020/2459826] [PMID: 33414890]




 

20. Oropallo A, Rao AS, Del Pin C, Ranire-Maguire M, Mathew A. An objective comparative study of non-surgical cleansing techniques and cleanser types in bacterial burden management. Int Wound J 2024;21(2):e14730. [DOI:10.1111/iwj.14730] [PMID: 38332560]
21. Weigelt MA, McNamara SA, Sanchez D, Hirt PA, Kirsner RS. Evidence-Based Review of Antibiofilm Agents for Wound Care. Adv Wound Care (New Rochelle) 2021;10(1):13–23. [DOI: 10.1089/wound.2020.1193] [PMID: 32496980]



 

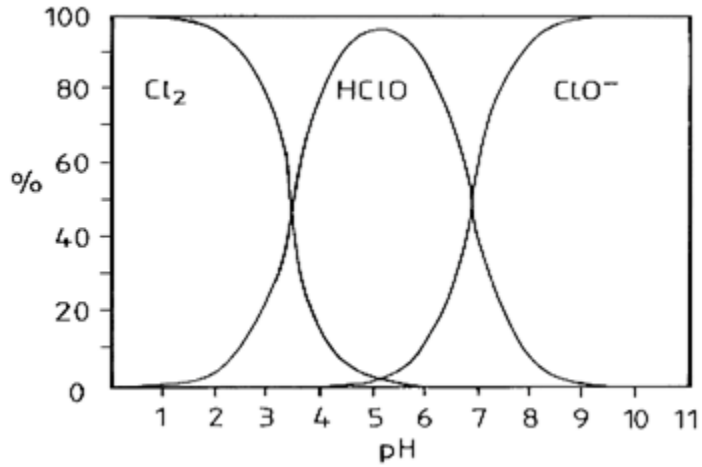


**Figure 1**. The ratio of hypochlorous acid and hypochlorous ion depending on the pH of the electrolytic sodium hypochlorite solution



 

**Figure 2.** Wound condition after initial excision; the wound was opened and successive necrotomies were performed



 

**Figure 3.** Necrotizing fasciitis of the anterior abdominal wall after multiple necrectomies and placement of sutures



 

**Figure 4**. The wound is completely closed



 

**Figure 5**. Definitive result after removal of suture material



 