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Research Paper

Efficacy of photodynamic therapy in controlling persistent scalp infections after temporal lifting: A case report

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ABSTRACT

Photodynamic therapy (PDT) is a promising approach for treating infections caused by antibiotic-resistant microorganisms. This case report discusses the successful use of PDT in conjunction with antibiotics to treat a persistent scalp abscess in a patient. After multiple failed antibiotic treatments, PDT was introduced, resulting in significant improvement and eventual resolution of the infection. PDT was performed using a formulation of methylene blue in an oily base at 0.05%, applied intralesionally with an 18G cannula and also topically, followed by exposure to red LED light at 50 J/cm^2. The treatment resulted in the resolution of the infection after two sessions. This case highlights the potential of PDT as an adjunctive therapy in managing complex skin infections, reducing persistent inflammation, and combating bacterial resistance. Additionally, PDT is suggested as a preventive measure in the immediate postoperative period to avoid late complications that might require antibiotics, thereby reducing the risk of developing microbial resistance. Future studies should explore photosensitizers that do not cause skin staining, as can occur with methylene blue, particularly on the face.

1. Introduction

Skin infections are common and can range from mild to severe, affecting people of all ages. These infections can be caused by bacteria, viruses, fungi, or parasites, with bacterial infections being the most prevalent. Among the most common bacteria are Staphylococcus aureus and Streptococcus pyogenes, with Staphylococcus aureus being particularly dangerous among staphylococci. This gram-positive coccus causes skin infections characterized by blisters, folliculitis, impetigo, abscesses (boils), cellulitis, and epidermal necrolysis. Due to the excessive and inappropriate use of antibiotics, many strains of Staphylococcus aureus have developed resistance to treatments. This resistance leads to re-infections that are harder to treat, as resistant strains multiply when non-resistant strains are eliminated by antibiotics [1].

The type of bacterial resistance and the antibiotics to which they are resistant depend on where the infection was contracted: in healthcare settings or the community. In hospitals, staff often carry resistant strains, which are generally resistant to several antibiotics, including almost all penicillin-related antibiotics. Beta-lactam antibiotics resistant to methicillin (MRSA) are particularly problematic. Hospital-acquired MRSA infections are treated with antibiotics such as vancomycin, linezolid, tedizolid, quinupristin/dalfopristin, ceftaroline, telavancin, and daptomycin, among others. Community-acquired MRSA infections can be treated with trimethoprim/sulfamethoxazole, clindamycin, minocycline, or doxycycline [2].

Antibiotics are essential for treating bacterial skin infections, both in prophylaxis and the treatment of established infections. For infections caused by Staphylococcus aureus and streptococci, dicloxacillin or cephalexin for seven days are adequate treatments. In case of suspected community-acquiredMethicillin-resistant Staphylococcus aureus MRSA, options like sulfamethoxazole-trimethoprim, clindamycin, or doxycycline are recommended. However, antibiotics can cause side effects such as nausea, vomiting, diarrhea, abdominal discomfort, allergic reactions, photosensitivity, and alterations in intestinal flora, leading to secondary infections like candidiasis. Resistance generally occurs due to inadequate antibiotic prescriptions, including improper dosages and durations [1,2].

Photodynamic therapy (PDT) is an innovative therapeutic approach that combines a photosensitizing agent with a specific light source to generate reactive oxygen species that destroy pathogenic microorganisms. PDT is effective against a wide range of microorganisms, including antibiotic-resistant bacteria, fungi, and viruses. One of the main

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advantages of PDT is its broad spectrum of action and low likelihood of resistance development, as it causes extensive damage to various cellular components. Additionally, PDT has a localized effect, minimizing systemic side effects [3,4].

PDT is an extremely efficient and versatile approach for controlling microbial infections, especially those caused by antibiotic-resistant microorganisms. Light interacts with chromophores, also known as photosensitizers, such as methylene blue and curcumin, as well as endogenous photosensitizers, with a particular emphasis on protoporphyrin IX (PPIX), which is formed from its precursor, aminolevulinic acid (ALA). This process generates reactive oxygen species (ROS) through a photodynamic (photochemical) reaction, effectively promoting the destruction of microbial and tumor cells [5–7].

PDT has shown promise in controlling microbial infections, especially those caused by antibiotic-resistant microorganisms. It can be applied alone or in combination with topical and oral antibiotics, depending on the type and early diagnosis of the infection. Studies show that PDT can be effective in treating skin infections, chronic wounds, and other conditions where pathogenic microorganisms play a critical role, leading to severe complications like necrosis [5,7–9].

PDT offers a potent and safe alternative to traditional antibiotic treatments. It is important to emphasize that infected tissue does not heal. Therefore, to stimulate the local inflammatory process, even using laser light and/or red LED, it is essential to achieve microbial control through PDT. Thus, PDT and photobiomodulation should be applied together: first to decontaminate and then to heal the tissue [10]. One of the most notable advantages of PDT is its ability to eliminate both superficial bacteria and biofilms, complex structures that are difficult to eradicate with conventional treatments [7,10].

Additionally, PDT does not induce microbial resistance, making it an attractive option in the face of the growing problem of antibiotic resistance. Studies demonstrate that PDT is effective against a wide range of pathogens, including Gram-positive and Gram-negative bacteria, fungi, and viruses [3]. This versatility makes PDT a valuable tool for both medical professionals and non-medical practitioners performing minimally invasive aesthetic procedures who need a potent solution against infections without resorting to antimicrobials [5,10].

In summary, PDT not only treats infections in a localized and effective manner but also minimizes the progression to more severe and even systemic infectious complications. This makes it a crucial addition to the current therapeutic arsenal, providing new solutions for challenging and resistant infections.

This article discusses a successful clinical case combining PDT with antibiotic therapy to treat a persistent inflammatory nodular infection that developed into a scalp abscess following a temporal lifting procedure in a patient.

Initially, the patient received antibiotic therapy, but the infection persisted and progressed. PDT was then applied along with appropriate antibiotic therapy, and the infection was monitored through several sessions. The successful integration of PDT with conventional antibiotic therapy underscores its efficacy in managing persistent infections and preventing severe complications. The promising results of this case suggest that PDT can be a critical tool in the fight against antibiotic-resistant bacterial infections, offering a safe, targeted, and efficient alternative to traditional treatments.

2. Methods

2.1. Clinical Study

This study presents the case report of a 65-year-old immunocompromised patient who, after a year of breast cancer treatment, underwent a non-invasive temporal lifting procedure using non-absorbable sutures on the scalp to achieve facial lifting. One year later, the patient returned to the clinic complaining of pain in the scalp area. Upon examination, signs of folliculitis were identified at the suture anchoring site on the scalp. Due to bacterial resistance, this condition progressed to an infectious nodular abscess on the scalp, making treatment more challenging. The following report provides a detailed account of the case, including the steps taken that led to the complete remission of the infection and the removal of the suture, a procedure that initially seemed impossible without surgical intervention due to excessive inflammation and infection that prevented proper healing.

2.2. Microbial control formulation

The microbial control formulation was developed using 0.05 % methylene blue in an oily base, similar to an ointment. This formulation was applied to the scalp using an 18G cannula, both on the surface and within the infected area, as preparation for the subsequent photodynamic therapy.

2.3. Equipment

The Lince LED equipment, developed by MMOptics, consists of red LEDs for treatment and a diagnostic system that uses violet LED light, called Evince. This equipment is widely used in medical applications, including the diagnosis of cancer and microorganisms, as well as the treatment of both.

2.4. Laser protocols

2.4.1. Photodynamic therapy protocol

Photodynamic therapy (PDT) was performed to control the infectious process using red LED light with an irradiation dose of 50 J/cm^2 and an intensity of 150 mW/cm^2, employing the Lince equipment (MMOptics - São Carlos, Brazil). The average application time was 7 min in the infected area. Two PDT sessions were conducted using the 0.05 % methylene blue formulation, with a 7-day interval between sessions.

After the final PDT session, a photobiomodulation session was carried out to modulate tissue healing. This photobiomodulation therapy was performed using red LED light with an irradiation dose of 10 J/cm^2, also with the Lince equipment, to enhance tissue healing. Two sessions were conducted per week for 15 days, totaling 30 days of complete treatment. Additionally, a topical antibiotic ointment containing neomycin was applied after the PDT and photobiomodulation process to assist in the healing process.

2.4.2. Photobiomodulation therapy protocol

Photobiomodulation therapy was administered to optimize tissue healing by modulating skin inflammation until complete healing was achieved. Laser sessions were conducted 1 to 2 times per week using red LED light with an irradiation dose of 10 J/cm^2, utilizing the Lince equipment (MMOptics - São Carlos, Brazil). The treatment was carried out for up to 30 days.

3. Results

Below is a detailed case report of the treatment of complications experienced by the patient one year after the temporal lifting procedure. The information is organized by weeks and months of treatment with antibiotics and anti-inflammatory medications, culminating in the application of photodynamic therapy, which resulted in the complete remission of the bacterial infection in the affected area of the scalp.

Week 1 - Session 1:In the first session, an evaluation of folliculitis was conducted, followed by the removal of the infected hair using 2% chlorhexidine to clean the area. The procedure was concluded with the application of a topical antibiotic ointment containing neomycin to the affected area. To complement the treatment, the antibiotic cephalexin 500 mg (every 8 hours) was prescribed for 7 days, combined with the steroidal anti-inflammatory prednisone 40 mg (every 12 hours) for 4 to 5 days, due to the elevated inflammation.

Week 11 - Session 2:After two months, the patient returned reporting local pain and hardened, inflamed areas, suggesting a recurrence of the infection. The area was cleaned with 2% chlorhexidine, and the procedure was concluded with the application of a topical antibiotic ointment containing neomycin. For treatment, the antibiotic moxifloxacin 400 mg was prescribed, to be taken once daily for 7 days, as it is suitable for immunocompromised patients with recurrent infections. Since the patient reported severe local pain, an intramuscular injection of ketoprofen 100 mg/2 ml was administered. Additionally, dexamethasone 4 mg was prescribed every 12 h for 4 to 5 days due to persistent inflammation.

Week 16 - Session 3: After one month, the infection had not yet subsided, and the patient was experiencing sensitivity, pain, and pus in the scalp area, indicating severe inflammation and infection. The infection had progressed to a nodular abscess in the region. The area was drained and cleaned with 2% chlorhexidine, and the procedure was concluded with the application of a topical antibiotic ointment containing neomycin. To complement the treatment, the antibiotic amoxicillin 500 mg with clavulanate 125 mg was prescribed every 8 h/ for 10 days, along with prednisone 40 mg every 12 h for 5 days.

Week 21 - Session 4: After another month, the infection persisted, and the patient continued to experience sensitivity, pain, and pus in the scalp area. The area was again drained and cleaned with 2 % chlorhexidine. To optimize the microbial control process, photodynamic therapy was performed using a formulation with 0.05 % of methylene blue in an oily vehicle, applied with an 18G cannula. Red LED light was applied with an irradiation dose of 50 J/cm^2 using the Lince equipment from MMOptics – São Carlos, Brazil. After about 7 min of irradiation, the excess methylene blue was removed, and a topical antibiotic ointment containing neomycin was applied to the area. The prescribed medication was then changed to a higher dose of amoxicillin combined with clavulanate (875 mg/125 mg) for 10 days, along with prednisone 40 mg every 12 h for 5 days.

Week 22 - Session 5: After 7 days, the inflammatory and infectious process significantly reduced but was not yet fully resolved. The area was drained and cleaned again with 2 % chlorhexidine and the prescribed antibiotic continued to be used for another 7 days, totaling 14 days. To achieve complete pathogen control in the area, photodynamic therapy was performed again with 0.05 % of methylene blue applied in an oily vehicle and inserted with an 18 g cannula. Red LED light was applied with an irradiation dose of 50 J/cm^2 using the Lince equipment from MMOptics – São Carlos, Brazil. After about 7 min of irradiation, the excess methylene blue was removed, and a topical antibiotic ointment containing neomycin was applied to the area.

Week 23 - Session 6: After 7 days from the second PDT session and 14 days from the first session, the inflammation and infection were eliminated. The area was drained and cleaned again with 2 % chlorhexidine and the suture thread was removed using anatomical forceps. Photobiomodulation therapy was performed using red LED light with an irradiation dose of 10 J/cm^2 utilizing the Lince equipment (MMOptics - São Carlos, Brazil) to modulate tissue healing. A topical antibiotic ointment containing neomycin was also applied.

After 3 Months - Session 7: The patient returned for a routine follow-up. The area was examined and showed no signs of inflammation or infection. The scalp healed well and there were no residual symptoms of folliculitis or abscess. The patient was instructed on proper scalp hygiene and advised to report any new symptoms immediately.

4. Discussion

Photodynamic therapy (PDT) emerges as an effective alternative, especially in cases where conventional antibiotics fail due to microbial resistance. The responsible use of antibiotics and adherence to medical guidelines are crucial to minimizing the risk of resistance and ensuring treatment efficacy. In this context, PDT presents itself as an excellent immediate treatment option, both as a first-line therapy and as a subsequent choice after evaluating resistance to commonly used antibiotics. This case illustrates the complexity of treating complications following a temporal lifting procedure in an immunocompromised patient with microbial resistance. The development of bacterial resistance after numerous unsuccessful antibiotic applications necessitated multiple adjustments to the antibiotic regimen, underscoring the need for alternative treatment strategies. Photodynamic therapy played a pivotal role in managing the persistent infection, demonstrating its efficacy in cases resistant to conventional antibiotics [5,10].

Due to the severe infectious and inflammatory condition, the non-absorbable suture could not be removed without surgical intervention. However, after the application of PDT, effective microbial and inflammatory control was achieved, facilitating the healing process and allowing for the successful removal of the suture from the scalp.

PDT stands out as a critical intervention, especially in scenarios where traditional antibiotic treatments prove ineffective. Its role in both primary infection control and as an adjunct to antibiotic therapy highlights its potential to significantly enhance treatment outcomes in resistant cases. In Fig. 1, we observe the treatment of a scalp infection in an immunocompromised patient following a temporal lifting procedure, where a suture thread was applied one year prior to the complication.

In Fig. 2, we can see the results before and after the PDT procedure associated with antibiotics in microbial control.

This case illustrates the complexity of managing complications following a temporal lifting procedure in an immunocompromised patient with microbial resistance. The bacterial resistance, which developed after several unsuccessful antibiotic treatments, required multiple adjustments in prescriptions, highlighting the need for alternative adjunctive treatment strategies.

Photodynamic therapy (PDT) played a crucial role in managing the persistent infection, demonstrating its effectiveness in cases resistant to conventional antibiotics. Due to the severe infectious and inflammatory condition, the non-absorbable suture could not be removed without surgical intervention. However, after applying PDT, microbial and inflammatory control was achieved, facilitating the healing process and allowing the successful removal of the scalp suture.

This infectious condition resulted from the inability to anticipate resistance patterns, which are typically identified through antibiograms—tests commonly performed only in hospitals to assess the level of antibiotic resistance in patients, particularly those who are immunocompromised. Additionally, patients who frequently visit hospitals or are in contact with others who do often develop resistance to cephalexin and other common antibiotics, which are the first line of defense against severe skin infections caused by Staphylococcus aureus.

In daily clinical practice, conducting prior antibiotic resistance assessments is uncommon due to the costs and urgency of situations requiring rapid interventions. Furthermore, this practice is not routine among non-medical professionals who perform minimally invasive aesthetic procedures, such as temporal lifting and other minor facial surgeries.

According to the findings of this case report, several clinical errors occurred during the treatment, contributing to the worsening of folliculitis into a severe infectious process (nodular abscess) on the scalp. The need to combine PDT with pharmacological practices involving antibiotics was crucial in enhancing the treatment's efficacy.

We conclude that the application of PDT in conjunction with antibiotics was essential in resolving the persistent infection. However, we suggest that the ideal approach would have been to apply PDT from the outset, after evaluating the patient's resistance pattern, rather than waiting for the condition to worsen. According to the results, PDT could have been combined in the first session with cephalexin or even with the combination of amoxicillin and clavulanate (500 mg/125 mg) at lower concentrations, potentially avoiding the need to progress to higher concentrations (875 mg/125 mg), depending on the infection's evolution.

If PDT (Photodynamic Therapy) had been applied immediately after

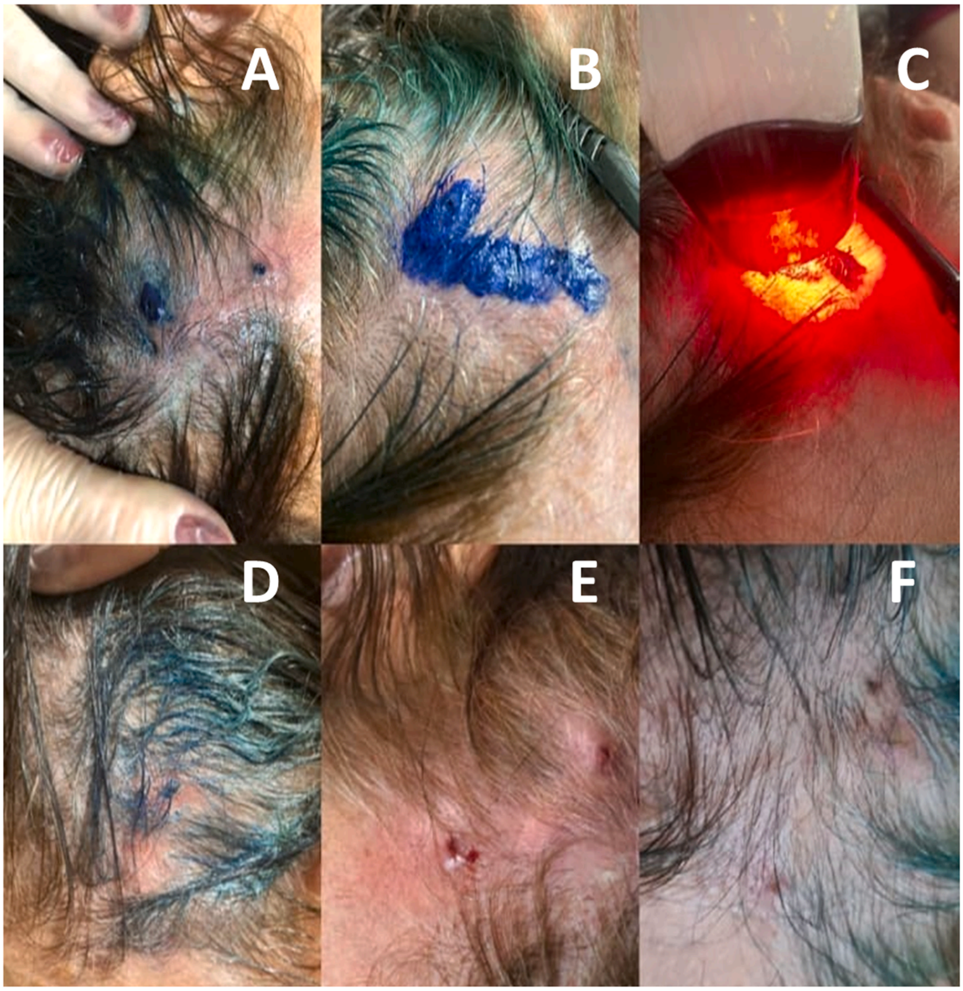

Fig. 1. (a) Application of methylene blue in ointment form with 18G cannulas intralesionally into the entry points of the non-absorbable suture thread; (b) Application of 0.05 % methylene blue formulation on the skin surface and inside the lesion using a cannula; (c) PDT procedure using the Lince equipment on the scalp with a red LED light device; (d) The scalp after the PDT session showing a bluish coloration that remains in the region for about 24–72 h; (e) Inflammation of the scalp region 7 days after the first PDT session; (f) Control of inflammation and infection 15 days after two PDT sessions and 30 days after completing the treatment.

the diagnosis of folliculitis in the first week, none of the subsequent issues would have occurred; we would not have faced increased resistance to treatments that led to the formation of a nodular abscess on the scalp. Regarding the abscess that formed due to the progression of folliculitis, if PDT had been combined with the initial choice of antibiotics, even if that choice was inadequate, the therapy would have already resolved the infection. Therefore, we can assert that photodynamic therapy is crucial both in primary control, avoiding the need for multiple antibiotic combinations, and in cases of antibiotic resistance, where it can be used as an additional safeguard in microbial control.

Combining PDT with oral antibiotics is essential for optimizing the control of microbial infections, especially in cases of resistant infections and exacerbated inflammation. Essential recommendations for clinicians include the early diagnosis of infections, allowing for immediate interventions that minimize bacterial resistance patterns. In this context, incorporating PDT due to its antimicrobial effects would be fundamental in significantly reducing the need for oral antibiotics, as well as the use of more specific antibiotics that should be reserved for cases of resistance to standard antibiotics.

Clinically, the use of PDT with formulations containing chromophores, such as methylene blue, would be ideal for controlling minor infections or minimizing infections before combining it with antibiotics to treat more severe infections, thus ensuring treatment efficacy and reducing microbial recurrence. Additionally, we suggest further studies on the application of aminolevulinic acid (ALA) in formulations for facial use, as the use of methylene blue on the face may cause pigmentation, which is undesirable.

5. Conclusion

The early diagnosis and immediate treatment of skin infections are essential to prevent the progression to more severe skin infections. While antibiotics are widely used, microbial resistance is a growing challenge that can lead to treatment failure due to persistent infections, resulting in chronic inflammation and impaired tissue healing. Implementing a treatment protocol that does not rely on systemic antibiotics would be a significant advantage for non-medical professionals and an effective alternative for patients under medical care. Requesting an antibiogram to assess resistance is ideal, but it is not always feasible in daily practice. Therefore, a thorough clinical history is crucial for accurate diagnosis and appropriate prescription, along with rapid and effective clinical evaluation following medication. Photodynamic Therapy (PDT) emerges as an effective alternative, particularly in cases where conventional antibiotics fail due to resistance. In scenarios involving resistant infections and exacerbated inflammation, combining PDT with oral antibiotics is essential. Acting both as a standalone treatment and as an adjunct to oral and topical pharmacological therapies, PDT provides a critical safety margin in microbial control.

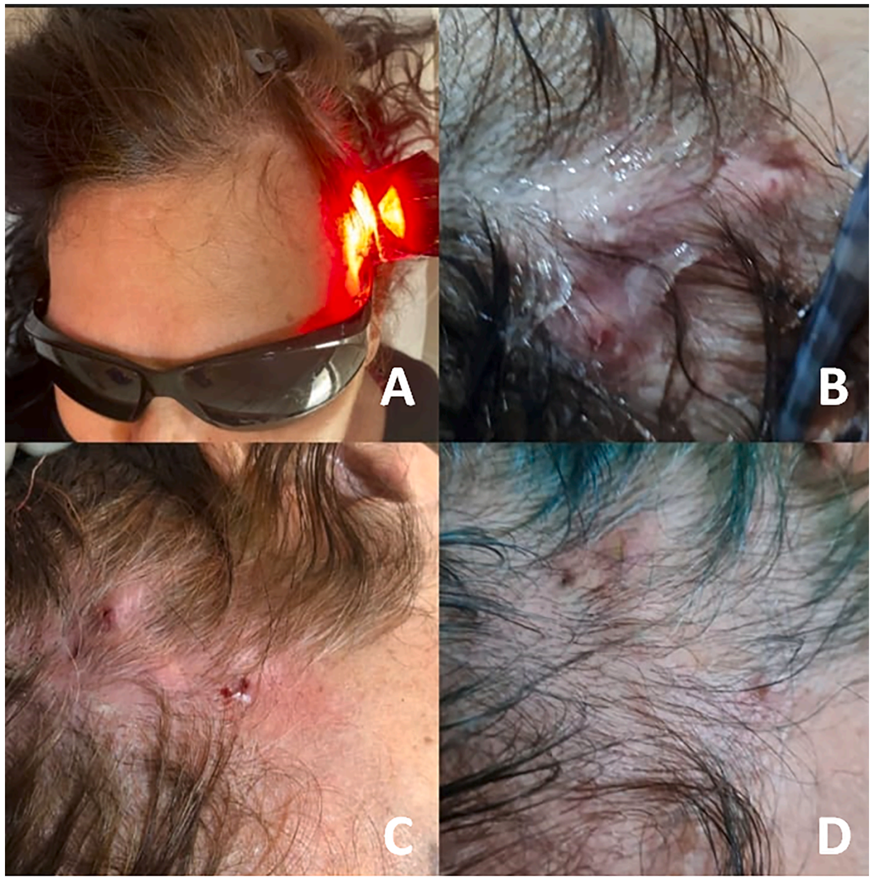

Fig. 2. PDT procedure on scalp (a). Excessive inflammation on the scalp due to severe infection (microbial resistance) (b), inflammation on the scalp after 7 days of the first pdt session (c), and after 20 days of two pdt sessions (d).

CRediT authorship contribution statement

Priscila Fernanda Campos de Menezes: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Conceptualization. **Vanderlei Salvador Bagnato:** Writing – review & editing, Supervision, Resources.

Declaration of competing interest

This text has been revised and edited as necessary and I assume full responsibility for the content of the publication.

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