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Review

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Treatment of infected soft tissue loss

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Abstract

Hand coverage in infected soft tissue loss (STL) is a challenging clinical condition. Appropriate and well-timed antibiotic therapy and careful debridement are crucial for the success of the subsequent reconstructive procedure. Debridement must be radical, and all nonviable or infected tissue should be removed. Strict medical control and multiple procedures can be required when infection recurrence is observed after primary procedure. Secondary healing of STL is usually necessary in these complex conditions. Negative pressure wound therapy (NPWT) is often used as a temporary instrument to reduce oedema and drainage, facilitating the attainment of a clean wound for subsequent reconstruction. According to the type and size of the defect, multiple options ranging from skin grafts and substitutes to local and free flaps can be selected for the treatment of infected STL. A reconstructive ladder approach and case-by-case decision making should always be considered. Due to the unique function and role of the hand, the surgical strategy must also take into account aesthetic and functional factors. Orthopedic and Plastic surgeons should manage this wide variety of treatment options in a multidisciplinary and high-specialized context including radiologists, microbiologists, infectious disease specialists and physiotherapists, customizing the treatment path to the specific patient's situation.

Keywords: Reconstruction, flap, skin substitute, soft tissue loss, infection, hand, coverage

INTRODUCTION

STL in hand infections represents a clinical challenge for hand surgeons due to the complexity of the lesion and the need for appropriate and multidisciplinary care. Understanding the principles of infection treatment and the knowledge of the available options for reconstruction of STL is essential for proper management[1].

The combination of antibiotics and sequential debridement is crucial in infection management[2]. The number of debridements and the interval before tissue coverage are primarily dictated by clinical examination, blood test and imaging diagnostics aiming to verify infection resolution.

Although rapid wound closure remains crucial, preserving hand function through adequate soft tissue coverage is the primary goal[3]. This can be obtained, provided that soft tissue reconstruction permits good tendon gliding and early postoperative rehabilitation.

At present, there is no consensus in the literature on standard treatment for the initial management and secondary reconstructive procedures, because patients may show different infection patterns and different host characteristics. Therefore, treatment strategy should be evaluated on a case-by-case basis[1-3]. This review aims to describe the acute treatment and subsequent defect coverage in post-infection hand STL to help surgeons in their practice when facing this complex multidisciplinary setting.

SEARCH STRATEGY AND STUDY SCREENING

A comprehensive literature search to identify studies that analyzed hand coverage in infected STL was performed on PubMed, Scopus, Cochrane Library, Web of Sciences, and Embase. The search was limited to September 2022. After collecting the studies, duplicates were removed. The remaining studies were screened based on title, abstract, and full text. The quality of the studies was assessed. Any information relevant to the review was considered to summarize acute treatment and subsequent defect coverage in infected hand STL. A treatment algorithm treatment for infected soft tissue loss was reported in Figure 1.

PRINCIPLES OF TREATMENT IN ACUTE PHASE

Antibiotic therapy

Clinical data supporting antibiotic therapy in infected STL of the hand is limited. Immediate empiric antibiotic therapy should only be performed in cases of severe and acutely evolving soft tissue infections. For established infection cases, wound cultures should be taken prior to antibiotic administration. After that, empiric antibiotic therapy can be started. Once cultures and antibiotic sensitivity data are available, an appropriate, agent-specific antibiotic treatment should be performed[4].

The empiric antibiotic therapy should be evaluated according to clinical history[5]. Infected STL related to human or animal bites and marine environment are often polymicrobial. Farming accidents are often caused by gram-negative (e.g., Enterobacter and Klebsiella species) or anaerobic strains (e.g., Clostridium)[6]. In contrast, infected STL related to domestic injuries, and post-surgical cases are usually associated with Staphylococcus epidermidis, Staphylococcus aureus, and Streptococcus group D.

In open contaminated injuries, antibiotic therapy should be started as soon as possible. In recent guidelines published by the British Orthopedic Association (BOA) and the British Association of Plastic Reconstructive Aesthetic Surgeons (BAPRAS), cephalosporin or amoxicillin-clavulanate has been suggested for 24-48 h. Furthermore, a single dose of gentamycin (3 mg/kg) can also be added at the time of surgical debridement[7].

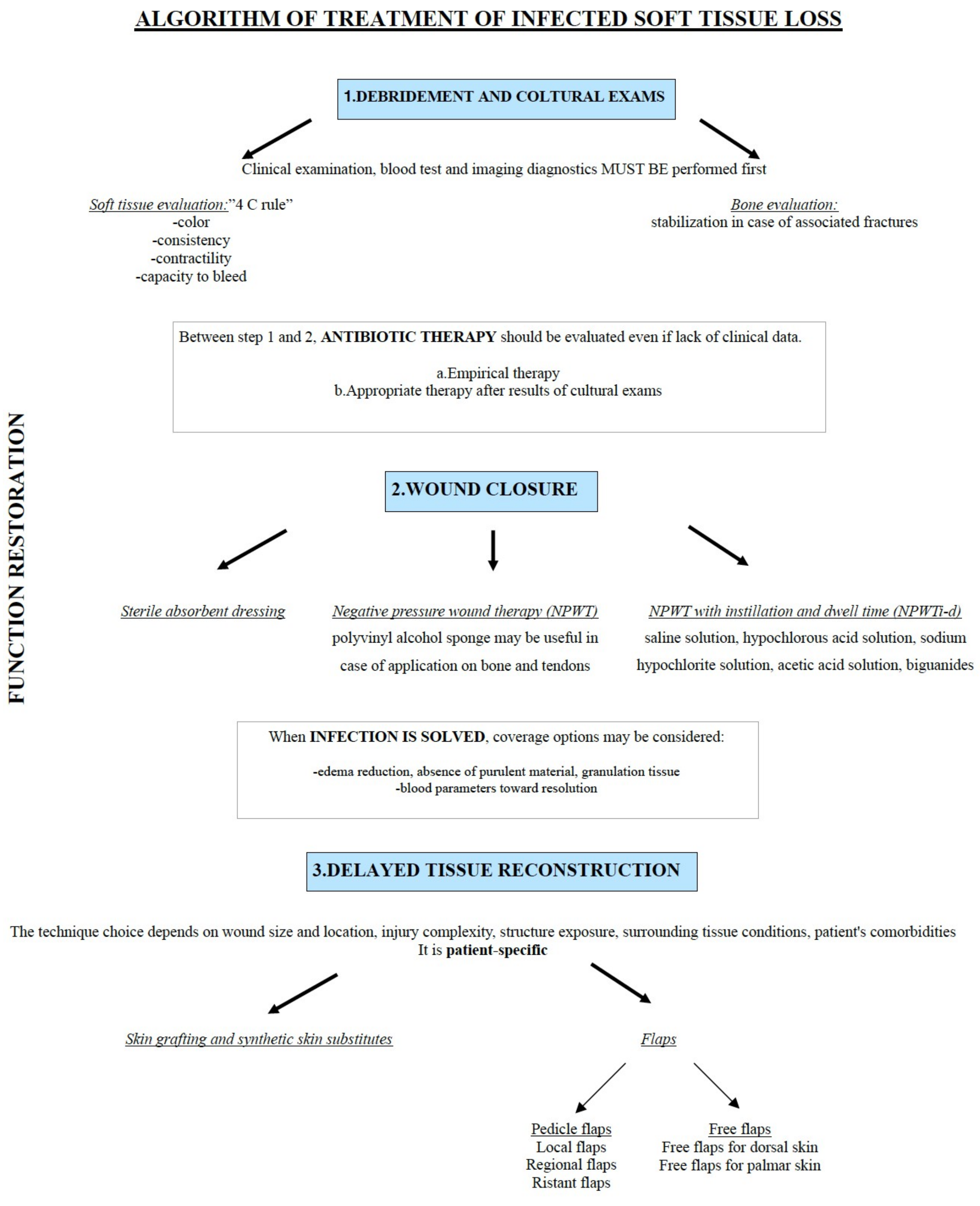

Figure 1. Algorithm of treatment of infected soft tissue loss.

Other cases of infections with SFL (e.g., post-surgical hand infections) should always be treated with vancomycin or other drugs effective against methicillin-resistant Staphylococcus Aureus that is, at present, the most common bacterium causing hand infections[8].

It must also be considered that worldwide antibiotic resistance is quite variable; therefore, referring to local institutional guidelines for proper therapy is necessary when they are available[6,9].

Debridement

Debridement is a crucial step for success in the treatment of infected hand STL. During debridement procedure, a systematic approach is recommended, evaluating the wound area from the margins to the center and from the surface to the deeper layers [Figure 2][10]. Surgery should commence with a thorough and extensive removal of all nonviable and infected tissues. Vessels, nerves, and tendons should be carefully examined and spared. In this phase, a tourniquet may be inflated in order to facilitate the identification of anatomical structures. After tourniquet removal, all residual nonviable tissues should be excised [Figure 3][10,11]. Determination of muscle tissue viability is based on subjective intraoperative parameters summarized in the "4 C rule": color, consistency, contractility, and capacity to bleed. Nevertheless, a recent histological study questioned the "4 C rule" ability to identify muscle tissue vitality correctly[12]. Simultaneously, multiple tissue samples should be retrieved for microbiological examination. Microbiologic cultures are essential in established infection, but in acute open fracture and wound, there is no need to take samples because the correlation between tissue culture obtained at the time of debridement, and subsequent infection has not been proved[13].

Once debridement is complete, abundant irrigation with saline or antiseptic solution is performed, and the wound is left open or approximated. Irrigation with saline or antiseptic solution aims to reduce the bacterial load and remove debris from the wound. In wounds that may be infected, recent guidelines recommend at least three liters of sterile saline solution in low-pressure irrigation because high-pressure washing may transport bacteria and debris into the deeper layers[12]. Whether this effect is relevant in the clinical setting needs further investigation[14,15]. In complex, highly contaminated wounds and/or severe infections, serial debridement is often necessary to remove all infected and nonviable tissue and prepare the site for subsequent reconstruction. In these cases, after primary debridement, strict clinical observation and prompt surgical revision are always mandatory.

Skeletal stabilization in open fractures contaminated and potentially infected

In post-traumatic infected STL of the hand associated with fractures, skeletal stabilization is essential to promote tissue healing and facilitate medications and dressings. External fixation and/or stabilization with Kirschner wires should be preferred because internal fixation devices can be easily contaminated by biofilm-forming bacteria[16]. In some cases, fixation is not possible because of bone loss, and a staged reconstruction should be considered. A temporary custom-made cement spacer may represent a useful instrument waiting for secondary bone reconstruction. Bone loss can be treated in secondary procedures with different techniques. As a general rule, minor bone loss (less than 2-3 cm) that is commonly observed at the hand is usually reconstructed with a non-vascularized bone graft from the iliac crest. Major bone loss (more than 2-3 cm) is not common at the hand and represents a surgical challenge. In these rare cases, bone reconstruction can be attempted by means of vascularized bone graft or induced membrane technique according to the concepts developed by Masquelet[17].

Wound closure

Once debridement of infected soft tissues and the treatment of associated skeletal injuries is completed, the wound can be loosely sutured to allow drainage of blood and fluid. Temporary sterile absorbent dressing can be used in the first days after operation to keep the wound bed hydrated and promote tissue healing. Alternatively, a temporary NPWT can be directly applied and used for a short period of time, enabling the assessment of the evolution of the healing process. Postoperative monitoring is essential because after primary debridement, local infection may persist, and in serious cases, sepsis may worsen, extending along

Figure 2. Post traumatic soft tissue loss on the dorsal face of the hand with metacarpal bone exposure and extensor tendon loss.

Figure 3. Final appearance after radical debridement.

the limb. In these unfavorable cases, prompt repetitive debridement should be performed; the definitive soft tissue reconstruction should be deferred until both local and general signs of infection have subsided and a healthy wound bed has been established[18].

NPWT

Nowadays, the use of NPWT in multiple tissues of hand and upper extremity injuries with STL is well established in the literature. NPWT promotes healing by increasing oxygen tension, blood flow, and granulation tissue formation, removing interstitial fluid, and reducing bacterial load, wound retraction forces, and interstitial oedema [Figure 4][18]. Therefore, it represents a unique resource in complex cases of STL, allowing an optimal temporary treatment before secondary reconstruction. NPWT can be used until a viable bed for skin graft is obtained, provided that neurovascular structures are not exposed and necrotic scars are not present. The application on bone and tendons is controversial, and in these cases, a polyvinyl alcohol sponge is indicated because the pore size is less prone to tissue ingrowth compared to the standard polyurethane sponge[14,19].

NPWTi-d

Differently from standard NPWT, the NPWT with instillation and dwell time (NPWTi-d) is alternated with topical wound solution instillation cycles to clean and remove infected material or debris. In the literature, the advantage of NPWTi-d over standard NPWT was described as a reduction in debridement needs, hospital length recovery, and time for definitive coverage surgery[20]. In 2020, the most recent expert panel

Figure 4. Control after 10 days of NPWT with a clean wound bed.

on NPWTi-d recommended its application with the instillation of saline solution, hypochlorous acid solution, sodium hypochlorite solution, acetic acid solution, and biguanides[21]. The superiority of one solution over the others has not been demonstrated, and it has been suggested that the instillation is the determining factor for the outcome of treatment. The antibiotics topical instillation is not currently recommended or supported by a clinical high level of evidence studies[20,21].

In summary, NPWT is highly important as it provides the necessary substrate to structures, such as bones or tendons, that would otherwise be unsuitable for covering with grafts through granulation tissue stimulation and formation.

TREATMENT OPTIONS FOR SOFT TISSUE RECONSTRUCTION

Adequate tissue coverage is necessary to restore hand function and reduce stiffness risk and disability. Infected wound debridement could leave a large STL, which may be treated with various strategies. The reconstructive procedures should be evaluated case-by-case according to several factors. They include wound size and location, injury complexity, structure exposure, surrounding tissue conditions, and patient comorbidities, such as diabetes and vascular disease, which may predispose to severe infections and surgical procedure failures[1]. In hand reconstruction, fundamental principles such as function restoration, donor tissue accurate assessment, and sensitivity and motility preservation should always be considered[22].

Early studies in the literature suggested an early coverage of STL to prevent flap failure because fibrosis and scarring may cause vascular impairment[1,10]. Recent studies have demonstrated that delayed coverage is effective and safe, reporting no differences in flap outcome based on reconstruction timing[11,23]. Furthermore, delayed coverage may positively affect flap viability due to multiple debridement and NPWT, which could optimize the wound bed and reduce the infectious risk before final soft tissue coverage[24-26].

The STL coverage should be delayed until the infection is solved. Clinically, oedema reduction, absence of purulent material, and adequate granulation tissue formation may be observed. At the same time, blood parameters should demonstrate a progressive trend toward inflammatory resolution. When these conditions are obtained, several coverage options can be adopted, varying from local skin substitutes in the case of a minor STL to flaps for more extensive lesions[27]. As a general rule, a progressive approach according to the reconstructive ladder should be followed, using the simplest possible procedure for soft tissue coverage. The risk-benefit balance has to be considered, especially in the most complex procedures, evaluating the expected result and discussing with the patient his functional requests.

Skin grafting and synthetic skin substitutes

After initial debridement and appropriate antibiotic treatment of infected lesions, skin graft and dermal substitutes can be a valuable solution for superficial STL of the hand, provided that no signs of infection are present.

Skin grafts of variable thickness may be used to cover STL areas, provided that the vascularization of the soft tissue bed is healthy. This type of graft is ideally applied when the defect does not require volume restoration and when deep structures are not exposed. Notably, in complex STL, due to complicated wound infection, scarring and fibrosis with non-optimal wounds are often observed, representing a potential cause of skin graft failure[28].

Full and split-thickness skin grafts may be harvested for soft tissue coverage, but split-thickness is the most commonly used. Split-thickness skin graft does not require donor site coverage, and it can be easily adapted to the area of tissue loss. Furthermore, it can mesh to cover a larger surface area, allowing eventual drainage for blood and serum[28].

Flaps

Flaps are the most reliable solution for covering medium to large infected STL of the hand. They are reserved for severe hand injuries that involve deep structures such as tendons, nerves, and blood vessels in which the defect can be covered by reconstructing tendons and bones in a single surgical procedure if needed[26].

Flaps are classified into cutaneous, fasciocutaneous, fascial, adipofascial, and composite (including bones and tendons) according to composition, and into the rotation, advancement, and transposition flaps according to transfer method. Flaps are further classified into local, regional, and distant flaps depending on their position regarding STL to restore[25].

Pedicle flaps

Local flaps

Local flaps consist of skin and subcutaneous tissue that originate close to the primary defects, and that is mobilized into the wound bed[29]. Local flaps, derived from tissue surrounding the hand injured area, offer many clinical advantages such as few days of hospitalization, early mobilization, and reduced stiffness risk[27].

Local flaps require several evaluations before being performed. First, the receiver area should be prepared with appropriate debridement to optimize flap positioning. Furthermore, the donor site may be evaluated before sampling through a Doppler ultrasound or angiography to assess the vascularization[25,29].

Local flaps are differentiated into random and axial pattern flaps[3]. Random pattern flaps have no established supply vessels and are characterized by subdermal vasculature with a random distribution pattern. Due to the restricted perfusion pressure, the flap size is limited to a 1:1 ratio. Rhomboidal, rotation and transposition flaps are random pattern flaps examples[25]. Instead, axial pattern flaps are based on a specific artery termed angiosome, which directly supplies the skin and subcutaneous tissues. Furthermore, interconnections between branches of adjacent axial vessels connect contiguous cutaneous territories. Consequently, axial flap size may be more extensive than random pattern ones due to the greater perfusion area provided by axial vessels. Axial pattern flaps examples are the first dorsal metacarpal artery (FDMA) flap, the dorsal metacarpal artery perforator flap (DMAP), and the advancement flap from the same thumb (Moberg type)[25].

Regional flaps

Regional flaps are obtained from an adjacent uninjured finger or hand region. The donor site is not adjacent to the wound, and a specific pedicle is recognized. The flaps may be moved to the STL area, and vascularization is provided by the pedicle, which remains anchored at the origin site.

Several regional flaps are described in the literature[30,31]. The posterior interosseous artery (PIA) flap, the radial artery perforator (RAP) flap, and the ulnar artery perforator (UAP) flap are the most widely used in hand STL.

PIA flap consists of the skin and subcutaneous tissue area sampled from the posterior aspect of the forearm. This flap is typically used to cover defects in the hand dorsal or volar region; at the same time, it is not suitable for treating STL distal to the proximal interphalangeal joint[30,31]. The anastomosis between the anterior and posterior interosseous arteries represents the pedicle; the major forearm arteries are not sacrificed.

RAP flap originates from the radial volar forearm at the distal base. It is vascularized by the deep palmar arch, which has retrograded flow. The flap must sacrifice one of the main axial arteries; therefore, a preoperative Allen test must be performed to ensure that ulnar artery vascularization compensates for the radial artery absence[26,32]. RAP flap is widely used to reconstruct hand and elbow STL. The flap is robust and versatile, although donor site scarring is a disadvantage[33] [Figure 5].

UAP flap is based on a dorsal branch of the ulnar artery, whose course is deep to the flexor carpi ulnaris (FCU) muscle. This flap is suitable for small to medium-sized defects involving the hand and wrist ulnar side. The advantages of the UAP flap over the RAP flap are a more hidden incision and relatively hairless skin in this forearm area[34].

Distant flaps

In the lower abdomen, several arteries branching off the external iliac artery and the superficial femoral artery may be reliably used to treat hand STL[3]. Among them, the most important is the circumflex superficial iliac artery (SCIA).

SCIA flaps do not require high microsurgical skills or major artery sacrifice; the main disadvantage is that the hand is tied to the trunk for two to three weeks in a dependent position with delayed rehabilitation. SCIA is indicated in young children's hand defects, high-voltage electrical burns with questionable major arterial patency, and multiple digital defects[35].

Free flaps

Free flaps are used when the size of infected STL after debridement is too large or too complex to be treated with local flaps. As most regional flaps, they are technically demanding, requiring careful planning and rigorous surgical technique. Flap selection is a fundamental step that must consider multiple factors, including the characteristics of the defect, patient's health status, functional expectations, and surgeon's skill[36]. Moreover, in hand surgery, aesthetic and functional factors play a major role in surgical choice[3].

Figure 5. Soft tissue and tendon reconstruction with ALT free flap.

Free flaps for dorsal skin

STL on the dorsal aspect of the hand can be treated with several types of free flaps. They include radial forearm flap (RFF), lateral arm flap (LAF), extreme lateral arm flap (ELAF), anterolateral thigh (ALT) flap, medial sural artery perforator (MSAP) flap, and dorsalis pedis flap[3]. All these flaps provide a skinny and pliable tissue ideal for hand reconstruction. Some of them, such as RFF and dorsalis pedis and MSAP flaps, are of limited use due to the size of the defect that must be covered. ELAF can be proposed as an alternative for large hand defects; it is supplied by terminal branches of the deep brachial artery (middle collateral artery and posterior radial collateral artery)[37]. ALT flap is probably the most versatile one, enabling the coverage of a large STL with minimal donor site morbidity [Figure 5].

Muscular fascia harvested with the flap may also be sutured and used to reconstruct extensor tendon. Nonetheless, especially in the female sex, liposuction or debulking in multiple stages may be necessary due to the flap thickness[3,30].

Free flaps for palmar skin

Glabrous skin is rare in body distribution. The foot plantar aspect is the only site other than the hand, where glabrous skin is available and could be used as a free flap to cover small and medium-sized palmar and digital defects. Larger flaps usually require skin graft addition, probably related to the unavoidable shear forces and the wetness of the donor site. The short arterial pedicle is another problem, which makes harvesting technically more challenging[3].

CONCLUSION

Infected hand STL management still represents a challenge for the orthoplastic surgeon. Treatment is controversial, but some cornerstones may be defined. It is essential to identify and eradicate the cause of infection with the support of antibiotic therapy and aggressive debridement. NPWT is essential in keeping the wound bed hydrated and promoting healing. Finally, several strategies may be considered to treat STL, including skin grafting and synthetic skin substitutes, local, distant, and free flaps.

DECLARATION

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Authors' contributions

Planned the study and reviewed the article: Artiaco S, Colzani G

Performed analysis and contributed to the writing of the text: Vezza D, Limone B, Bosco F, Giustra F

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable. Informed consent was obtained from the patients involved in this manuscript.

Consent for publication

The pictured patients who were treated by the authors of this manuscript have given their approval to have their images published for research purposes.

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