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Surgical treatment of diabetic foot ulcers during the COVID-19 pandemic in China[☆]

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ABSTRACT

Diabetic foot ulcers are among the most serious complications of diabetes. If left untreated, these ulcers can lead to severe infection and gangrene; in some instances, they may result in death. Thus, timely treatment of diabetic foot ulcers is extremely important. However, timely patient treatment during the COVID-19 pandemic is particularly challenging, because of the higher volume of patients and the need to ensure safety of medical personnel. This article describes a proposed strategy for diagnosis and treatment of diabetic foot ulcers, based on experiences with infection and control strategies during the COVID-19 pandemic in China.

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1. Introduction

In December 2019, cases of COVID-19 were reported in Wuhan, China. COVID-19 quickly spread to other countries around the globe, including South Korea, Italy, Iran, and the United States, et al. The number of infected individuals continues to increase rapidly. As of March 23, 2020, there were more than 330,000 confirmed cases of COVID-19 and 14,000 deaths worldwide. The National Health Committee of China has classified the disease as a Class B infectious disease under the Law of the People's Republic of China on the Prevention and Control of Infectious Diseases. China has also adopted measures for prevention and control of a Class A infectious disease, and has called for a level one response from major public health emergencies.

Medical personnel in Wuhan were infected by the virus in large numbers. From among the 422 medical institutions used to treat patients with COVID-19, a total of 3019 medical staff were infected and five died.¹ The COVID-19 outbreak has threatened human health and greatly affected the Chinese economy. Among other impacts, the outbreak has depleted hospital resources at all levels, and the treatment of some patients with acute conditions has also been affected.

Multiple studies have shown that patients with diabetes are at greater risk of COVID-19. A study included 41 patients with COVID-19; 32% of infected patients had other diseases. Of these patients with other diseases, the three most common underlying conditions were diabetes (20%), hypertension (15%), and vascular disease (15%).² On February 7, 2020, a report of the epidemiological data of 138 patients with COVID-19 was published; among the critically ill patients in that study, 22.2% had diabetes. The proportion of patients with comorbid diabetes was also high among the patients who died.³

Diabetic foot ulcers (DFUs) constitute a serious chronic condition resulting from diabetes complications. Approximately 10–15% of patients with diabetes develop foot ulcers⁴; of those patients, more than half develop infections.⁵ The incidence of amputations in patients with moderate or severe DFUs is approximately 20%⁶; approximately one million patients worldwide undergo amputation due to DFUs each year.⁷ DFUs are estimated to cause approximately 20% of hospitalizations in patients with diabetes; the 5-year risk of death for patients with DFUs is 2.5-fold greater than that of patients without DFUs.⁸ Therefore, it is important to reduce hospital-related COVID-19 transmission and optimize the diagnosis and treatment of DFUs to ensure safety for patients with diabetes.

As the designated hospital for treatment of patients with severe COVID-19, the Renmin Hospital of Wuhan University has experience treating patients with COVID-19 who have DFUs. Because many patients were diagnosed and treated for DFUs during the COVID-19 pandemic, the hospital gained additional experience in diagnosis and treatment of patients, as well as protection of staff members. The following treatment strategy includes information

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set out in China's COVID-19 Diagnosis and Treatment Program (Seventh Edition) and Technical Guidelines for the Prevention and Control of COVID-19 in Medical Institutions (First Edition), combined with the recent literature regarding diagnosis and treatment of DFUs.

2. Screening and preliminary management of COVID-19 in patients with DFUs

2.1. Screening for COVID-19

Safe diagnosis and management of all DFUs first requires the exclusion of COVID-19. This involves optimization of diagnosis and treatment, while reducing contact between personnel and equipment, as well as prevention of nosocomial infections. During a severe COVID-19 outbreak, the outpatient emergency department should carefully determine whether each patient has a history of exposure to an affected area, whether patients have a suspected or confirmed history of contact with individuals who have COVID-19, and whether patients exhibit COVID-19 symptoms such as fever, cough, dyspnea, and weakness.⁹ Some patients with DFUs may exhibit fever due to COVID-19; this fever is generally low- or middle-grade with respiratory symptoms. In other patients, loss of smell and taste has also been reported.

During the COVID-19 pandemic, prevention and control of nosocomial infection has been important. To ensure the safety of medical personnel and avoid nosocomial infections, each medical doctor should be familiar with methods to prevent and control such infections, including the clinical manifestations, epidemiological characteristics, diagnosis, and treatment of COVID-19. Blood and chest computed tomography are recommended as routine examinations for outpatient emergency departments, as these will facilitate rapid and accurate screening for COVID-19. Computed tomography procedures require special machinery and disinfection procedures, in accordance with national regulations.

The clinical symptoms of COVID-19 are not specific, with fever, fatigue, and dry cough, while other symptoms such as loss of smell and taste have also been documented. During the early stages of COVID-19 onset, the total number of white blood cells can be normal or low, while the lymphocyte count is low, compared with healthy individuals. Most patients have higher C-reactive protein, higher erythrocyte sedimentation rate, and normal procalcitonin. Lower respiratory tract secretions can be used for SARS-CoV-2 nucleic acid testing (i.e., the causative agent of COVID-19), and lung imaging shows characteristics similar to those of pneumonia, which are ground-glass opacities (GGOs) and consolidation with or without vascular enlargement, interlobular septal thickening, and air bronchogram sign. Preliminary screening for COVID-19 involves clinical symptoms, outpatient laboratory testing and nasopharyngeal swabbing for nucleic acid examination, combined with lung imaging.¹⁰ If the findings are negative for these screening assays, patients are not suspected to have COVID-19 at the time of screening.

If a patient has an epidemiological history of pneumonia, fever, respiratory symptoms, or imaging characteristics of pneumonia, the COVID-19 expert group should be consulted as soon as possible to determine whether COVID-19 should be suspected. For patients with suspected COVID-19, respiratory specimens should be collected and submitted for SARS-CoV-2 nucleic acid testing as soon as possible. Individuals who have come in close contact with patients who have COVID-19 should also undergo SARS-CoV-2 nucleic acid testing.

Patients with DFUs may also have fever symptoms; these are typically accompanied by local redness, swelling, pain, inflammatory secretions, elevated inflammatory response indicators (e.g., white blood cells, C-reactive protein, erythrocyte sedimentation rate, and/or procalcitonin), and positive wound bacterial culture. Patients who meet the diagnostic criteria for confirmed or suspected COVID-19 should be transferred to a designated hospital as soon as possible. If the unit has conditional admission or infected patients cannot be transferred immediately, infected patients should be isolated in a single

room; medical staff should use level three protection measures, which refer to using protective masks (N95 or above), protective clothing, disposable caps, shoe covers, gloves, as well as goggles and respiratory protectors. Medical staff should ensure that they wear and remove this protective equipment correctly, pay close attention to personal hygiene, and protect their respiratory tract, oral cavity, nasal mucosa and eyes.

2.2. Reasonable blood glucose control in patients with DFUs

Poor glycemic control has been reported as a key predisposing factor for DFUs.¹¹ A reasonable glycemic control during the treatment of DFUs could facilitate ulcer healing without increase of mortality in patients with DFUs.¹² Glycemic control is important in any patient who has COVID-19, since patients with poor glycemic control have increased risk of complications and death.¹³ Blood glucose monitoring is essential. Insulin therapy to control blood glucose levels is recommended in this patient group, and glucose levels should be measured before breakfast, 2 h after each meal, and before bedtime.

In accordance with the diagnostic criteria set out in the COVID-19 Diagnosis and Treatment Program (Seventh Edition), COVID-19 can be characterized by mild, moderate, severe, and critical disease. For patients with mild and moderate COVID-19, the existing oral insulin regimen can be maintained. If oral medications do not control blood glucose levels, subcutaneous injections of insulin are recommended. Three short-acting doses are recommended, in addition to one long-acting insulin dose. The corresponding insulin dose adjustments can be made in accordance with the patient's meal intake and results of blood glucose monitoring.¹⁴ For patients with severe and critical COVID-19, glucose control should be performed by means of continuous intravenous pump insulin infusions. Insulin dose adjustments are based on blood glucose monitoring. If blood glucose is difficult to control or if the patient experiences acute complications of diabetes, an endocrinologist should be consulted to establish a blood glucose control plan.

2.3. Preliminary management of DFUs

During treatment of DFUs, it is essential to adhere to the "safety rescue principle," effective protection protocols, and evidence-based treatment. Medical care and patient safety should be regarded as equally important goals to avoid unnecessary contamination and to prevent transmission.

During critical stages of COVID-19 prevention and treatment, stricter processes are needed for standard surgical procedures. A multidisciplinary team is also recommended,¹⁵ and elective surgery (such as vacuum sealing drainage, transverse tibial bone transport technique, arterial reconstruction) should be temporarily postponed. In patients who require limited surgery (such as interventional treatment, amputation), operations can be delayed as appropriate when such delays do not affect the current condition or its treatment; this plan must be properly communicated to affected patients. For patients who require emergency surgery (debridement, local decompression), the normal surgical procedure can be followed when COVID-19 has been excluded. However, patients with suspected or confirmed COVID-19 should be reported to the appropriate hospital department and hospital management department. After consultation with medical doctors from the operating room, anesthesiology department, and other related departments, surgery should be performed under level three protection.

DFUs should be detected and treated early; this ensures that deterioration can be effectively prevented, thereby avoiding irreversible damage to the foot tissue.¹⁶ Treatment of DFUs involves regular debridement, infection treatment, appropriate wound care, routine bacterial culture of wound secretions, drug sensitivity tests, and selection of effective antibiotics for anti-inflammatory treatment. However, this basic treatment is insufficient for some patients with severe DFUs.

3. Management of patients without COVID-19 who have DFUs

During the COVID-19 pandemic, the Renmin Hospital of Wuhan University has explored and implemented a “double triage, double buffer, and dual mode” working mode for the diagnosis and treatment of patients without COVID-19. “Double triage” refers to triage tests for fever and COVID-19 that patients entering the hospital must undergo in the triage office. All patients with fever will be treated by fever clinics; the other patients will be transferred to the emergency department. After the outpatient pre-examination and triage, a separate triage test is performed in the emergency department, where the risk of exposure to infection is high. All emergency patients are subject to a CT examination and blood tests, among other examinations. Patients suspected of COVID-19 are transferred to a “hot clinic”. After the “double triage” process, COVID-19 has initially been ruled out; thus, the patient can enter the “buffer ward”. “Double buffer” refers to observations that take place in the buffer ward, and in the “buffer zone” of the general ward. Every hospitalized patient must be isolated and treated in a single room in the buffer ward for 3 days. During this time, patients are examined to fully rule out the possibility of COVID-19. During their time in the buffer ward, patients are isolated. Patients are transferred to the general ward after COVID-19 has been ruled out in the buffer ward. The general ward is divided into “clean area” and “buffer zone” sections, which are physically separate. Patients entering the general ward from the buffer ward should first enter the buffer zone of the general ward, and then transfer to the clean area for treatment after a period of observation. “Dual mode” refers to the “fully enclosed” and “semi-enclosed” management modes used in the isolated and non-isolated wards. These procedures effectively reduced the impact of patients with COVID-19 on the general ward, medical staff, and other patients (Fig. 1).

To prevent patients with COVID-19 from entering the general ward, Renmin Hospital of Wuhan University set up a 120-bed buffer ward (and a buffer zone in the general ward) for outpatients and emergency patients requiring hospitalization, to prevent cross-infection inside the hospital. As of the date of publication, Renmin Hospital had screened

15 and 1 COVID-19 patients in the buffer ward and buffer zone of the general ward, respectively. Soon after the start of the epidemic, the so-called “double-diagnosis, double-buffering, and double-mode” model was implemented throughout Hubei province.

In addition, patients who develop a fever after surgery or during hospitalization must be closely monitored. The origin of the fever should be identified based on signs, symptoms, blood test results (especially lymphocyte counts), changes in inflammatory indicators, and imaging study results. Patients with fever and respiratory symptoms should be isolated in accordance with the procedures for suspected COVID-19. Additionally, lung computed tomography and a nasopharyngeal swab for SARS-CoV-2 nucleic acid testing should be performed.

The presence of COVID-19 should be appropriately assessed before surgery and other emergency operations in orthopedics. Patients should not undergo surgery without prior disease screening, with the exception of surgeries that are necessary to avoid endangering life and physical function. The indications for emergency surgery should be stricter than usual during a pandemic. Emergency surgery should be only indicated if all following conditions are met: the patient's physical condition can tolerate surgical treatment, the patient exhibits unstable vital signs, the injury exhibits progressive aggravation, and non-surgical treatment cannot stabilize the condition.¹⁷

In cases with infected diabetic foot ulcers, local abscesses, a severe inflammatory reaction, or even septic shock, local treatment is urgently required for drainage and control of systemic infection. Patients with irreversible necrosis of the limbs, progressive infection, toxin absorption leading to severe liver and kidney dysfunction, or septic shock, and those in whom non-surgical treatment failed, require emergency amputation surgery as a life-saving measure.

An expert team should determine whether there is an indication for emergency surgery, as well as whether COVID-19 has been properly excluded prior to surgery. The risks of surgery and precautions for pandemic prevention and control should be clearly explained to the patient. Finally, the surgery should be performed in accordance with principles of secondary protection.

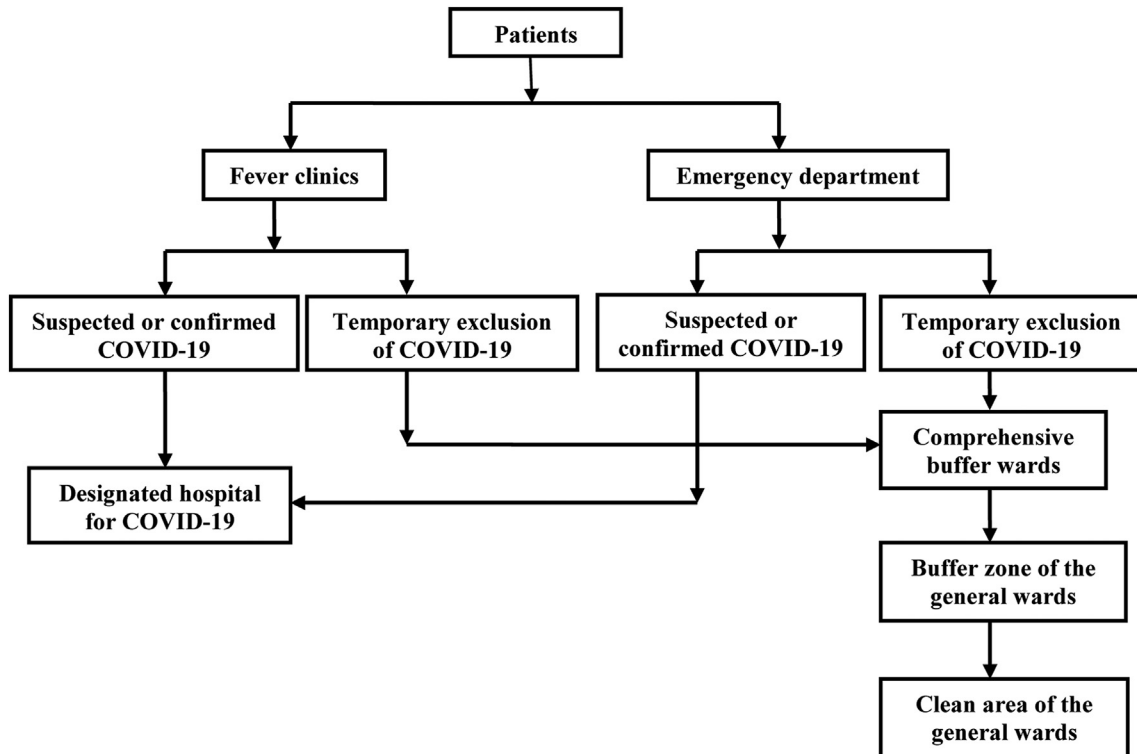


Fig. 1. The model of “double triage, double buffer, and dual mode”.

4. Management of patients with DFUs and suspected or confirmed COVID-19

Patients with DFUs who have suspected or confirmed COVID-19 should be immediately isolated and reported to public health agencies, in accordance with infection prevention and control regulations. They should also be hospitalized in COVID-19 designated hospitals with effective isolation and protective conditions. COVID-19 patients with normal or near-normal breathing can tolerate more extensive or longer operations; any such patients who also have diabetic foot ulcers can receive surgical treatments such as conservative treatment, interventional treatment, debridement, amputation, etc. Severe and critically ill patients, i.e., those who have already suffered lung function failure, may show further deterioration.¹⁸ Therefore, the severity of pneumonia needs to be considered when selecting from among the treatment options for patients with diabetic foot ulcers. Simple, rapid, safe, and effective treatment methods should be used. After careful evaluation of the patient, conservative treatment, debridement, and local decompression can be applied. Amputation involves greater trauma, and takes longer, so needs to be considered carefully. It is recommended that other surgical methods be delayed until COVID-19 symptoms have disappeared or improved, depending on the specific circumstances of the patient.

Clinical treatment for DFUs and the associated patient prognosis rely strongly on the DFU classification. The most common classification system used is the Wagner classification standard.¹⁹ After consultation with a multi-disciplinary team, if a patient has suspected or confirmed COVID-19 and requires surgery, the operation must proceed under strict protective conditions. The surgical method should be simple, effective, and minimally invasive; it should have a low likelihood of contamination, such as conservative treatment, interventional treatment, debridement, local decompression, etc. The general principle is to reduce surgical trauma and shorten the operation time.

4.1. Conservative treatment

Patients with suspected or confirmed COVID-19 should be transferred to an isolation ward if they exhibit stable vital signs. After they have been admitted to the hospital, patients' blood glucose levels should be actively controlled during treatment of COVID-19; nutritional support should be strengthened; and appropriate antibiotic and anti-inflammatory treatment should be administered. For patients with relatively small DFUs associated with mild infections (i.e., Wagner grades I and II), doctors can perform simple debridement under local anesthesia, using level three protection measures in an isolation ward. Regular wound dressing changes and new dressings for ulcers should also be supplied as required. These procedures must be supplemented with local offloading treatments, such as total contact plaster support, removable plaster support, half boots, modified surgical shoes, foot plaster, and any other necessary treatments. This process enables DFU healing and gradual improvement for most patients^{20,21}; for a small number of patients with poor results, this process provided additional time until secondary surgery was necessary.

4.2. Interventional therapy

Diabetic peripheral vascular disease involves small and medium arteries, resulting in poor compensation of collateral circulation and peripheral neuropathy. Therefore, patients with diabetic peripheral vascular disease have a higher rate of disability, compared to patients with non-diabetic vascular disease.

Percutaneous transluminal angioplasty (PCTA) is the gold standard for placement of narrow blood vessels with or without stents; it can also improve blood flow and promote healing in a timely manner. PCTA is essential when peripheral vascular disease endangers limb survival and conservative treatment fails. The use of PCTA can save limbs by avoiding amputation or reducing the level of amputation²²; this

treatment has a success rate of 80–90% and a 2-year limb salvage rate of 86%.²³ In contrast to traditional open surgery, PCTA uses local anesthesia and is minimally invasive. Furthermore, patients have higher tolerance, lower surgical complications, and lower mortality.

Most interventional operating rooms are not negative-pressure operating rooms and require terminal disinfection after surgery. All patients undergoing PCTA surgical treatment require level three protection. After treatment, they can be returned to the isolation ward. Notably, PCTA treatment is suitable for patients with mild and moderate COVID-19. Given that patients with severe and critical COVID-19 are in critical condition, this procedure must be carefully considered; it involves patient transfer, a lack of rescue equipment in the intervention room, and the potential for worsened disease after surgery.

4.3. Surgical treatment

4.3.1. Debridement

Severe DFUs are often associated with deep local abscesses, subfascial abscesses, septic arthritis, osteomyelitis, and necrotizing fasciitis on the feet or legs; they are also often infected by multiple microorganisms. Treatments for these infections are frequently unsuccessful; thus, such infections constitute the main cause of amputation in patients with diabetes. In patients with severe DFUs, the infection can cause septic shock and is life-threatening.²⁴ Therefore, debridement surgery is necessary for severely infected ulcers and is considered a surgical emergency.

4.3.2. Amputation

There is a high rate of amputation in patients with DFUs, which can be life-threatening. According to Wagner's classification standard, higher classification indicates greater ulcer area, greater depth, and greater degree of infection. These characteristics are associated with a higher rate of amputation. Patients with Wagner grades IV and V DFUs have irreversible damage in the lower limbs, often accompanied by severe vascular disease or ischemic infection. To save the life of an affected patient, amputation may be the only available treatment option.²⁵ For patients with DFUs who have previous failed amputations and require additional amputation for gangrene infection, their conditions must be carefully considered; effective limbs should be retained when possible. Before amputation, other alternative treatments should be considered first.²⁶

Given the increased risk of disease transmission by patients with COVID-19 during surgery, the need for hospital-level prevention and control has greatly increased. Furthermore, the lung function of patients with severe and critical COVID-19 is substantially impaired. Trauma from surgery and anesthesia is expected to intensify, thus increasing postoperative mortality and complications. Therefore, surgery should be limited to patients whose physical condition can tolerate surgery, patients with progressive infection, patients who will fail to achieve stable disease without surgery, and patients with severe liver and kidney dysfunction caused by toxin absorption. For patients with severe and critical COVID-19 combined with the abovementioned surgical indications, the main goal is survival. The risks and benefits of surgery should be carefully evaluated prior to selection of surgical treatment. Rapid and effective measures are recommended to stabilize the orthopedic condition and switch the treatment to a limited or elective surgery, which can achieve the same goals as if surgery was performed.

Patients with diabetic foot ulcers of Wagner grade I–III have small ulcers and mild infections. Regardless of the severity of the COVID-19 symptoms, conservative treatment and small-scale debridement can be performed according to the needs of the patient. In patients with diabetic foot ulcers of Wagner grade IV–V, irreversible injury and necrosis have already occurred. As the infection progresses, toxin absorption leads to severe liver and kidney dysfunction. To save the lives of patients who cannot be stabilized by non-surgical treatment, amputation must be performed. Patients with mild to moderate COVID-19 symptoms

can tolerate more extensive or longer operations, which can be performed according to surgical plans under the three-level protection measures in a “negative pressure operating room”. For patients with severe or critical COVID-19, it is necessary to fully evaluate the potential risks and benefits of surgery, which cannot be tolerated by all patients. Operations are mainly intended as life-saving treatments, and can include debridement or amputation if appropriate.

If patients with suspected or confirmed COVID-19 must undergo surgery, multidisciplinary cooperation should be implemented on the basis of prevention and control. The procedure should be negotiated with relevant departments such as anesthesiology, operating room staff, endocrinology, and the intensive care unit to implement individualized diagnosis and treatment plans. Surgery should be performed in a designated hospital under protective conditions. The operation should be performed in a negative-pressure operating room, where negative pressure should be maintained below -5 Pa. All medical staff participating in the surgery should wear personal protective equipment according to level three protection requirements.¹⁵ The appropriate anesthesia method should be chosen according to the patient’s condition and surgical requirements; general anesthesia should be avoided. The effective power of the electric knife should be as low as possible and a smoking device should be used to reduce the generation of aerosols.

If patients with DFUs require other surgical treatments (e.g., negative pressure wound therapy, tibia lateral bone movement technology, vascular reconstruction technology, and others) that do not endanger life and

limb function, or are limited operations, it is recommended to wait until the COVID-19 pandemic has ended.

5. Conclusion

Thus far, COVID-19 has been effectively controlled in China; however, COVID-19 is now a worldwide pandemic that presents a considerable challenge for healthcare workers. In this context, the traditional treatment strategy for DFUs has limitations. The guidance provided in this article is based on practical experience at the front-lines of clinical treatment during the pandemic in China and refers to the recommendations and guidelines of relevant domestic experts. It includes reasonable recommendations for the diagnosis and treatment of DFUs, optimization regarding the diagnosis and treatment process, reduction of cross-infection in hospitals, and treatment of affected patients by means of multidisciplinary collaboration (Fig. 2). The diagnosis and treatment strategies described here should ensure that patients receive timely and reasonable treatment with effective COVID-19 prevention and control.

Author contributions

Conceptualization, Hai Tao; Formal analysis, Hai Tao and Hui Cao; Funding acquisition, Xiaoyan Tang; Investigation, Hai Tao and Wei Xiang; Methodology, Lin Jin and Xiaoyan Tang; Project administration, Fenghua Tao and Xiaoyan Tang; Resources, Fenghua Tao and Xiaoyan

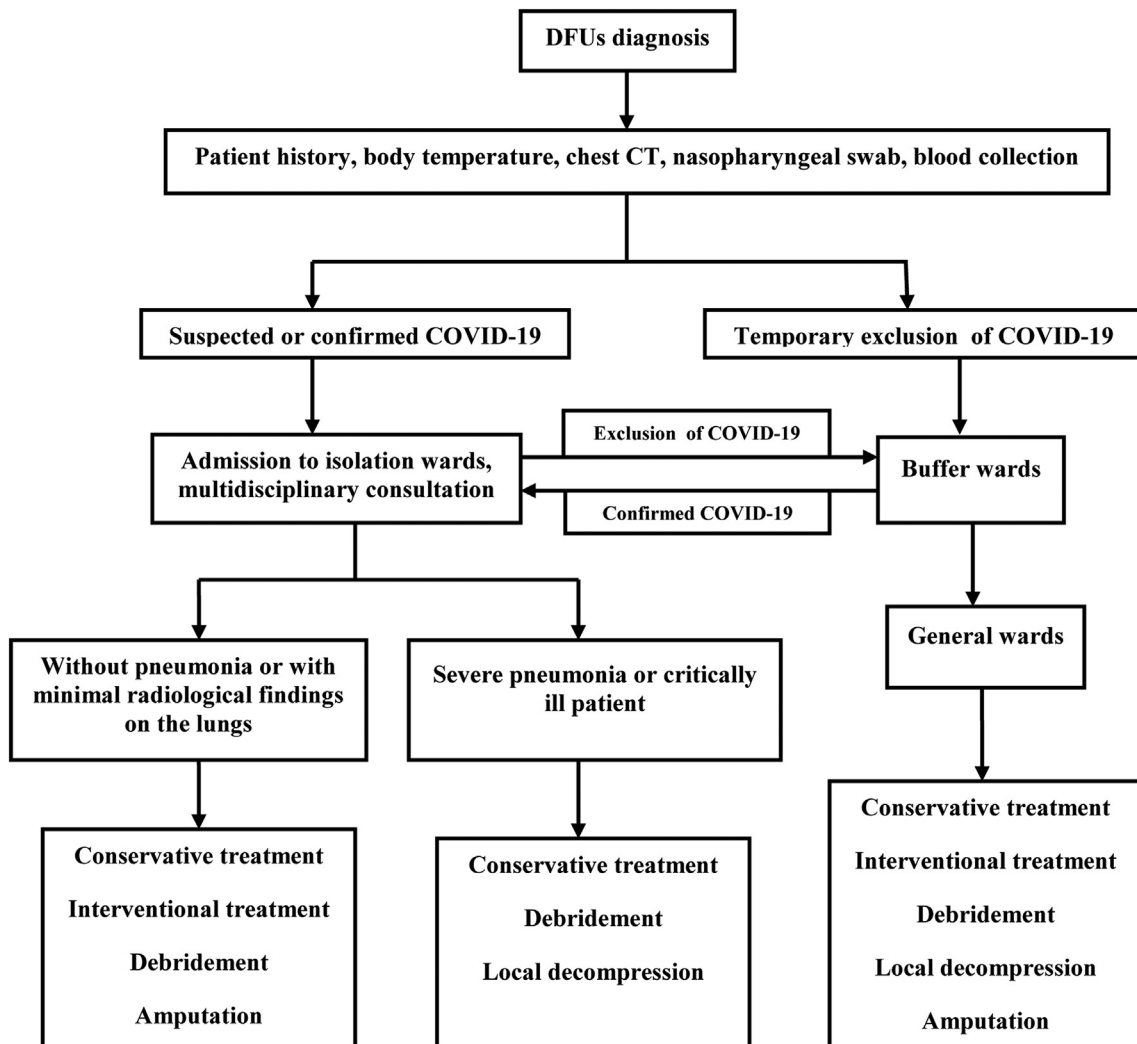


Fig. 2. Surgical treatment process of DFUs during the COVID-19 pandemic.

Tang; Software, Yingchun Zhao and Yue Luo; Writing-review & editing, Hai Tao and Fenghua Tao.

Ethical approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. This study was approved by the Institutional Review Board (IRB) of Renmin Hospital of Wuhan University.

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