

A Review on Abscess Pathophysiology, Types, Developmental Stages, and Novel Techniques for Healing

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Abstract

An abscess refers to a local accumulation of pus in the form of an abscess in the tissues or organs following infection or injury by microbes. It is an immune reaction of the host to limit infection by the immune system, which usually results in tissue damage and systemic problems in the event of untreated infection. The pathogenesis of an abscess is a complicated process of interaction between pathogenic agents and the immune forces of the host body, which leads to inflammation, necrosis, and encapsulation. Different abscesses, such as cutaneous, periodontal, pulmonary, hepatic, and intracranial abscesses, have diverse clinical manifestations and severity, even though they exhibit similar pathophysiological processes. The process follows a series of steps, namely, initiation, suppuration, encapsulation, rupture, and resolution. Old methods of management like incision, drainage, and antibiotic treatment are still in use, although new methods have emerged that target accelerated and more effective healing, such as nanotechnology-based drug delivery

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systems, photodynamic therapy, focused ultrasound (histotripsy), and regenerative biomaterials. The review addresses the mechanisms, pathophysiology, significant types, the stages of development, and the current developments in the treatment of the abscess, with an emphasis on the necessity of the integration of classical microbiology with modern biomedical innovations to achieve better patient outcomes.

Introduction

The typical pathological consequence of pyogenic infection is an abscess, which is an accumulation of pus in the local area accompanied by inflammation and necrosis of tissues (Wang & Xue, 2023). It acts as a shield of protection that limits infection, thus denying the expansion of the infection to the nexus. The word Abscess is derived from the Latin word *abscedere*, which translates to go away, and represents the body struggling to isolate infection. Although this is protective in nature, abscesses are usually painful, swollen, and fevers can develop and evolve into sepsis or chronic inflammation. The pathogenesis of abscess development is initiated by the invasion of microorganisms within the epithelial or mucosal barriers by trauma, obstruction, or haematogenous transmission (Amachawadi & Nagaraja, 2022). The innate immune system reacts by recruiting neutrophils that release proteolytic enzymes and reactive oxygen species to destroy entering pathogens. Nevertheless, such a high-intensity defence also harms host tissues, leading to liquefactive necrosis and pus. Dead neutrophils, bacteria, and tissue debris are the main components of the pus (Islam, Aziz, Rahman, Rahaman, & Hossain, 2024). With time, the lesion is encircled by macrophages and fibroblasts to form a fibrous capsule, which encloses the infection. This capsule keeps the infection of bacteria at bay, but it also prevents the flow of blood and access to antibiotics, resulting in slow healing. The abscess may be either superficial or deep-seated according to the location. Superficial abscesses, including both cutaneous and periodontal abscesses, are easier to diagnose and treat, whereas deep abscesses, including abscesses of the liver, lungs, or brain, are extremely problematic to diagnose and treat (Boothpur, Archana, Kondal Rao, Jyothi, & Lakshmi). The most common causative organism is *Staphylococcus aureus*, although most abscesses are polymicrobial (anaerobes include *Fusobacterium nucleatum*, *Prevotella intermedia*, and *Porphyromonas gingivalis*). Recent studies prove that bacterial biofilms in abscesses develop protective matrices that retard penetration of antibiotics and immune clearance, which explains chronic and recurrent infections. The mechanisms of abscess development are alike, but differences in the site of localization and pathogenic agents affect clinical expression and treatment (Tang, Zhou, & Zhang, 2022). The knowledge of these mechanisms and types can serve as the basis for creating more efficient therapeutic interventions that can control infection and regenerate tissues.

Pathophysiology of the Abscess Formation

The mechanisms of pathophysiology of abscess formation comprise a series of cellular and molecular events indicative of the inflammatory and immune responses of the host (Harvanová & Duranková, 2025). It begins with the invasion of bacteria into tissue and then identification of microbial components by pattern recognition receptors of macrophages and dendritic cells. This triggers the action of cytokines, including interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α), which are involved in the vasodilation and attraction of immune cells. In the early stage, neutrophils play a central role. They go to the place of infection, ingest bacteria, and empty enzymes and free radicals that destroy pathogens; however, this results in collateral tissue damage. The resulting necrotic material is liquid, and this is the pus of abscesses. Recent immunological discoveries have shown that neutrophil

extracellular traps (NETs) can assist in immobilizing bacteria inside the abscess cavity during the early phase of infection, but when used in excess will exacerbate acute inflammation and slow recovery (Schultz, Acevedo, Kalergis, & Bueno, 2022). During later stages of infection, neutrophils are replaced by macrophages, and tissue repair starts with the stimulation of fibroblast activity. Fibroblasts lay down collagen and create a fibrous capsule around the center of necrosis. The infection is enclosed in this capsule, which also decreases vascularity and oxygen concentration, forming an anaerobic microenvironment in which bacteria can survive. It has been demonstrated that the interior of an abscess is hypoxic, acidic, and of high osmotic pressure-conditions that favour the survival of pathogenic bacteria and decrease the efficacy of antibiotics. The balance between the immune defence and the microbial survivability defines the outcome of the abscess. Should the immune system prevail, the load of bacteria reduces, inflammation goes away, and healing starts. In case of contained rupture, the abscess can turn into a chronic lesion that results in fibrosis or systemic infection (Nepal, Ojili, Kumar, Kaur, & Nagar, 2020).

Types of Abscesses

Abscesses can develop in various anatomical locations, and each location has a characteristic though shares pathophysiological similarities (Castillo & Manterola, 2020). The most common form is the cutaneous abscesses, which occur most often and is normally caused by bacterial invasion through hair follicles, minor trauma, or blocked glands. These infections are dominated by *Staphylococcus aureus*, which results in the development of tender and fluctuant swellings containing pus. The inflammation mediated by neutrophils is necessary in clearing bacteria, but also leads to tissue damage and expansion of the cavities. Peritonsillar abscesses are derivatives of acute tonsillitis, which causes the formation of pus between the tonsil and the surrounding tissue (Klug, Greve, & Hentze, 2020). These are commonly induced by *Streptococcus pyogenes*, *Staphylococcus aureus*, and anaerobic bacteria. These abscesses are characterized by sore throat, trismus, and hoarse voice, and must have urgent drainage to avoid airway obstruction. Periodontal and dental abscesses are the outcomes of infection of the tooth pulp or periodontal structures. *Fusobacterium nucleatum*, *Prevotella intermedia*, and *Porphyromonas gingivalis* are the key bacteria. The presence of biofilm in these abscesses gives a lot of resistance to antibiotics and host defence, thus causing repeated infection and tissue necrosis (Vestby, Grønseth, Simm, & Nesse, 2020). The pulmonary abscesses are fissures in the lung parenchyma due to an anaerobic bacterial aspiration or post-pneumonia secondary infection. They are full of necrotic and purulent tissue. Radiological analysis shows air-fluid levels in thick-walled cavities, which is a sign of liquefaction of tissues. The symptoms consist of fever, foul sputum, cough, and chest aches. Hepatic abscess may be pyogenic or amoebic. Pyogenic abscesses are either biliary or haematogenous spread of bacteria like *Klebsiella pneumoniae* and *E. coli*, and amoebic ones are caused by *Entamoeba histolytica* (Folkert, Khalil, & Sawyer, 2023). The hepatic microenvironment composition is unfavourable to bacteria, with low oxygen content and high density of nutrients, and it complicates the process of antibiotic treatment. Brain abscesses are severe infections and may be a result of otitis media, sinusitis, or trauma. They pass through cerebritis, capsule formation, and liquefaction stages. Neurological manifestations include seizures or headaches. Early drainage of surgical sites and antimicrobial treatment are essential. Intra-abdominal abscess is a result of gastrointestinal perforation or an operation. They are polymicrobial abscesses that may contain *Bacteroides fragilis*, *E. coli*, and *Enterococcus* (Sanchez-Haro et al., 2025). It has been demonstrated that the defective fibrin degradation in these abscesses causes the formation of thick fibrin networks that entrap the bacteria and

slow the healing. Although the locations of abscesses are diverse, all of them have a common defensive but devastating pathology, which is an attempt to hold the infection, which leads more often than not to collateral tissue damage (Nayak, Mishra, & Verma, 2021).

Different Stages of development of abscesses

The abscesses undergo some overlapping phases. The first phase starts with the inoculation of bacteria and the immune response (Nayak et al., 2021). Cytokine release makes the vascular permeable, enabling the migration of leukocytes and plasma proteins into the tissue. During this step, neutrophil extracellular traps (NETs) are generated to limit the diffusion of bacteria. The suppuration stage comes later, in which neutrophils are accumulated, bacteria are phagocytosed, and enzymes are released to liquefy tissue, forming pus. The lesion increases when the osmotic pressure in the abscess increases and tears the surrounding tissues apart. The researchers show that intralesional pressures can up to several thousand mmHg, which stimulates the growth of an abscess (Akiki & Mehrzad, 2020). Then, at the encapsulation phase, fibroblasts lay down collagen, forming a fibrous wall that entraps the pus. This restricts the spread to the system at the expense of oxygen and nutrient supply. The intra-abdominal abscesses exhibit a high deposition of fibrin that traps the bacteria and extends the infection. Unattended, the abscess matures and breaks with or without natural means through fistula or spontaneously. The chronic cases cause continued formation of biofilms along the wall of the cavity, which is hard to eradicate. Lastly, in the resolution, the macrophages remove debris, the fibroblast heals tissue, and the cavity seals. The process of healing takes place either through fibrosis or complete regeneration, which is based on tissue damage. Recent regenerative research indicates that growth factor-based scaffolds and stem-cell-derived biomaterials can hasten healing processes through the stimulation of angiogenesis and collagen remodelling (Golchin et al., 2022).

New Methods and Developments in Healing

Conventional management of abscesses, which includes incision, drainage, and antibiotics, is still conventional but with constraints, because of biofilms and lack of drug penetrability (Menegas, Moayedi, & Torres, 2021). New technologies are intended to eliminate these barriers to improve healing. The use of advanced imaging features like ultrasonography, CT, and MRI is necessary to identify abscesses and drainage guidelines. PET-CT (molecular imaging) has real-time visualization of the activity of the infection, and increases the accuracy of diagnosis of deep-seated abscesses, such as hepatic or cerebral ones, etc. Image guidance, minimally invasive catheterization with drainage, can be done more precisely and with less trauma. Maxillofacial abscess has been found to respond to vacuum sealing drainage (VSD) with continuous irrigation, which enhances quicker recovery and fewer reinfections (Hu, Xiao, Nie, & Wang, 2025). Drug delivery system Nanotechnology has been applied to solve the problem of low penetration of antibiotics. Drugs can be released by polymeric nanoparticles and liposomes in response to pH or enzymes in the abscess and enhance retention and delivery to resistant bacteria. Silver and zinc oxide nanoparticles are good supplements in therapy due to their strong antibacterial properties against the biofilms of *S. aureus* and *P. aureginosa* (Abdelghafar, Yousef, & Askoura, 2022). Photodynamic therapy (PDT) involves light-reactive molecules that cause the production of reactive oxygen species, which cause the destruction of microbes. Its use is particularly effective in dental and periodontal abscesses, where biofilms have been hard to treat. It has been clinically demonstrated that PDT is very effective in reducing bacterial load and inflammation without damaging normal tissue.

Focused ultrasound (histotripsy) employs high-intensity sound waves to mechanically disrupt abscess contents and kill bacteria (Ambekar, 2025). Preclinical studies demonstrate that histotripsy reduces bacterial burden and enhances drainage in deep abscesses without surgery. Hydrogels with growth factors (VEGF, PDGF), stem-cell-derived exosomes also facilitate tissue healing after drainage through angiogenesis and collagen formation. The innovations are meant to replace normal tissue and not just to close the cavity.

Limitations and Future Aspects

Despite significant advancements in knowledge and treatment of abscesses, there are still a number of important limitations that have been introduced to successful treatment and full recovery (Alaoui Mdarhri et al., 2022). Such restrictions are due to the pathophysiological peculiarities of abscesses, which are their encapsulated structure, multimodal microbiology, and physical barriers that safeguard pathogens against host responses and therapeutic agents. The fact that it poorly penetrates the abscess cavity is one of the most critical challenges. The fibrous capsule is thick, and the necrotic core has a high level of vascularity, which limits diffusion, resulting in a low concentration of drugs at the site of infection. Recent pharmacological research has demonstrated that the concentration of antibiotics in pus frequently does not exceed 10 percent of the same in plasma, which is the reason why systemic therapy is rarely curative (Viaggi et al., 2022). Drainage, therefore, whether surgical or percutaneous, is always necessary in a majority of cases. This is a more severe limitation in deep-seated abscesses, like those in the brain or liver, where there is a high risk of surgical access. Hydrocarbons. The other significant limitation is the occurrence of bacterial biofilms in abscess cavities. These biofilms create complex communities of microorganisms surrounded by a self-generated matrix, inhibiting penetration of antibiotics and immune elimination. Bacteria located in biofilms are found to be resilient to high concentrations of antibiotics, even a thousand times more than those that are effective against free-floating bacteria, and thus, it is hard to eliminate them (Azeem et al., 2025). Horizontal gene transfer also occurs through biofilms, which increase antimicrobial resistance (AMR). Threats to treatment: Multidrug-resistant organisms (MDROs) such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Klebsiella pneumoniae*, and extended-spectrum β -lactamase (ESBL)-producing Enterobacteriaceae have further complicated treatment. These pathogens are known to colonize abscesses, making most of the first-line antibiotics ineffective (Temkin, Margalit, Nutman, & Carmeli, 2021). The data of surveillance all over the world demonstrates the continuous rise of the number of resistant abscess-related infections, especially among immunocompromised patients or patients in a hospital. There is yet another problem of diagnostic challenges. Although simple abscesses are easily recognized, deep brain, abdominal, or pelvic abscesses have generalized symptoms that are very easy to miss, which causes the postponement of diagnosis. Computed tomography, magnetic resonance imaging, and PET-CT are imaging modalities that have enhanced the detection; however, the high cost and availability restrict their use in most health care providers. Abscesses may grow due to misdiagnosis or late diagnosis, spread to another place, burst, or cause plant infection (Long & Gottlieb, 2022). The drawbacks of old-fashioned incision and drainage should be known therapeutically. Even though it is effective in the short run when it comes to decompression, it may lead to scarring, secondary infection, and partial pus evacuation. The look of inaccessible abscesses, including those in the spinal or retroperitoneal areas, might be inaccessible to this method. Recurrence is largely due to incomplete drainage, particularly in multi-lobulated abscesses. Fibrosis and delayed recovery of tissues after treatment are still another problem (Zhao, Kwan, Yip, Liu, &

Liu, 2020). Collagen-rich scar tissue instead of full regeneration is a common outcome of the healing process. Histology has demonstrated that the long-term abscess cavity can be a fibrotic, poorly vascularized space even after infection is cured, which can worsen the functioning of organs and increase susceptibility to reinfection. There are a number of new technologies with potential for the future. The delivery systems based on nanotechnology have the potential to enhance local antibiotic concentration due to controlled release and specific delivery. Photodynamic therapy (PDT) is a treatment method that utilizes photoswitchable photosensitizers to produce reactive oxygen species, which are effective in killing bacteria within biofilm-rich environments- e.g., periodontal abscesses. One non-invasive method that might be used is focused ultrasound (histotripsy) to physically interrupt abscess contents and promote drainage without surgical intervention. The new frontiers in the healing of abscesses are being created by the advancement of regenerative biomaterials and stem cell therapy (Riester, Borgolte, Csuk, & Deigner, 2020). Angiogenesis and tissue regeneration also occur after drainage stimulated by hydrogel loading with growth factors such as the vascular endothelial growth factor (VEGF) and platelet-derived growth factor (PDGF). Equally, exosomes produced by stem cells have potential in stimulating collagen remodelling and decreasing fibrosis. The use of such technologies in the future to create a multimodal approach to therapy, comprising the use of antimicrobial therapy, regenerative therapy, and immunomodulatory therapy, is likely to be incorporated in the future as part of the overall management of abscesses. Diagnostic imaging and outcome prediction with the help of artificial intelligence (AI) might become an extra benefit in terms of early diagnosis and individual treatment (Bi et al., 2019). Nevertheless, the widespread use of these innovations will require cost-effectiveness, safety validation, and the creation of standard clinical guidelines. In general, although contemporary restrictions are still substantial, the progressive development of diagnostic and treatment strategies suggests a change in abscess treatment as more of a surgical area as opposed to a more precise, regenerative one (Fitch, Manthey, McGinnis, Nicks, & Pariyadath, 2007).

Conclusion

The development of abscesses is an impressive but destructive feature of host defence. Even though it localizes infection and avoids systemic spreading, it is also the process that protects the pathogens, harms tissues, and postpones recovery. Abscesses have a clinical biological duality of protection and destruction and a progressive but pathologic sequence of acute inflammation, neutrophil infiltration, necrosis, and encapsulation, independent of location or etiology. The knowledge of these mechanisms gives a chance to target interventions, which clear the infection and promote tissue repair. Conventional management-incision, drainage, and antibiotics, is still very fundamental, though it is being constantly tested by resistance to antimicrobials, poor drug penetration, and biofilm formation. These constraints necessity new approaches other than the destruction of bacteria. New strategies like nanotechnology-based delivery systems, photodynamic therapy, focused ultrasound, and regenerative biomaterials have potential due to their ability to increase the anti-browning effects of antibiotics, minimize tissue damage, as well as improve healing. The management of future abscess treatment will be based on precision-driven multimodal therapies that incorporate microbiology, bioengineering, and regenerative medicine. AI diagnostics will help in early diagnosis and treatment planning, whereas global antimicrobial resistance surveillance via the One Health paradigm will also be essential. The final aim is to no longer just drain, but to repair normal tissue structure

and functioning using more advanced systems of therapy, enhance recovery, lower recurrence, and increase the quality of life in the patient.

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References

- Abdelghafar, A., Yousef, N., & Askoura, M. (2022). Zinc oxide nanoparticles reduce biofilm formation, synergize antibiotics action and attenuate *Staphylococcus aureus* virulence in host; an important message to clinicians. *BMC microbiology*, 22(1), 244.
- Akiki, R. K., & Mehrzad, R. (2020). Practical management of common skin injuries, lacerations, wounds, trigger fingers, and burns. *The Journal of the American Board of Family Medicine*, 33(5), 799-808.
- Alaoui Mdarhri, H., Benmessaoud, R., Yacoubi, H., Seffar, L., Guennouni Assimi, H., Hamam, M., . . . Diawara, I. (2022). Alternatives therapeutic approaches to conventional antibiotics: advantages, limitations and potential application in medicine. *Antibiotics*, 11(12), 1826.
- Amachawadi, R. G., & Nagaraja, T. G. (2022). Pathogenesis of liver abscesses in cattle. *Veterinary Clinics: Food Animal Practice*, 38(3), 335-346.
- Ambekar, P. (2025). Effects of Histotripsy on Bacterial Viability in Suspension.
- Azeem, K., Fatima, S., Ali, A., Ubaid, A., Husain, F. M., & Abid, M. (2025). Biochemistry of bacterial biofilm: insights into antibiotic resistance mechanisms and therapeutic intervention. *Life*, 15(1), 49.
- Bi, W. L., Hosny, A., Schabath, M. B., Giger, M. L., Birkbak, N. J., Mehrtash, A., . . . Dunn, I. F. (2019). Artificial intelligence in cancer imaging: clinical challenges and applications. *CA: a cancer journal for clinicians*, 69(2), 127-157.

- Boothpur, J. R., Archana, B., Kondal Rao, D. P., Jyothi, D. S., & Lakshmi, S. M. Bacteriological (Aerobic) Study of Deep Seated Abscess and Its Antibiotic Susceptibility Pattern in Mahatma Gandhi Memorial Hospital, Warangal.
- Castillo, S., & Manterola, C. (2020). Morphological characteristics of liver abscesses according its etiology. *International Journal of Morphology*, 38(2).
- Fitch, M. T., Manthey, D. E., McGinnis, H. D., Nicks, B. A., & Pariyadath, M. (2007). Abscess incision and drainage. *N Engl J Med*, 357(19), e20.
- Folkert, K. N., Khalil, S., & Sawyer, R. (2023). Hepatic Abscesses. In *Textbook of Emergency General Surgery: Traumatic and Non-traumatic Surgical Emergencies* (pp. 911-922): Springer.
- Golchin, A., Shams, F., Basiri, A., Ranjbarvan, P., Kiani, S., Sarkhosh-Inanlou, R., . . . Rasmi, Y. (2022). Combination therapy of stem cell-derived exosomes and biomaterials in the wound healing. *Stem Cell Reviews and Reports*, 18(6), 1892-1911.
- Harvanová, G., & Duranková, S. (2025). Inflammatory process: Factors inducing inflammation, forms and manifestations of inflammation, immunological significance of the inflammatory reaction. *Alergologia Polska-Polish Journal of Allergology*, 12(1), 54-61.
- Hu, S., Xiao, J., Nie, X., & Wang, C. (2025). Vacuum sealing drainage combined with continuous irrigation for the treatment of oral and maxillofacial abscesses—a retrospective study. *BMC Oral Health*, 25(1), 257.
- Islam, S., Aziz, Z. T., Rahman, M. A., Rahaman, S., & Hossain, M. B. (2024). Characterization of the microorganisms of human pus samples-a tertiary care hospital based study. *Molecular Mechanism Research*, 2(1), 6171.
- Klug, T. E., Greve, T., & Hentze, M. (2020). Complications of peritonsillar abscess. *Annals of clinical microbiology and antimicrobials*, 19(1), 32.
- Long, B., & Gottlieb, M. (2022). Diagnosis and management of cellulitis and abscess in the emergency department setting: an evidence-based review. *The Journal of Emergency Medicine*, 62(1), 16-27.
- Menegas, S., Moayedi, S., & Torres, M. (2021). Abscess management: an evidence-based review for emergency medicine clinicians. *The Journal of Emergency Medicine*, 60(3), 310-320.
- Nayak, J., Mishra, J. N., & Verma, N. K. (2021). A brief study on abscess: a review. *EAS J. Pharm. Pharmacol*, 3(5), 138-143.
- Nepal, P., Ojili, V., Kumar, S., Kaur, N., & Nagar, A. (2020). Beyond pyogenic liver abscess: a comprehensive review of liver infections in emergency settings. *Emergency Radiology*, 27(3), 307-320.
- Riester, O., Borgolte, M., Csuk, R., & Deigner, H.-P. (2020). Challenges in bone tissue regeneration: stem cell therapy, biofunctionality and antimicrobial properties of novel materials and its evolution. *International journal of molecular sciences*, 22(1), 192.
- Sanchez-Haro, E., Molinos, S., Troya, J., Tapiolas, I., Vela, S., Cardona, P.-J., & Parés, D. (2025). Bacteriology of Anorectal Abscess and Anal Fistula: A Systematic Review of the Literature. *Surgical Infections*, 26(9), 707-719.
- Schultz, B. M., Acevedo, O. A., Kalergis, A. M., & Bueno, S. M. (2022). Role of extracellular trap release during bacterial and viral infection. *Frontiers in Microbiology*, 13, 798853.
- Tang, H., Zhou, H., & Zhang, R. (2022). Antibiotic resistance and mechanisms of pathogenic bacteria in Tubo-ovarian abscess. *Frontiers in Cellular and Infection Microbiology*, 12, 958210.
- Temkin, E., Margalit, I., Nutman, A., & Carmeli, Y. (2021). Surgical antibiotic prophylaxis in patients colonized with multidrug-resistant Gram-negative

- bacteria: practical and conceptual aspects. *Journal of Antimicrobial Chemotherapy*, 76(Supplement_1), i40-i46.
- Vestby, L. K., Grønseth, T., Simm, R., & Nesse, L. L. (2020). Bacterial biofilm and its role in the pathogenesis of disease. *Antibiotics*, 9(2), 59.
- Viaggi, B., Cangialosi, A., Langer, M., Olivieri, C., Gori, A., Corona, A., . . . Di Paolo, A. (2022). Tissue penetration of antimicrobials in intensive care unit patients: a systematic review—part II. *Antibiotics*, 11(9), 1193.
- Wang, H., & Xue, X. (2023). Clinical manifestations, diagnosis, treatment, and outcome of pyogenic liver abscess: a retrospective study. *Journal of International Medical Research*, 51(6), 03000605231180053.
- Zhao, X., Kwan, J. Y. Y., Yip, K., Liu, P. P., & Liu, F.-F. (2020). Targeting metabolic dysregulation for fibrosis therapy. *Nature reviews Drug discovery*, 19(1), 57-75.