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REVIEW ARTICLE

A review on fungal surgical site infections: epidemiology, risk factors, main fungal agents, and prevention

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ABSTRACT

Fungal surgical site infections (SSIs) may be less common than bacterial SSIs but are a significant clinical issue due to their challenging diagnosis, higher morbidity, and rising incidence, particularly in immunocompromised patients. The epidemiology, risk factors, prevalent fungal pathogens, and prevention of SSIs caused by fungi are discussed in this narrative review. Systematic literature search for the period 2000 to 2024 was conducted on top databases using relevant MeSH keywords. The most frequent solitary pathogens were *Candida* spp., followed by *Aspergillus* and *Mucor* spp., especially in transplant, cardiac, and GI infections. The greatest challenge is extended length of hospital stay, broad-spectrum antibiotics, immunosuppression, and invasive interventions with prosthetic device or shunts. While it creates added burden, fungal SSIs go unnoticed by clinical practice and are rarely included in SSI prevention strategies. The review declares the significance of enhanced clinical vigilance and tailored antifungal prophylaxis in high-risk exposure surgical procedures. The review, based on the integration of existing information, provides clinicians and infection control practitioners with a framework of fungal SSIs so that they can be better equipped to assess risk, detect infection sooner, and focus prevention efforts.

Keywords: Surgical wound infection; Mycoses; Candidiasis; Aspergillosis; Mucormycosis; Postoperative complications; Antifungal agents; Risk factors; Immunocompromised host; Infection control

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INTRODUCTION

The history of surgical site infections (SSIs), including fungal infections, is a significant topic in medical history. Before the mid-19th century, postoperative complications of fever, pus from the wound, sepsis, and death were common occurrences. The discovery of antiseptic principles by pioneers like Ignaz Semmelweis and Joseph Lister dramatically reduced these complications. Lister's antiseptic surgery, using carbolic acid to destroy germs, was prompted by Louis Pasteur's germ theories and was a revolution in surgical practice in the 1860s (1).

There were chairs and tables in the middle of early teaching operating rooms, with rows of sloping seats surrounding them where other onlookers and students could observe the ongoing operations. The surgeons wore street clothes covered by aprons to prevent bloodstains and operated bare-handed using unsterilized instruments and equipment.

In 1884, German surgeon Gustav Neuber developed a complete set of limitations to guarantee sterilization and asepsis for surgery. This included gowns, caps, shoe covers, and surgical instruments, all sterilized in his new autoclave design. In 1885, he constructed a private hospital with walls, floors, hands, arms, and faces of personnel washed with mercury chloride. The equipment was installed with smooth surfaces, and there were glass shelves for ease of cleaning. He also introduced single rooms for infectious as well as non-infectious patients and used warmed and filtered air in the theater to destroy microbes (2, 3).

Well over 177 years have now passed since Hungarian physician Ignaz Semmelweis first placed a strong focus on the use of surgeons' hand cleanliness as an infection-preventing method after surgery. Hand hygiene is still one of the strongest guardians against SSIs (4).

Surgical site infections (SSIs) are infections of the tissue, organ, or other body part that occur following surgery. One of the most common postoperative complications is the operation site infection (5, 6). Based on the Centers for Disease Control and Prevention (CDC), a surgical site infection is defined by an infection occurring within 30 days following surgery in the area around the operative site (7). It is also visible after 1-2 years if an implant or an external device has been utilized in surgery (8).

The three categories of SSIs are superficial SSI, which involves only the skin and subcutaneous tissues, deep SSI, which involves the deeper, softer tissues like fascia and muscles, and organ/space SSI, which involves the primary organ (9). Thus, the term "surgical wound infection" has now been replaced by "surgical site infection," which is more accurate, keeping in mind that surgical wound infections can extend beyond the incision site and into nearby deeper structures (10).

An SSI is characterized by clinical findings which can be one or more of the following: First, purulent exudate draining from a wound. Second, an operative site where a positive culture of fluid was obtained. Third, the operative site, which will have to be reopened by the surgeon. Fourth, the diagnosis of infection as made by the surgeon (11).

Bacterial, fungal, viral, and parasitic causes of surgical site infection exist. Surgical site infections by fungi are common due to various fungal species (6). Most frequently encountered normal fungal pathogens are *Aspergillus flavus*, *Candida glabrata*, *Candida albicans*, *Candida tropicalis*, *Fusarium solani*, *Mucor racemosus*, and *Cunninghamella spinosum*. On some occasions, yeast may co-infect with bacterial pathogens (12). Surgical site infection (SSI) defined by National Healthcare Safety Network (NHSN) is the infection of the wound of the surgical site 30 to 90 days following surgery, categorized into three general types, i.e., superficial incisional surgical site infection, deep incisional surgical site infection, and organ or space surgical site infection (13). Despite all precautions taken before, during, and after surgery, one of the dangers of any operation can be wound infection, the most frequent cause of which is bacterial, i.e., staphylococci (14).

SSI extends the duration of hospital stay, morbidity, mortality, and cost, and reduces quality of life (QoL). Whether or not bacteria are the most frequent causative agent of surgical wound infection, the pathogenic role by fungi, particularly *Candida*, cannot be downplayed since *Candida* is part of the patient's cutaneous normal flora and may move along the surgical incision, spread to more distant tissues, and result in SSI.

In abdominal surgeries, *Candida* species, being an intestinal and colonic normal flora, can invade the surgical field and later lead to fungal SSI. Fungal SSI is related to other surgeries including gastrointestinal and abdominal surgeries, particularly in patients with esophageal candidiasis (12). Fungi are not common pathogens of SSI but will be a possibility

in surgery with a contaminated wound by debris and environmental waste, or vegetation (15).

In the literature review, one of the reasons associated with a high risk of fungal SSI, especially *Candida*, has been discussed, underlying causes leading to immunodeficiency (16). Fungal SSI is characterized by the absence of a typical clinical presentation and challenging diagnosis, long-standing course, and silent nature of such infections, ignoring fungal agents as the pathogen of the infection, and so on. In such patients, fatal consequences may occur (15).

The primary causes of mortality among immunocompetent as well as immunocompromised surgical ICU patients are fungal infections; the prevalence of *Candida* species has also been on the rise, and this is one of the organisms commonly isolated in bloodstream infections. *Aspergillus* is also more prevalent among recipients after lung or heart transplant. In surgical patients who are not neutropenic, independent risk factors for fungal infection are the use of broad-spectrum antibiotics and having a central venous catheter. Immunodeficiency, transplantation, and burn make patients susceptible to fungal infection (17).

Overall, nosocomial fungal infections are on the rise these days, particularly if it's the surgical site, and among those surgeries reported with surgical site fungal infection are Left Ventricular Assist Device (LVAD) and pancreas and kidney transplant (18, 19).

Persons having received organ transplantation, for some reasons, including immunodeficiency due to immunosuppression therapy, and also the operation site, can be exposed to fungal wound infection at the operative site, including invasive Aspergillosis in pulmonary or *Candida* infection with pancreas transplantations, most commonly gallbladder drainages. On occasion, fungi like mucormycosis are etiologic for surgical wound infection (20).

Fungal surgical site infections (SSIs) are often underdiagnosed and underreported compared to bacterial SSIs, despite their association with significant morbidity, prolonged hospital stays, and increased mortality, particularly in high-risk patient populations. While bacterial SSIs have been extensively studied, the literature on fungal SSIs remains fragmented, with limited integration of their epidemiology, risk factors, causative agents, and preventive approaches in a single source. This review aims to address this gap by providing a comprehensive synthesis of current knowledge on fungal SSIs, emphasizing their emerging clinical relevance and the need for increased awareness among surgical teams and infection control practitioners. By highlighting the growing burden and diagnostic challenges of fungal SSIs, this review seeks to support better risk assessment, early recognition, and the development of targeted preventive strategies.

MATERIALS AND METHODS

There are a number of basic scientific questions: Firstly, fungal infections such as *Candida* and *Aspergillus* are liable to be subclinical until they develop at a critical level, which results in late treatment and detection. Secondly, the literature evidence suggests that evidenced fungal SSIs are associated with increased hospital stay, higher cost of treatment, higher need for surgical revision, and higher rates of mortality than bacterial SSIs. Third, fungal SSIs seem to be on the increase in high-risk environments, particularly with greater application of immunosuppressive therapy, broad-spectrum antibiotics, and prosthetic surgery, factors all favorable to fungal growth. In suggesting this hypothesis, the review aims to study the significance of the identification of fungal SSIs as a serious clinical issue and call for more attention in surveillance, prophylaxis, and treatment strategies, especially in high-risk surgical populations.

Inclusion Criteria: We considered studies that specifically addressed fungal surgical site infections (SSIs), their epidemiology, risk factors, etiologic fungal species, or prevention. Articles should have been English language publications in peer-reviewed journals.

Exclusion Criteria: We excluded non-surgical site infection studies, non-peer-reviewed articles, case reports that were not comprehensive, and articles that were not published in full text.

Selection Process: Titles and abstracts were independently screened by two reviewers, followed by full-text review for eligibility. Discrepancies were settled by consensus.

Quality Consideration: Although formal risk-of-bias or quality grading was not conducted, as it is most commonly the case with narrative reviews, we gave precedence to studies with larger sample sizes, clinical significance, and methodological clarity. Landmark reviews and guideline-based items were given value, too.

These revisions are our effort to encourage the transparency and validity of the review process.

We performed a narrative systematic review by searching PubMed, Scopus, Web of Science, and Google Scholar with relevant MeSH terms. Sources were required to be English articles published from 1930 to 2024. Those meeting the qualifications were original clinical studies, case reports, and review articles solely focused on fungal surgical site infections. Titles and abstracts were screened for relevance, followed by a full-text review of potentially eligible articles. After applying inclusion and exclusion criteria, a total of 52 articles were included in the final analysis.

Based on MeSH, keywords were selected and searched in databases such as WOS, Pubmed, Scopus, and Google Scholar and they are as the following:

1. Infections, Surgical Wound
2. Invasive candidiasis due to surgery
3. Invasive fungal infections due to surgery
4. Risk factors of fungal infections due to surgery
5. Fungal infection after surgery
6. Post operation infection

Abstracts of the obtained articles were studied and those similar to our topic were selected and other studies were removed. For this study, a flow diagram Fig. 1 was drawn. The selected articles were studied; finally, the collection of discussions and conclusions of related articles was used. The written order of the different parts of the manuscript will be as follows: introduction, definition and epidemiology of fungal SSI, risk factors, main fungal agents involved in SSI and the prevention methods.

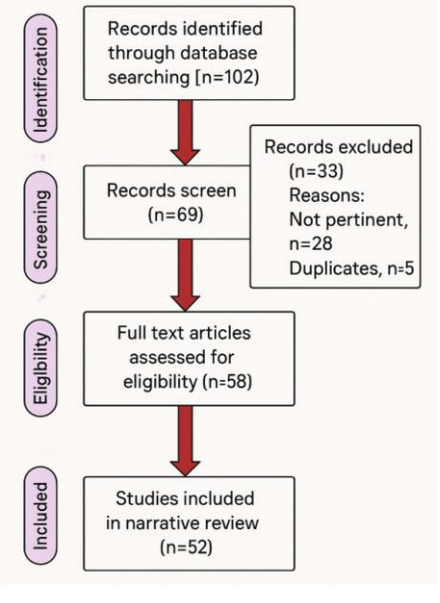

Fig. 1. Flow diagram of narrative review of literature

This is a traditional narrative review and intended to synthesize the existing literature on fungal surgical site infections (SSIs) in terms of their epidemiology, risk factors, key fungal pathogens, and prevention. Although the article did not adhere to the systematic or scoping review structure, a structure was adopted to ensure maximal transparency. A systematic search of appropriate databases was performed, and inclusion and exclusion criteria were used at the screening stage. In an effort to enhance clarity, a flow diagram has been inserted to describe the literature selection process as well as for transparency purposes.

Epidemiology. SSIs are the most common type of nosocomial infection and the third most common infection that occurs in 12-16% of all nosocomial infections. A postoperative SSI is developed by one in every 24 patients in the US undergoing inpatient surgery. 2% to 5% of the 16 million surgical procedure patients develop SSIs each year. Depending on site and type of wound, surgical site infection incidence might vary drastically, ranging between 5 percent to 30 percent (14, 21).

The application of prosthetic devices and grafts, broad-spectrum antibiotics, hyperalimentation, immunosuppressive, and antineoplastic agents has enhanced the rate of fungal wound infections (22). *Candida* spp. are the most frequent causative agent of fungal SSI (23, 24).

Table 1 illustrates the epidemiology of fungal SSIs, using data from various studies in various clinical and surgical conditions. Table 2 presents reported rates of incidence and tabulates common fungal species isolated in each study.

Risk factors. Three factors affect the development of fungal SSI: 1- Degree, type, and amount of microbial contamination before, during, and after surgery. 2- Operation and surgeon's skill. 3- Host factors that have major roles like obesity, diabetes mellitus, malnutrition, immunosuppression, age, chronic inflammatory process, sarcoidosis, peripheral vascular disease, anemia, prosthetic device and graft application, radiation, malignant disease, intravenous drug abuse, chronic dermatological disease, renal failure, transcutaneous catheters, prolonged hospital stay, tuberculosis, immobilization, endotracheal intubation, carrier state of organisms, and recent surgery (16, 31-34) (Table 2).

Table 1. Epidemiology of fungal surgical site infections.

	Studies	Incidence	Ref
1	Dowd S et al.	• Fungal SSI*: 23% of 915 chronic surgical wounds • 97.4% Bacterial SSI	(24)
2	Kaya D et al.	• 2% Fungal SSI: ✓ 55.6% *Candida albicans* ✓ 33.3% *Candida tropicalis* ✓ 11.1% *Candida glabrata*	(16)
3	Pasqualotto AC et al.	• Most frequent pathogen: *Aspergillus flavus* in 41.2% of all cases	(25)
4	Costa-Paz et al.	• 21 fungal SSIs due to *Mucoromycotic* spp.	(26)
5	Bekiari A et al.	• Fungal SSI: 8.4% of SSI • The most common species: *Candida*	(27)
6	N.Chea et al. (Liver transplant procedures and SSIs) (Fig. 2.B)	• The most common species: *Candida* • 17.2% of liver transplant procedures • 18.1% in the bile duct, liver, or pancreatic surgeries	(28)
7	E. Hämäläinen et al. (Fungal DSWI**)	• 7.5% to 20.5% • The most common species: *Candida*	(29)
8	M. Carugati et al. (Lung transplantation SSI)	• 20.5% due to yeasts • 70.9% due to non-*albicans Candida* species • 1.7% due to *Mucor* spp., *Aspergillus* spp., and *Curvularia* spp.	(30)

*SSI: Surgical Site Infection

**DSWI: Deep Sternal Wound Infection

Certain host conditions predispose the patients to fungal SSIs that are described in detail below (Table 2):

• Persons with medical conditions as well as those who are taking cancer treatment will have a greater likelihood of acquiring a fungal surgical site infections. Infections can be caused by a wide range of reasons, including trauma to the mucous membranes and skin, immunological failure, tumor-associated abnormalities, malnutrition, surgery, chemotherapy, radiation therapy, and psychoses (35).

• Some states leading to a compromised immune response are responsible for causing fungal SSI. These are endocrine disorders, including polyendocrinopathy, hypoparathyroidism, hypothyroidism, Cushing syndrome, and diabetes mellitus (36). Malnutrition is also still the most frequent cause of immunodeficiency in the world and has a pivotal position in leading to immunological reactions (37).

• The consumption of antibiotics impacts the onset of fungal infections like fungal SSI. Antibiotics alter the microorganism ecosystem in the gut and on the skin allowing *Candida* and other unwanted microorganisms to proliferate (38).

A less usual etiology for neurosurgical shunt infection is fungi. Risk factors of fungal shunt infection include immunosuppression (especially neutropenia and lymphoreticular malignancy), abdominal surgery, history of bacterial meningitis, use of steroids or broad-spectrum antibiotics, and parenteral nutrition (39).

There are also certain aspects of the operating room environment and the procedures done during surgery that are of first concerns to fungal SSIs (6) (Table 2):

• Pre-operative shaving or hair removal

• Excessive staff traffic during the procedure

• The unnecessary use of electrosurgical cautery units

• The use of a prosthesis or other foreign material

• Prolonged operative time and degree of tissue injury. Kim (2014) suggested that the danger of developing severe infections from bacteria, fungi, and protozoa was higher for patients whose operation took more than 12 hours on average (40).

• Blood transfusion needed.

Certain organism-related factors are also provided below:

• Postoperative fungal wound infections are caused by *Candida* in the overwhelming majority. Antibacterial ointments and occlusive dressings contribute to

Table 2. Risk factors of fungal surgical site infections

	Host factors	Procedure factors	Organism-related factors
1	Malignancy	Hair removal (especially shaving) before surgery	Risk of *Candida* SSI*: • Antibacterial ointments and occlusive dressings • Increasing use of preventative and empiric antibiotics.
2	Weakened immune response: • Polyendocrinopathy • Hypoparathyroidism • Hypothyroidism • Cushing syndrome • Diabetes Mellitus • Malnutrition • Aging • Chronic inflammatory process • Tuberculosis • Renal failure • Use of steroids	Blood transfusion requirement	Risk of Rhizopus SSI*: • Elastoplast bandages • Using oral antibiotics for preoperative bowel preparation may rise the risk of mycotic wound infection after surgery.
3	Broad-spectrum antibiotics	Prolonged operation time	Risk of Aspergillus SSI*: • Endocarditis, sternal wound infections, osteochondritis, and mediastinitis in immunocompetent persons who have had heart surgery.
4	Recent operation	Degree of tissue trauma Excessive staff traffic during the procedure Excessive use of electrosurgical cautery units The presence of a prosthesis or other foreign body Prolonged hospitalization Transcutaneous catheters Endotracheal intubation	
5	Radiation		
6	Sarcoidosis		
7	Peripheral vascular disease		
8	Intravenous drug use		
9	Chronic skin disease		
10	Immobilization		

*SSI: Surgical Site Infection

delayed wound healing due to *Candida* wound infections. The rising prevalence of disease, the growing population of immunocompromised patients in need of surgery, and widespread application of preventative and empiric antibiotics are likely causes for the recent trend toward resistant microbes and *Candida* species (41-45) (Table 2).

• There has been a recent association of Elastoplast dressings with *Rhizopus* wound infections, and its causative role in this case is possible. Current evidence suggests that preoperative oral antibiotics increase the fungal load of the colon and the small intestine, and this may increase the risk of mycotic wound infection after surgery (41) (Table 2).

• Despite *Aspergillus* species being unusual fungal infections, they can be causative pathogens in immunocompetent as well as immunocompromised individuals (17, 43). *Aspergillus* has the potential to infect hospital environments and equipment and exists in soil, dust, rotting vegetable matter, and in the air. *Aspergillus* surgical site infection (SSI), despite being unusual, has been reported in immunocompetent individuals receiving heart surgery for endocarditis, sternal wound infection, osteochondritis, and mediastinitis (44) (Table 2).

Main fungal agents. There are about 100000 described species of fungi and only 150 fungal organisms are now known to be pathogenic to animals and humans (15). Various studies have reported various

fungal species responsible for SSI after different surgeries. However, *Candida* and *Aspergillus* seem to be the most well-documented species to infect wounds post-surgery.

Candida spp., as the most common yeast genus with 200 species, contribute to most of the fungal infections globally, including surgical site infections (45, 46). As an example, *Candida* species are responsible for 7.5% to 20.5% of deep sternal wound infections (DSWI) and mediastinum after heart surgeries and carry a related mortality rate of 56%. In addition, *Candida* DSWI patients are more likely to have a longer hospital stay (fivefold) and death (twofold) than bacterial DSWI patients (47).

In 2023, research was carried out in Japan to evaluate the effect of preoperative oral antibiotics among patients with colorectal cancer undergoing resection with stoma creation on preventing SSI. According to the findings, peristomal candidiasis was more common among the group that was administered high-dose oral antibiotics, indicating the effect of excessive antibiotic administration on *Candida* infection (48).

Another research comparing various treatment modalities with respect to DSWI identified *Candida* species as the most frequent fungal etiologic agent. The aforementioned survey revealed that vacuum-assistance therapy (VAC) as a treatment modality for DSWI is more related to *Candida* infection (29).

In 2021, one Greek general surgery unit documented that fungal agents accounted for 8.4% of SSIs following different elective surgeries, all of which were *Candida* species (27). Raftery et al. also conducted a study where *Candida albicans* was unexpectedly the second most frequent organism (29%) for postoperative wound infection among patients undergoing esophagectomy for malignancy (49).

Likewise, a United States study came up with results contrary to what would be expected on the incidence of SSI in patients who receive a solid organ transplant. In 2015, yeasts caused 80% of SSI following lung transplant. Additionally, this study revealed SSI were caused by yeasts in 20.5% of all transplant cases and that non-*albicans Candida* species were responsible for the majority (70.9%). Not all SSI cases were associated with *Candida* species. The same study found that molds *Mucor* spp., *Aspergillus* spp., and *Curvularia* spp. had caused 1.7% of SSIs (30).

Several studies have revealed that *Candida* spp. are one of the most prevalent pathogens in liver transplant procedures (LTP) SSI (50, 51) (Fig. 2B). One study indicated that *Candida* species are responsible for 17.2% and 18.1% of SSIs caused by LTP and bile duct, liver, or pancreatic procedures, respectively, and that over 95% are organ/space infections (Fig. 1). *Saccharomyces cerevisiae*, *Aspergillus Fumigatus*, *Fusarium* spp., and *Rhizopus* spp. were some of the other fungi to be causative agents for SSI for these procedures (28).

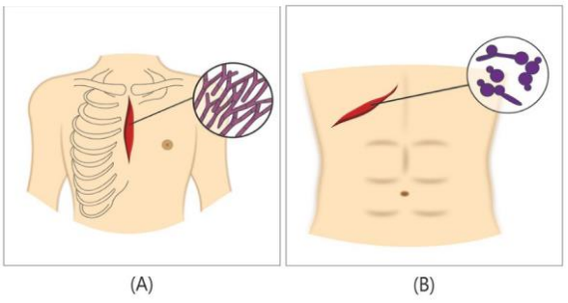

Fig. 2. Fungal agents could be responsible for SSI after various types of operations.
(A) shows *Aspergillus* species causing sternal wound infection after cardiac surgery. (B) shows *Candida* species causing SSI after a liver transplant surgery.

In addition, fungal postoperative infections are a common complication of cerebral shunts. A Taiwanese study on shunt implantation patients with pediatric hydrocephalus was performed. In the course of the study, 17% of infections caused by fungal organisms were found. Of interest is that all the infected infants with a fungus were preterm and had a ventriculoperitoneal shunt. As would be expected, the most frequent fungal microbe was *Candida* spp. (52). Some instances have also been reported of increased frequencies of shunt infection with fungus, such as 25% by Baradkar et al., 59% by Viudes et al., and 74% by Fernandez et al. (53, 54).

As noted earlier, *Aspergillus* spp. are one of the other frequent fungal causes of wound infection in most operations. *Aspergillus* fungi are a form of filamentous fungi which may be found in most environments, such as soil, water, and rotting plant material; that is why they are referred to as ubiquitous (25, 55).

The initial case to be described in the literature about *Aspergillus* was that of a 14-year-old girl, upon whom surgery was done for an abdominal mass in 1933. Dressing was taken off on the 16th day postoperative and had it a black powder on it that showed growth of *Aspergillus niger* (56).

A review on postoperative Aspergillosis done in

2006 revealed that half of the patients were solid organ transplant recipients, and the majority of those with wound Aspergillosis were immunosuppressed. *Aspergillus flavus* was introduced as the most frequent pathogen appearing in 41.2% of confirmed case (25).

Though numerous authors have cited *Candida* spp. as the fungal pathogen for sternal wound infection after cardiac surgery in their research, a few have opined that *Aspergillus* species are the most commonly isolated causative organism (57) (Fig. 2A).

Orthopedic surgeries are susceptible to fungal infections as well. Costa-Paz et al. in 2021 published a series of 21 fungal SSIs by *Mucoromycotic* spp. (26) (Table 3).

Prevention. To our knowledge, there is no routine practice of giving antifungal prophylactic drugs to decrease the frequency of wound infection due to fungal pathogens. Nevertheless, the Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery (59) suggested antifungal prophylaxis in some situations. It has been suggested under this guideline, that recipients of lung and lung-heart transplantation receive prophylactic antifungal therapy including drugs against *Aspergillus* and *Candida* when indicated by patient risk factors for particular colonization and infection (i.e., cystic fibrosis), regional epidemiology, and culture during pre- and post-transplantation and more particularly when lung donor's or recipient's airway culture demonstrates fungi.

Likewise, the case is true for liver transplantation. As mentioned, *Candida* spp. are likely to be fungal pathogens involved in SSI in liver transplant conditions. Fluconazole, lipid complex amphotericin B, and caspofungin are some of the most effective antifungal drugs that are currently utilized during perioperative times. Apart from those, for daily colonization of *Candida* spp. and the other fungi of duodenum and wound culture, among the transplantation of the pancreas, fluconazole is the foremost preventive drug to be given in addition to regimens. However, a lipid-based complex of amphotericin B is an improved one, in case non-*albicans Candida* spp. are common in culture.

Sutures are among the most commonly used materials for wound closure, obtained by bringing the edges of the wound together after surgery. Any foreign material introduced into the surgical area would be a source of infection, and sutures are not an exception (60). Prabha et al. studied the efficacy of chitosan-coated surgical sutures prepared from marine waste against a mixed biofilm of *Staphylococcus epidermidis* and *C. albicans* species. While Triclosan-coated sutures decreased *S. epidermidis* biofilms, they were unable to eliminate the prevalence of *C. albicans* cells on suture surfaces. Chitosan-coated sutures, however, caused a decrease in hyphal cells (61).

Table 3. The main fungal agents causing surgical site infections.

	Type of surgery	Main fungal agents	Ref
1	DSWI* following cardiac surgeries	• *Candida* spp. (7.5% to 20.5%) - a mortality rate of 56% • VAC** is more connected to *Candida* infection	(29, 47)
2	Colorectal cancer patients undergoing resection with stoma creation	• Peristomal candidiasis was more prevalent in the group receiving high-dose oral antibiotics	(48)
3	Elective procedures in a Greek general surgery department	• *Candida* spp. (8.4%)	(27)
4	Esophagectomy following a malignancy	• *Candida albicans* (29%)	(49)
5	Solid organ transplants	• non-*albicans Candida* spp. (14%) • *Mucor* spp., *Aspergillus* spp., and *Curvularia* spp. (1.7%)	(30)
6	Liver transplant procedures/ bile duct, liver, or pancreatic surgeries (Fig. 2B)	• *Candida* spp. (17.2% and 18.1% respectively) • *Saccharomyces cerevisiae, Aspergillus fumigatus, Fusarium* spp., and *Rhizopus* spp. were also involved.	(28)
7	Cerebral shunt implantation	• *Candida* spp.	(58)
8	Postoperative Aspergillosis	• *Aspergillus flavus* (41.2%)	(25)

*DSWI: Deep Sternal Wound Infections

**VAC: Vacuum Assistance Therapy

Aspergillus spp. are cosmopolitan microorganisms, i.e., they can thrive in many varied conditions, e.g., air and water. Thus, air in the operating theatre could also be the infective agent in patients in the course of surgery. Those conventional ventilation machines used in most operating theatres are not effective in eradicating *Aspergillus* spores of size 2.5-3.0 μm. Alternatively, HEPA filtration and laminar airflows can remove particles larger than 0.3 μm with an efficiency of 99.97%. Under proper maintenance, the use of these ventilation systems in operating rooms can reduce the likelihood of postoperative fungal infection. As stated earlier, fungi also develop in water; thus, the patient's wound should not be exposed to tap water (25).

In addition, several other preventive methods are used to minimize the risk of fungal SSI, particularly in operating theatres. They are as follows: controlling temperature and humidity level in the operating theatre, avoid usage of sterilizing fluids, best preparation of surgical instruments with proper lumen size and cleanliness of cannulated bit, performance by well-trained personnel (62) (Table 4).

CONCLUSION

The study in hand was directed to study SSIs caused by fungal pathogens. Although the incidence of fungal SSIs is low, their prevention is strongly recommended due to their stealthy nature, the permanent damaging complications, and the difficulty in diagnosis and treatment of fungal infections.

Neoplasms, either by itself or the course of treatment process, other conditions resulting in immune system deficiencies, and the use of excessive doses of antibiotics through alteration of normal body flora are some of the patient's parameters that make the patient susceptible to fungal SSIs. Such patients must be taken care of with increased vigilance during operations. Long hospitalization, shaving, and congested operating rooms are some other risks of fungal colonization of the wound.

Candida appears to be the most frequent cause of fungal SSIs. *Candida* has been designated by several studies as the fungal organism responsible for wound infection, and it is not surprising to discover that there is a basis for this designation. It is one of the normal skin flora, and therefore, it can easily penetrate a wound and establish an infection. *Aspergillus* spp. are also a frequent cause of post-operative infection, as per our literature review, probably due to its extensive prevalence.

Nearly all operations are susceptible to fungal infections. *Candida* spp. in the usual bowel and colonic flora raise the rate of fungal infections in gastrointestinal and abdominal surgery. These operations have to be conducted under very controlled conditions. The same applies to all sternum-opening operations, transplant operations (especially heart, lung, and liver), and even operations involving implantation of a foreign device, shunt, etc. As far as we know, these operations are now more vulnerable to surgical wound infection by fungal pathogens.

Lastly, how do we avoid post-operative fungal infection?

In short, the following could reduce the incidence of fungal SSIs:

1) According to Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery, prophylactic antifungal therapy should be administered before certain procedures in high-risk patients.

2) Fungal agents can survive in most environments. Therefore, there is a need to keep the operating room water and air supplies clean. In addition, the operating rooms' temperature and humidity levels should be kept optimal.

3) Sterilization and proper usage of surgical equipment and materials should be ensured.

4) Decreasing the number of surgical staff decreases the risk of infection transmission.

Table 4. Preventive practices for fungal surgical site infections

	Preventive measures regarding fungal SSI
1	Consider antifungal prophylaxis based on patient risk factors before certain surgeries
2	Keep the operating room’s air and water supplies clean
3	Maintain the humidity and temperature in the operating rooms at optimal levels
4	Ensure proper usage and sterilization of surgical instruments and materials
5	Don not overcrowd the operating room

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