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REVIEW ARTICLE OPEN ACCESS

A review of the practice of surgical antibiotic prophylaxis

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Abstract
Background: Surgical Antibiotic Prophylaxis (SAP) is defined as the use of antibiotics to prevent infections at a surgical site. The appropriate use of SAP is an effective and efficient modality of preventing surgical site infections.
Main body: The practice of SAP is however fraught with several challenges e.g., diverse opinions among surgeons regarding the duration of surgical prophylaxis, a dearth of institutional guidelines, and poor compliance with existing guidelines. Unfortunately, the inappropriate use of SAP results in adverse clinical (e.g., increased length of hospitalization, occurrence of surgical site infections, morbidity etc.) and economic consequences (e.g., increased healthcare costs) in surgical patients.
Conclusion: This review article discusses the practice of SAP and the challenges regarding SAP. Finally, some recommendations to overcome the challenges are discussed.

Keywords: Surgical antibiotic prophylaxis, Surgical site infection, Guidelines, Compliance, Quality improvement

Background

Surgical antibiotic prophylaxis (SAP) is defined as the use of antibiotics to prevent infections at a surgical site (1). It involves the initial administration of a short course of an antimicrobial agent before surgery to prevent surgical site infections (2). The appropriate use of SAP is an effective and efficient modality of preventing surgical site infections (SSI) (1, 3). Antibiotics however carry the risk of adverse effects and drug resistance (4). The choice of an antibiotic for SAP should therefore ensure coverage of organisms likely to cause an infection at the surgical site and be influenced by the strength of association between the antibiotic used and these adverse effects (5). The above statement is best achieved with regular audits of the practice of SAP and the design of local antibiotic formularies which would ensure that the most appropriate antibiotic, dose, timing of administration, and duration are used for effective prophylaxis (5).

The use of SAP takes into consideration the following: the need to decide if the surgical procedure requires the use of antibiotic prophylaxis; a knowledge of the bacterial flora most likely to cause a surgical site infection; the choice of an antibiotic, based on the steps above, with the narrowest antibacterial spectrum required; the

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choice of the less expensive drug if two drugs are otherwise of the equal antibacterial spectrum, efficacy, toxicity, and ease of administration; the administration of the antibiotic at the right time and the right dose; the use of surgical prophylaxis for a short period (one dose if surgery of four hours duration or less); the avoidance of antibiotics likely to be of use in the treatment of serious sepsis; the knowledge by the surgical team that SAP is not an attempt to overcome poor surgical technique and the presence of (and periodic reviews of) local guidelines on SAP (1).

To ensure optimum best practices in surgery and quality healthcare delivery several attempts have been made at institutional, national, and international levels to develop guidelines and recommendations for SAP (4). Several studies have however documented poor compliance with existing guidelines. Sadly, the adverse effects (e.g., the occurrence of surgical site infections, inappropriate use of antibiotics, emergence of drug resistance, increased costs to the patient, the risk of drug toxicity etc.) of poor guideline compliance are borne predominantly by surgical patients (6). For example, a study done by Fukatsu et al found a correlation between prolonged use of surgical prophylaxis and the development of methicillin-resistant *Staphylococcus aureus* (7). While some sections in this paper, discuss the epidemiology, risk factors and microbiology of surgical site infections the focus of this narrative review is the practice of SAP.

Main body

Methods

This paper is a narrative review of the practice of surgical antibiotic prophylaxis. It essentially involved a literature review of existing theories and recommendations regarding the practice of surgical antibiotic prophylaxis. In line with narrative reviews, there was no predetermined research question nor specified search strategy or protocol regarding the topic i.e. surgical antibiotic prophylaxis.

The concept of surgical antibiotic prophylaxis

Surgical antibiotic prophylaxis (SAP) is defined as the use of antibiotics to prevent infections at a surgical site (1). It refers to a very brief course of an antimicrobial agent commenced just before the onset of an elective surgical procedure (1). It is not an attempt to sterilize tissues involved in the surgery nor does it seek to prevent surgical site infections caused by contamination, in the post-operative period (1). Rather it is a decisive and properly timed process which is indicated in an elective operation in which skin incisions are closed during surgery (1). It serves to reduce the microbial burden of intraoperative contamination to a level that cannot overwhelm the patient's host defences (1). Its tacit aim is to prevent surgical site infections through the administration of safe, cost-effective antimicrobials which possess a spectrum of activity against pathogens that are likely to cause an infection at the surgical site (1).

The appropriate and timely administration of antibiotic prophylaxis has been shown to reduce the incidence of surgical site infections (1). Dettenkofer et al (2002) state that approximately 30 to 50% of antibiotic use in hospital practice is for surgical prophylaxis and that between 30% to 90% of this prophylaxis is inappropriate (e.g., inappropriate timing or duration) (8). Such injudicious use of antibiotics also increases the selective pressure favouring the emergence of antimicrobial resistance (1).

Ideally, an anti-infective drug for surgical prophylaxis should achieve the following goals: it should prevent the occurrence of a postoperative infection at the surgical site; prevent postoperative infectious morbidity and mortality; it should reduce the duration and cost of health care; it should produce no adverse effects, and have no adverse consequences for the microbial flora of the patient or the hospital (8, 9). To achieve these goals, an anti-infective drug should be: active against the pathogens most likely to contaminate the wound; given in an appropriate dosage and at a time that ensures adequate concentrations at the incision site during the period of potential contamination; safe; and administered for the shortest effective period to minimize adverse effects, development of resistance, and cost (8, 9).

Historical background

In the nineteenth century, the works of Louis Pasteur and Joseph Lister laid the background for the introduction of asepsis and prophylaxis in surgical practice (4).

While Louis Pasteur discovered that microbes were responsible for disease and putrefaction Joseph Lister's discovery of aseptic procedures was instrumental in wound healing and reduced mortality rates associated with surgeries at this time (4).

Despite these major discoveries, the use of surgical prophylaxis was fraught with opposition from surgeons and academicians involved in the teaching and practice of surgery (4). For example, in 1880, nearly 15 years after the discoveries of Pasteur and Lister, a surgeon called William Halstead was ordered from the operating theatre

for daring to challenge a senior surgeon's non-compliance with aseptic surgical techniques (4). Furthermore, many surgeons could not reach a consensus on the need for prophylaxis in surgery (3). However, studies done between 1961 and 1963 by investigators in Cincinnati and Boston showed the isolation of Staphylococcus aureus from the operative field, despite the application of standard aseptic techniques. The investigators concluded that while standard aseptic techniques could decrease but not eliminate bacterial contamination of the surgical field, the addition of surgical prophylaxis (to standard aseptic techniques) is vital in preventing infections at the surgical site (10, 11, 12).

The second discovery showed that early administration of surgical prophylaxis was associated with the prevention of infection at the surgical site (13, 14, 15). The efficacy of prophylactic antibiotics has been verified and peri-operative antibiotics and aseptic techniques have become routine aspects of care in most major surgical procedures (4).

Surgical site infections

A surgical site infection (SSI) is "an infection related to an operative procedure that occurs at or near the surgical incision within 30 days of the procedure, or within 90 days if prosthetic material is implanted at surgery" (16). Surgical site infections are classified as follows (17);

Superficial incisional SSI

A superficial incisional SSI is an SSI which occurs within 30 days following an operative procedure (where day 1 = the procedure date) and which involves the skin and subcutaneous tissue of the incision. A patient with a superficial incisional SSI may have any of the following clinical features: pain, tenderness, swelling, erythema or drainage of pus occurring at the incision site and microbiological isolation of an organism from the incision (17). There are two specific types of superficial incisional SSIs (17):

a. Superficial incisional primary (SIP): This is a superficial incisional SSI that occurs in the primary incision in a patient that has had surgery involving one or more incisions such as a caesarian section incision (17).

2. **Superficial incisional secondary (SIS)** – this is a superficial incisional SSI that occurs in the secondary incision in a patient that has had surgery involving more than one incision such as the donor site incision for coronary bypass graft surgery (17).

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Deep incisional SSI

A deep incisional SSI is an SSI which occurs within 30 or 90 days following the operative procedure (where day 1 = the procedure date) and involves deep soft tissues of the incision such as fascial or muscle layers. A patient with a deep SSI may have any of the following clinical features: fever (>38°c), localized pain, tenderness, an abscess or purulent drainage at the site of deep incision; and microbiological isolation of an organism from the deep soft tissue of the incision (17). There are two specific types of deep incisional SSIs:

1. **Deep incisional primary (DIP):** This refers to a deep incisional SSI that occurs in a primary incision in a patient that has had surgery involving one or more incisions such as a caesarian section (17).
2. **Deep incisional secondary (DIS):** This is a deep incisional SSI that occurs in the secondary incision in a patient that has had surgery involving an operation with more than one incision for example the donor site incision for coronary bypass graft surgery (17).

Organ space SSI

This refers to an SSI that occurs within 30 or 90 days following surgery (where day 1 = the procedure date) and involves any part of the body deeper than the fascial/muscle layers that are opened or manipulated during the operative procedure (17). A patient with an organ space SSI may have any of the following clinical features: purulent drainage from a drain placed into the organ/space; organism(s) identified from fluid or tissue in the organ/space; an abscess or other evidence of infection involving the organ/space (17).

Epidemiology of SSI

SSIs are associated with patient morbidity and mortality and increased healthcare costs borne by the patient and healthcare providers (18, 19). In many low- and middle-income nations (LMICs), SSIs account for the highest frequency of healthcare-associated infections (20, 21). Globally the pooled incidence of SSI is estimated to be 2.5% [95% ci: 1.6, 3.7] (22). It ranges between 0.6 and 9.5% in Europe (23). In the USA a study showed an overall SSI rate of 1.9% (24). In the Asia-pacific region, the incidence of SSI varies per country with cumulative incidences of 2.8% in Australia, 2-9.7% in the Republic of Korea and China, 7.8% in south-east Asia and Singapore and 4% in China (20, 24, 25, 26, 27, 28). The pooled cumulative incidence of SSI in sub–Saharan Africa is 14.8% (29).

In Nigeria, a meta-analysis showed a cumulative incidence of SSI of 14.5%, [95% ci: 0.113–0.184]

(30). SSIs in Nigeria were found to be quite common following colorectal surgeries (29.2%, 95% ci: 0.216–0.382), abdominal surgeries (20%, 95% ci: 0.064–0.649), and among the paediatric populations [29.6%, 95% ci: 0.136–0.529] (30). The north-eastern region of Nigeria has reported the highest rates of SSI (27.3%, 95% ci: 0.132–0.481) followed by the northcentral region [26.3%, 95% ci: 0.116–0.493] (30). However, the lowest rate of SSI was reported in the south-south region (8.0%, 95% ci: 0.065–0.098) of the country (30).
The most frequently encountered type of SSI is the superficial incisional SSI, which occurred in 62.5% (ci: 0.333–0.848) of cases (30). The SSI incidence was also predominantly reported among patients with dirty wounds (52.7%, 95% ci: 0.367–0.682) and contaminated wounds [24.0%, 95% ci: 0.164–0.336] (30). Similarly, the highest incidence of 18.62% SSI was reported among patients aged 60 years and above followed by an incidence rate of 16.91% among patients aged <20 years (30).

Risk factors for surgical site infections
The risk factors for SSI include patient-related or endogenous factors (such as age, gender, weight, comorbidities etc.) and exogenous or process/procedural-related factors (such as duration of the surgery, adherence to infection control and prevention protocols etc.) (31).
Findings from a systematic review involving 57 studies from high-income countries and LMICs revealed that the following factors were associated with an increased risk of SSI: diabetes, prolonged duration of surgery, a high body mass index; a severe score according to the US National Nosocomial Infections Surveillance (NNIS) risk index; and a severe wound class (32). In a study conducted in Pakistan SSI was found to be more common in older patients (11.4% vs. 6.4%; p=0.009); patients with more than 24 hours of preoperative hospital stay (11.2% vs. 64%; p=0.013), in emergency surgeries (19.2% vs. 7.5%; p=0.0001) and in procedures of longer duration (1.53 ± 0.35 vs 2.57 ± 0.17; p<0.0001) (33).
In a study done in Nigeria SSI was found to be more common in patients with diabetes mellitus (or = 1.2; ci: 0159–9.109); elderly patients (or = 1.02; 95% ci: 0.993–1.055); prolonged duration of postoperative hospital stay (or = 1.07; 95% ci: 1.011–1.131) and cigarette smoking (or = 6.24; 95% ci: 0.274–142.15) (34). Another Nigerian study showed that age (>60 years), anaemia, obesity, number of individuals (> 6 individuals) in the operating room and duration of surgery were all significantly associated with the occurrence of SSIs (35).

Microbiology of SSI
A significant proportion of organisms responsible for SSIs are acquired endogenously or exogenously from the patient's environment (36, 37). In addition, the location of the health facility, duration of the surgery, site of the surgery and the presence (and level of adherence) of strict infection prevention and control protocols may also influence the type of pathogens involved in SSIs (38, 39).
However, bacteria are the organisms predominantly implicated in SSIs (38, 39). Among bacteria, *Staphylococcus aureus* is the most frequently isolated pathogen in SSIs (38, 39). However, in some studies gram-negative bacteria, such as E*scherichia. Coli,* are the most frequently isolated pathogen (40).
Specifically, multi-drug resistant bacteria such as methicillin-resistant Staphylococcus aureus (MRSA), methicillin resistant coagulase-negative Staphylococci, vancomycin-resistant enterococci and extended spectrum beta-lactamase (ESBL) producing Enterobacteriaceae are also very important causes of SSI particularly due to the significant morbidity and mortality associated with these organisms (41, 42).

Preventing surgical site infections
A variety of measures have been suggested for preventing surgical site infections. Examples include pre-operative bathing; decolonization with mupirocin ointment for the prevention of staphylococcus aureus infection in nasal carriers; screening of ESBI colonization; mechanical bowel preparation and the use of oral antibiotics; hair removal around the surgical site and surgical site preparation with antiseptic solutions (43). Other measures include the use of antimicrobial skin sealants; enhanced nutritional support; perioperative discontinuation of immunosuppressive agents; perioperative oxygenation, maintaining normal body temperature (normothermia); intensive perioperative blood glucose control in diabetics; maintenance of adequate circulating volume control/ normovolemia; prophylactic negative pressure wound therapy; the use of antimicrobial -coated sutures; the use of laminar flow ventilation systems in the operating suite; and the administration of surgical antibiotic prophylaxis (43).
The World Health Organization has however adopted a multi-modal strategy to prevent the occurrence of SSIs (44). This strategy is a cohesive

approach to ensure implementation and scalability of efforts to curb SSIs, particularly in resource-constrained settings which lack required infrastructure such as laminal flow ventilation systems, water, sanitation and hygiene (wash) facilities etc (44). This strategy is made up of five components:

1. **System change:** adequate infrastructure, resources and protocols must be in place in efforts to curb SSI and also ensure the sustainability of these efforts (44). In addition, the right infrastructure, resources and protocols ensure that interventions to curb SSIs are streamlined, consistent and sustainable (44). For example, appropriate surgical techniques must go hand in hand with the availability of hand hygiene facilities in the theatre and post-operative wards (44).

2. **Training and education:** continuous training regarding infection prevention and control (IPC) protocols to curb SSIs is required for all healthcare staff who are involved in the management of surgical patients (44). Such training should present the rationale for IPC protocols in efforts to curb SSIs and incorporate behavioural change components to ensure improved outcomes in efforts to curb SSIs (44).
3. **Monitoring and feedback:** it is important to monitor and evaluate compliance with interventions to curb SSIs. For example compliance with hand hygiene, monitoring of blood glucose control in diabetics etc. In addition, monitoring and evaluation will also provide evidence on SSI rates and risk factors and use this knowledge to adjust or design interventions to curb SSIs (44).
4. **Reminders and communications for awareness raising:** for example, posters can be placed in strategic places in the hospital to remind or educate health workers patients and/or their relatives about surgical site infections (44)**.**
5. **Institutional safety climate and culture change:** the leadership of each healthcare facility must create an enabling environment to curb SSIs. For example, acquiring the required infrastructure, ensuring compliance with IPC protocols and procuring antibiotics required for surgical prophylaxis (44).

However, a major component required to prevent surgical site infections is surgical antibiotic prophylaxis. This review further discusses surgical antibiotic prophylaxis (SAP).

Principles of surgical prophylaxis

The following are clearly defined principles regarding the practice of SAP.

1. **Indications for surgical prophylaxis**

To understand which surgeries, require SAP or not, surgical wounds, are classified according to their potential risk for infectious complications. This classification which has greatly facilitated the study and practice of surgical antibiotic prophylaxis is ranked in the following manner:

Classification of surgical wounds **(1, 17)**

Class I/clean: refers to uninfected operative wounds devoid of inflammation and in which the respiratory, alimentary, genital, or uninfected urinary tract is not entered. Examples include herniorrhaphy, mastectomy, cosmetic surgery, insertion of prosthesis (e.g. Hip replacement) or artificial devices (e.g. Heart valves) (1, 17).

Class II/ clean-contaminated: this is an operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Examples include laryngectomy, uncomplicated appendicectomy, cholecystectomy, and transurethral resection of the prostate gland (1, 17).

Class III/ contaminated: these include open, fresh, accidental wounds, operations with major breaks in sterile technique (e.g., open cardiac massage), or gross spillage from the gastrointestinal tract and incisions in which acute, non-purulent inflammation is encountered are included in this category (1, 17). Examples include large bowel resection, and biliary or genitourinary tract surgery with infected bile or urine (1, 17).

Class IV/dirty-infected wounds: these are old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation (17).

Based on the classification above SAP is uniformly recommended for all clean-contaminated and contaminated procedures and operations involving the insertion of an artificial device or prosthetic material (1).

2. **Choice of antibiotics for surgical prophylaxis**

The following factors are considered in selecting antibiotics for SAP. These include: ensuring that the choice of antibiotics provides coverage against

the expected endogenous flora at the surgical site; antibiotic penetration into the surgical site; antimicrobial costs to the patient, the existence of patient allergies to any of the antibiotics; a knowledge of the ecology of local nosocomial wound pathogens, and ensuring appropriate antibiotic dosing and administration (4). In addition, where two or more antibiotics (which are equal in the antibacterial spectrum, efficacy, toxicity, and ease of administration) are available the least expensive drug should be chosen (1, 5).

3. **Route of antibiotic administration**

The intravenous route is the usual mode of administering prophylactic antibiotics. They are usually administered as a bolus at induction of anaesthesia to ensure adequate tissue concentrations at the time of surgical incision (1).

The intramuscular route of administration is a less commonly used route than the intravenous route. Intramuscularly administered prophylactic antibiotics are given at the time of pre-medication so that peak tissue levels are attained at the most critical time (i.e. The time of surgical incision) (1).

Other routes of administration include oral or rectal routes which are commonly used in bowel surgeries. Topical antibiotics are not recommended routes for surgical prophylaxis, with the exceptions of ophthalmic or burns surgery (1).

The use of antibiotic-impregnated cement placed directly into the operative wound (as a local antimicrobial *brachytherapy*) has also been deployed as a method of SAP particularly in procedures involving the replacement of infected prosthetic joints (45, 46). It has been significantly associated with a reduction in surgical site infections (45, 46).

4. **Timing of antibiotic administration**

Appropriately timed antibiotic prophylaxis is defined as "the delivery of the antibiotic within one hour before incision, with the exception that vancomycin and the fluoroquinolones should be given within two hours before incision because of the need for a longer infusion time" (4, 8).

Inappropriate timing of antibiotic prophylaxis has been associated with suboptimal tissue levels and an increased risk for surgical site infections (4). For example, Classen and colleagues noted that the risk of SSI was reduced when antibiotics were administered within two hours before incision (47). Also, investigators involved in the trial to reduce antimicrobial prophylaxis errors (trape) examined the association between SSI and timing of prophylaxis in cardiac, orthopaedic, and hysterectomy patients and found that SSI risk was lowest in those patients who received prophylaxis within 30 minutes (if given cephalosporins) or within 1 hour (if given vancomycin or a fluoroquinolone) before incision. They also found that post-incision administration of prophylaxis was associated with a significantly increased risk for SSI (48).

However, oral or rectal antibiotics are given earlier than the time frames mentioned above, to achieve optimal tissue concentrations (1). For example, metronidazole suppositories, which are commonly used in bowel surgery, must be given two to four hours before surgery (1).

5. **Duration of antibiotic administration**

The discontinuation of prophylactic antibiotics within 24 hours of completing surgery is recommended by most guidelines for SAP (8). For surgeries not exceeding four hours a single dose of the antibiotic is usually sufficient while in prolonged surgeries exceeding four hours, further antibiotic doses may be required to maintain the concentration, particularly if the antibiotic has a short half-life (1, 8).

For cardiac surgery, experts recommend continuing prophylaxis for 48 hours, based on concerns that more data are needed before uniformly recommending a shorter duration of antibiotic administration (49). The prolonged administration of antibiotic prophylaxis in the postoperative period (e.g., until surgical drains have been removed) does not improve efficacy and increases toxicity, cost and drug resistance (4). For example, Harbath and co-workers found that prolonged antibiotic prophylaxis (>48 hours post-incision) was significantly associated with an increased risk of acquiring an antibiotic-resistant pathogen (50). Another study conducted by Arrigan et al (2007) in Zambia found that prolonged administration of surgical prophylaxis beyond 24 hours resulted in no benefit to the patients and was associated with an increased risk of surgical site infections, increased length of hospitalization and increased costs borne by the patient (51).

Challenges, regarding the practice of surgical antibiotic prophylaxis

Globally the use of surgical prophylaxis is supported in several surgical procedures e.g., gastrointestinal, oropharyngeal, vascular, orthopaedic, etc (52). However, the practice of SAP is fraught with variations and controversies regarding issues such as indications for SAP, choice of antibiotics, timing, and duration of prophylaxis (3, 4, 53). These variations and controversies are essentially due to several factors:

1. ***First*** is a lack of institutional or national guidelines for SAP. This problem is particularly pronounced in low- and middle-income countries (lmics) with weak governance structures and fragile health systems (54, 55).
2. ***Second*** is the poor compliance by surgeons with available guidelines and recommendations on SAP. The problem of compliance with guidelines is global (8, 53), as evidenced by previous studies in several institutions which have shown wide ranges of compliance ranging from 0% to 71.9% with the majority of studies showing compliance rates below 50% (56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68). For example, findings from a multi-centre audit of elective procedures in thirteen hospitals in the Netherlands showed that only 28% of the procedures achieved full adherence to all parameters of the local hospital guidelines (i.e. Choice of antibiotic, duration, dose, dosing interval and timing of first dose (54).also, a study done in a hospital in Doha, Qatar showed a compliance rate of 68.5% and 40.7% regarding the hospital's guidelines on antibiotic selection and duration of SAP respectively **(**69). Another study in the united arab emirates showed a compliance rate of 30.4% regarding international guidelines on dosage (66) while a study done in Sudan showed an overall compliance rate of 2.7% with international guidelines (70). In Nigeria, previous studies have shown compliance rates less than 50% **(71**, 72, 73, 74).

A lack of guidelines or poor compliance with available guidelines contributes to the inappropriate use of antibiotics for SAP in several healthcare facilities, as a variety (rather than a uniform regime) of prescriptions for SAP will emanate from each surgical unit (49). Sadly, inappropriate antibiotic use exerts adverse clinical and economic impacts on surgical patients (75, 76). While the adverse clinical impacts include increased hospital costs borne by the patients, the adverse clinical impacts include the occurrence of surgical site infections, prolonged hospital stay, increased consumption of antibiotics, the emergence of antibiotic resistance, morbidity and mortality (75, 76). Also, previous studies have shown that in the absence of guidelines the prescribing patterns of physicians for SAP tend to be based on diverse rationales such as personal preferences, medical literature (77), discussions with colleagues (78) etc. In addition, there is a misconception among some surgeons that prolonged regimens with multiple antibiotics are more effective than short courses of narrow-spectrum antibiotics in reducing or eliminating the risk of surgical site infections (79).

Improving the practice of SAP will involve developing institutional guidelines. The approach to developing these guidelines should be multi-disciplinary and must involve the hospital's antimicrobial stewardship team, surgeons, microbiologists, anaesthetists, and pharmacists (8, 52).

To ensure compliance with guidelines it will be necessary to conduct regular institutional audits on the practice of SAP (5). An audit is defined as "a quality improvement process that seeks to improve patient care and outcomes through a systematic review of all aspects of care against explicit criteria and the implementation of change. Where indicated, changes are implemented at an individual, team, or service level and further monitoring is used to confirm improvement in healthcare delivery" (80).

Continuing medical education (e.g., seminars, courses, workshops etc.) Will also be necessary to ensure updates and exposure to current best practices regarding surgical antibiotic prophylaxis (81, 82).

More cost-intensive measures may include the deployment of information technology (e.g., computer-based order systems) to avoid excessive duration of surgical antibiotic prophylaxis (83).

The commitment of a hospital's leadership is integral to improving the practice of surgical antibiotic prophylaxis (84). Examples of leadership commitment include making available the required human, financial, and information technology resources (84).

Improving the practice of surgical antibiotic prophylaxis is however not a standalone effort but should go alongside other quality improvement initiatives (i.e., antimicrobial stewardship, infection prevention and control, improved diagnostic microbiology capacity, patient safety etc.) In the hospital (81).

Conclusion

Surgical antibiotic prophylaxis (SAP) is useful in preventing surgical site infections and improving post-operative outcomes (1). However, the practice of SAP is challenged by poor guideline adherence resulting in adverse clinical and economic outcomes for surgical patients (3, 4, 53, 75, 76). Improving the practice of SAP will include developing guidelines, conducting regular audits to

assess guidelines and continuing medical education (5, 8, 52, 80, 81, 82). The leadership of a healthcare facility must also be committed to improving the practice of SAP by making available the needed human, financial, and material resources (84). Finally, efforts to improve the practice of SAP in a healthcare facility must be deployed in consonance with other quality improvement initiatives such as antimicrobial stewardship, infection prevention and control, and improved diagnostic microbiology capacity (81).

List of Abbreviations

DIP: Deep Incisional Primary
DIS: Deep Incisional Secondary
IPC: Infection Prevention and Control
LMIC: Low- and Middle-Income Countries
SAP: Surgical Antibiotic Prophylaxis
SIP: Superficial Incisional Primary
SIS: Superficial Incisional Secondary
SSI: Surgical Site Infection
Trape: Trial to reduce antimicrobial prophylaxis errors
WASH: Water, Sanitation and Hygiene

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
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Authors' contributions
IIO conceptualized, designed the study, and drafted the manuscript.

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