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Magnitude, bacterial etiology profile and associated factors of surgical site infection in Ethiopia: Systematic review and meta-analysis

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Research article

Keywords: Surgical site infection (SSI), Bacterial etiology, Ethiopia

Posted Date: August 22nd, 2019

DOI: https://doi.org/10.21203/rs.2.13405/v1

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Abstract

Background: Surgical site infection is the third most commonly reported nosocomial infection. Different primary studies on Surgical site infection (SSI) were conducted in Ethiopia. However, variation among those studies was seen. This study was aimed to estimate the national prevalence of SSI, its bacterial profile and associated factors of SSI in Ethiopia.

Methods: PubMed, Cochrane library, and Google Scholar were searched. A funnel plot and Egger's regression test were used to see publication bias. I-squared statistic was applied to check heterogeneity of studies. A weighted inverse variance random-effects model was applied to estimate the national prevalence of SSI, its bacterial profile and the effect size of associated factors. The subgroup analysis was conducted by region, study design, and year of study conducted.

Result: A total of 18 studies were used for prevalence of SSI, its bacterial profile and associated factors. The pooled prevalence of SSI was 11.58 (95% CI 9.78, 13.38). The pooled prevalence of culture positive SSI infection among patients who develop clinical sign and symptoms of SSI was also 80.42% (95% CI 70.86, 89.99). SSI was majorly caused by S. aureus (28.47%) and E. coli (15.93%). Drinking an alcohol (AOR = 6.28; 95%CI: 2.9–13.3); women's having chorioaminities (AOR = 8.67; 95%CI: 4.63–16.27); patients living in rural areas (AOR = 3.10; 95%CI: 1.57–6.14); patients who undergo previous surgery (AOR = 3.94; 95%CI: 1.7–7.17) and women's who had rupture of membrane >12 hour (AOR=5.29; 95%CI: 2.73–10.25) were identified factors of SSI.

Conclusions: The prevalence of SSI in Ethiopia was high. This indicates calling for the need of better allocating resources and implementing a program for controlling Surgical site infections in Ethiopia.

Background

Among the range of avoidable harms associated with health care, health acquired infections (HAI) have been described as a significant burden. The third most commonly reported HAI or nosocomial infection is postoperative wound infections which accounts for approximately a quarter of all nosocomial infections. Surgical site infections (SSIs) are also the most frequent HAI in low- and middle-income countries (LMICs), and can affect up to one-third of surgical patients [1].

Surgical site infections are an infection that occurs at or near surgical incision within 30 days of operation or after 1 year if implant is placed [2, 3].The infection is also associated with the intensity of bacterial contamination of the wound at surgery or later in wards during wound care that follows interference with the skin barrier [4]. *Staphylococcus aureus,* coagulase-negative staphylococci (CoNs), *Enterococcus* spp., and *Escherichia coli* remain the mostfrequently isolated pathogens. An increasing proportion of SSIs are caused by antimicrobial resistant pathogens, such as methicillin-resistant *S. aureus,* multidrug resistantand carbapenemase producing Entrobacteriacae and *P. aeruginosa* [5–7].

Globally, SSI rates have been found to be from 2.5% to 41.9% [8, 9]. In higher income settings, SSI are the second most frequent HAI in Europe [10] and the United States of America (USA) [11]. They threaten the lives of millions of patients each year and contribute to the spread of antibiotic resistance. In the USA, these infections are estimated to contribute to patients spending more than 400 000 extra days in hospital at a cost of an additional US$ 10 billion per year [11]. In Africa, surgical site infections were the leading infections in hospitals (pooled cumulative incidence of 5.6 per 100 surgical procedures), strikingly higher than proportions recorded in developed countries [12]. Another study done in Africa indicated cumulative incidence of SSIs ranged from 2.5 to 30.9% [13].

Similarly, in Ethiopia, variety of studies was conducted to estimate the prevalence of SSIs. However, prevalence of SSIs rate, which shows the prevalence of patients with clinical signs and symptoms of SSI from all patients that undergo surgery, ranges from 3.5% [14] to 20.6 % [15] which showed variation across different geographical settings and different time periods. Likewise, the prevalence culture positive SSI among SSI patients, patients with clinical sign and symptoms of SSI is also ranges from 71.1 % [16] –92% [17]. The distribution of pathogens isolated from SSIs in Ethiopia has not reviewed systematically. Moreover, there was no nationally represented pooled data of SSIs and its associated factor in Ethiopia. Therefore, this systematic review and meta-analysis was aimed, firstly, to estimate the pooled prevalence of surgical site infection and secondly, to identify the prevailing bacterial etiologies and associated factors of surgical site infection in Ethiopian context.

Objectives

General Objective:

The overall aim of this review was to systematically identify, collect, review, summarize and synthesize the available evidence on magnitude, bacterial profile and associated factors of surgical site infection in Ethiopia,2018.

Specific objectives

- To estimate the pooled prevalence of surgical site infection in Ethiopia
- To identify the prevailing bacterial etiologies of surgical site infection in Ethiopia
- To determine the pooled effect sizes of factors contributing for surgical site infection in Ethiopia

Methods

Protocol registration and review reporting

This systematic review and meta-analysis was registered at the international prospective register of Systematic Review and meta-analysis (PROSPERO) with the registration number of CRD42019126017.

The results of this review were reported based on the Preferred Reporting Items for Systematic Review and Meta-Analysis statement (PRISMA) guideline [18].

Searching strategy and information sources

To find potentially relevant articles, a comprehensive search with no date limits were performed in the following databases: PubMed, Google Scholar, and Cochrane Library. All searches were limited to articles written in English given that such language restriction does not alter the outcome of the systematic reviews and meta-analyses [19]. Gray literature of observational studies were searched through the review of reference lists and input of content experts. In addition, to find unpublished papers relevant to this systematic review and meta-analysis, some research centers, including the Addis Ababa Digital Library was searched.

The search strings or terms were stemmed from the following key words: prevalence, magnitude, surgical site infection, post operative infection, bacterial profile, bacterial etiology, and Ethiopia. The search terms were used to retrieve relevant literature in combined form adapted to the requirement of the specific database. In the advanced searching databases, the searching strategy was built based on the above-mentioned terms using the" Medical Subject Headings (MeSH) " and "All fields " by linking "AND" and "OR" Boolean operator terms as appropriate.

Inclusion and Exclusion Criteria

Inclusion:

- Cross-sectional, case-control and cohort studies reporting the prevalence of SSI to allow us to compute the estimate were included.
- We were also included studies published only in English
- Any study that was using the Centers for Disease Control and Prevention (CDC) criteria for diagnosis of SSI was also eligible.

Exclusion:

- Studies in which the diagnosis of SSI was not based on the CDC/National Healthcare Safety Network (NHSN) criteria
- Case reports, case-series, letters, commentaries, notes, editorials and conference abstracts
- Studies that were conducted among a very select group of patients (eg, HIV patients) as they would not be generalizable to the entire population and more susceptible to infection.

- Articles which was not fully accessible after at least two-email contact with the primary authors were excluded. Exclusion of these articles were because of the inability to assess the quality of articles in the absence of full text.
- Review articles, meta-analyses, or non-English studies were excluded

Study screening and selection processes

All articles were accessed from databases and electronics search engines and from reference lists were exported reference manager software, Endnote version 7, to remove duplicate studies. The remaining articles were also evaluated in the context of the topic, language and study area. Then those articles did not full fill the inclusion criteria of the review were rejected. Finally the abstracts and the full-texts of the remaining studies were reviewed.

Quality assessment

Four independent reviewers (MK, BG, FM and EA) will examine the quality of the included studies. The quality of each article will be assessed using JBI critical appraisal tool prepared for cohort studies and cross-sectional studies [20].

Briefly, items will be used to appraise cohort studies are as follows: (1) similarity of groups, (2) similarity of exposure measurement, (3) validity and reliability of measurement, (4) identification of confounder, (5) strategies to deal with confounder, (6) appropriateness of groups/participants at the start of the study, (7) validity and reliability of outcome measured, (8) sufficiency of follow-up time, (9) completeness of follow-up or descriptions of reason to loss to follow-up, (10) strategies to address incomplete follow-up, and (11) appropriateness of statistical analysis. Likewise, items that will be used to appraise cross-sectional studies: (1) inclusion criteria, (2) description of study subject and setting, (3) valid and reliable measurement of exposure, (4) objective and standard criteria used, (5) identification of confounder, (6) strategies to handle confounder, (7) outcome measurement, and (8) appropriate statistical analysis. Different opinions on scoring will be resolved through discussion among the research group until a consensus will reached. The quality scale of primary studies will be considered as low risk for both systematic review and meta-analysis if the studies got 50% and above.

Data extraction process

Data was extracted using a standardized data collection form. Two reviewers were independently extract data including the name of the first author and year, the study region, the study design, the target population, the sample size, SSI rate, culture positive prevalence of SSI among patients who showed clinical sign and symptoms of SSI and name and prevalence of each identified bacteria among SSI patients. Where the prevalence was not reported directly, we were calculate it using the sample size and number of outcomes. Moreover, we were also extract the number of patients who developed and who do

not developed the surgical site infection within 30 days of surgery for each of associated factor if they were reported by the studies. If this was not reported by the studies we were extract the AOR of associated factors for SSI and upper and confidence interval of AOR associated factors.

Outcome measures

The primary outcome measures were the prevalence of SSI rate within 30 days of surgery involving any of the operative incisions made and culture positive prevalence of SSI among patients who developed SSI based on criteria of CDC. CDC criteria for SSI require the patient to have at least one of the following:

- Purulent drainage from the superficial or deep (fascia or muscle) incision but not from within the organ/space component of the surgical site
- At least one of the following: pain or tenderness; localised swelling; redness; heat; fever and the incision is opened deliberately or spontaneously dehisces
- Abscess within the wound (clinical, histopathological or radiological detection)

This measure was adopts the definitions within the 2008 Centre for Disease Control and Prevention definitions of SSI [2]. The secondary outcomes that were derived from this study were identification of the prevailing bacterial pathogens and associated risk factors for SSI rate in Ethiopia.

Data processing and analysis

Data was extracted in Microsoft Excel format, followed by analysis using STATA Version 14 statistical software. The existence of heterogeneity among studies were examined by the forest plot as well as I^2 heterogeneity test, In which 0–40%, 50–60%, 50–90% and 75–100 % represented low, moderate substantial and considerable heterogeneity respectively [21, 22]. I^2 heterogeneity test of ≥50% and a p-value of <0.05 was assured the presence of heterogeneity. Thus, the Dersimonian laired random-effects model was employed [23]. To identify the influential studies that resulted in variation, first the extracted data was checked for any error that might happen during the process of extraction then sensitivity analysis was carried out using the " metaninf" command[24]. Finally, if the data was free of errors and when there is no outlier using sensitivity analysis further subgroup analysis was conducted. The subgroup analyses was employed by assuming the region, study design and year of the study as grouping variables and sources of variation.

Using the "metafunnel" command [25] and objectively by Egger's regression test publication bias was detected [25]. Accordingly, asymmetry of the funnel plot and/or statistical significance of Egger's regression test (p-value<0.05) was suggestive of publication bias. Therefore, using " metatrim" command, a nonparametric trim and fill (Duval and Tweedie's) method of analysis was done [26]. The presence of an association between the determinants and the pooled proportion of surgical site infection was

estimated based on the effect size. Furthermore, all statistical interpretations were reported based on the 95% CI.

Result

Selection of studies

A total of 346 articles searched through the electronic searches of which 86 duplicated articles were excluded. From the remaining 260 articles, 235 articles were excluded after reading of titles and abstracts. One article was removed because of an availability of full text. Finally, 24 full text articles were accessed for eligibility criteria. Based on the predefined criteria and after critical appraisal 18 were included in the final analysis (Figure 1).

Characteristics of included studies

The total of eighteen articles was included in this meta-analysis and systematic reviews that met the inclusion criteria. All the included studies were conducted between 2009 and 2018. They were also published from 2011 up to July, 2019.

The articles those fulfill eligibility criteria for this systematic review and meta analysis were conducted on four regions and in the Federal capital city of Ethiopia, Addis Ababa, but no study on SSI was obtained from other regions (Afar, Benishangul-Gumuz, Gambela and Somali). Five studies at South Nations Nationalities and Peoples of Ethiopia national regional state (SNNP) [16, 17, 27–29]; four studies were conducted in Addis Ababa [15, 30–32]; similarly four studies at Tigray national regional state [33–36]; three studies at Amhara national regional state [37–40] and lastly two study at Oromia regional state[41, 42].

Fourteen of the studies were done using primary data[15–17, 27–34, 36, 37, 41] while the rest were done using secondary data [35, 38, 40, 42]. Most of the studies (16) were done by cross sectional study design and other two done through Co-hort study design (Table 1). Five of the studies were conducted only on women's who give birth through cesarean section[28, 32, 34, 35, 41] and the other thirteen studies were conducted on patients which undergo different type of surgery.

Quality of studies

The JBI quality appraisal criteria established for cross-sectional and cohort studies were used. Since all the studies that fulfill the eligibility criteria of this systematic review and meta-analysis had got 50% and above, all of them were considered [15–17, 27–38, 40–42].

Pooled prevalence of Surgical site infection in Ethiopia

Pooled prevalence of Surgical site infection rate

The pooled prevalence of Surgical site infection rate in Ethiopia based on CDC criteria was 11.58 (95% CI 9.78, 13.38) (Figure 2). As shown in the forest plot below, substantial heterogeneity was identified (I2 = 82.1; p < 0.001) indicating that the use of random effects models for estimating the pooled estimates is applicable. Moreover, it also suggests the need to conduct subgroup analysis to identify the sources of heterogeneity.

Subgroup analysis

Subgroup analysis was done based on study area (regions), study years and sampling design to identify the possible source of heterogeneity across studies (Table 2). The subgroup analysis result directed that the source of heterogeneity was due to the study area, but not due to sampling design and study years (p < 0.001) (Table 2). According to the result the pooled prevalence of SSI in Amhara and Oromia region was 9.16 and 10.63, respectively.

Sensitivity analysis

The sensitivity analysis shown that all of the studies were found within the confidence interval limit, hadn't an impact on the overall estimation (Figure 3).

Publication bias

A funnel plot showed an asymmetrical distribution (Figure 4). Egger's regression test p-value was 0.007, which indicated the presence of publication bias.

Trim and fill analysis

Due to the presence of significant publication bias through egger test further trim and fill analysis was conducted. As shown in figure 5, this analysis was filled five studies. According to trim and fill analysis, the pooled prevalence of SSI rate was 13%.

Pooled prevalence of culture positive Surgical site infection

Seven studies were included to determine the pooled prevalence and to identify bacterial profile of culture positive surgical site infection. A shown in Figure 6, the pooled prevalence of culture positive SSI infection among patients who develop clinical sign and symptoms of SSI was 80.42% (95% CI 70.86, 89.99)(I2 = 9.4; p >0.05) (Figure 6).

Bacterial profile of culture positive Surgical site infection

From bacterial isolates that cause SSI in Ethiopia, the pooled prevalence of Gram-negative bacteria isolates (60.2%) was higher than that the Gram positive isolates (39.9%) which were obtained from patients who develop SSI. But When we come to each individual isolates, the pooled prevalence of *Staphylococcus aureus (*28.47%)was higher followed by *Escherichia coli(*15.93%*),* Klebsiella species(15.62%), Coagulase-negative staphylococci (CoNs)(8.99%), Proteus species(8.20%), *Pseudomonas aeruginosa(*7.17%), Entrobacter species (1.94%) and Citrobacter species(1.93%) (Table 3). Although they had very low prevalence, Morganella spp[30], Enterococcus species[31], Acinetobacter spp [30]. Providencia stuartii [31] and Streptococcus spp [17] were also etiologies of SSI in Ethiopia.

Pooled effect of associated risk factors on SSI

Although in primary studies study variables such as duration of surgery greater than one hour, drinking an alcohol [15, 36], chorioaminities[35, 38, 42], residence [35, 42], previous surgery [15, 27], HIV [27, 35], anemia [28, 32], prolonged labor [28, 34, 35, 38], rupture of membrane >12 hour [15, 28, 32, 34, 35, 42] and duration of surgery > 1hour [15, 27–29, 38, 40] had shown significant association with the SSI, when the odds those associated risk factors of two or more studies become pooled only drinking an alcohol, chorioaminities, residence, previous surgery and rupture of membrane >12 hour were significantly associated with SSI in Ethiopian context.

As shown in Figure 7, patients drinking an alcohol (AOR = 6.28; 95%CI: 2.9–13.3) as compared to those didn't drink an alcohol; women's having chorioaminities (AOR = 8.67; 95%CI: 4.63–16.27) as compared to those hadn't chorioaminities; patients living in rural areas (AOR = 3.10; 95%CI: 1.57–6.14) as compared to those living in urban areas; patients who undergo previous surgery (AOR = 3.94; 95%CI: 1.7–7.17) as compared to those didn't undergo previous surgery and women's who had rupture of membrane >12 hour (AOR = 5.29; 95%CI: 2.73–10.25) as compared to women's who had rupture of membrane < 12 hour were more likely to develop surgical site infection.

Discussion

This systematic review and meta-analysis was conducted to estimate the pooled prevalence of surgical site infection rate and its associated factors among patients who undergo surgery in Ethiopia from 2009 up to 2018. Moreover it was also estimated the pooled prevalence of culture positive SSI among those had clinically confirmed SSI and their bacterial profile.

This meta-analysis was shown that the national prevalence of SSI in Ethiopia. Accordingly, the national pooled prevalence of SSI was 11.58 (95% CI 9.78, 13.38). This result was relatively higher than annual epidemiological report for 2016 of SSI by European Centre for Disease Prevention and Control (ECDC) ranged between 0.5% to 9.0%, depending on the type of surgical procedure[43]; and from meta analysis result of SSI among neonates (5.6%)[44] and in China (4.5%) [45]. The lower prevalence of SSI in

developed counties may be due to strong economies, having a high set up hospitals, their degree of adherence to aseptic techniques and surgical procedure may be done by well experienced surgeons. The relatively higher SSI in Ethiopia may be due to lack of proper facilities for surgical procedure; limited application of infection control measures as well as poor hand hygiene practice and due to the reason that most of surgical procurers may be done by general practitioners (GP) and residents.

Publication bias may have existed, as indicated by the Egger's test P values (0.007). Before CDC criteria for SSI was released, studies of surgical site infection in Ethiopia might be done based on different clinical identification and this might also had influence for publishing those studies.

The pooled prevalence of culture positive SSI infection among patients who develop clinical sign and symptoms of SSI was 80.42%. This indicates that CDC criteria for the detection of SSI among health centers which don't have a microbiology laboratory section will become more help full. Moreover, most of SSI was highly caused by Gram negative bacteria's than the Gram positives bacteria's. This is in consistent with the other review done by Purba *et al.*[[46]. Among each individual isolated SSI was majorly caused by *S. aureus* and *E. coli.* This was in line with annual surveillance done in European countries and in other review[43, 46].

The odds of patients who were drinking an alcohol were nearly eight times more risk to have SSI. this may be because alcohol exposure significantly reduced levels of key components of the immune system involved in healing. This finding was also concordant with results of a systematic review and meta analysis done by Shabanzadeh D and Sørensen L [47].

The odds of patients who lived in rural areas were nearly two times more risk to have SSI after surgery was done. This could be due limited access to hygienic materials and poorer hygiene for persons living in rural areas when compared to those in urban areas. This might be attributable to the fact that as income increases, personal nutritional status, level of education, self-care practice, and other individual behaviors will be improved.

The odds of patients who had history of surgical procedures were four times more likely to develop SSI. Higher incidence of SSI in patients with previous surgery may be due to exposure to long operation time, difficult surgery, high class wounds and using the same incision site with the previous one.

Our review shown that the odds of women's who had rupture of membrane greater than twelve hour were nearly five time more risk to have SSI after the CS. Normally during pregnancy, cervical mucus and amniotic fluid serve as barrier to infection. However if the membrane is ruptured, this protective effect is gradually reduced over as amniotic fluid become no longer sterile. Thus, it was though that the non-sterile amniotic fluid might act as a transport medium by which bacteria got the chance to contact with uterus and skin incision and this might resulted in chorioamnionitis and further SSI. Moreover, the odds of women's who had chorioaminities were nearly nine times more risk to have SSI after CS.

The result of this review will provide information for health care providers specifically to surgeon working in health care system of national and international level; for Ethiopian ministry of health; for World Health organization (WHO) to decrease the rate of SSI and related complications with SSIs.

Strength and limitation

This systematic review and meta-analysis is shown the national SSI rate conducted in Ethiopia. It may be lacked national representativeness because no data were found from Benishangul Gumuz, Afar, Gambella, Somalia, Dire Dawa, and Harare regions. Due to lack of reporting of the prevalence SSI based on the type surgical procedure this review was not also reported SSI infection prevalence among the type surgery.

Conclusion

The prevalence of surgical site infection rate is 11.6% in Ethiopia. This high prevalence of SSI in Ethiopia indicates calling for the need of better allocating resources and implementing a program for controlling Surgical site infections. Health policymakers in Ethiopia can help reduce surgical site infection by implementing appropriate policies, such as educational programs and improving the quality of surveillance system.

Declarations

Abbreviations

AOR = Adjusted odds ratio; CDC/NHSN = Centers for Disease Control and Prevention/ National Healthcare Safety Network criteria; CI = Confidence interval; CS = Cesarean section; ECDC = European Centers for Disease Control and Prevention; GP = General practitioner; JBI = Joana Brig's Institute; PRSRMA = Preferred Reporting Items for Systematic Review and Meta-Analysis statement; SSI = Surgical site infection; WHO = World health organization

Ethics approval and consent to participate

We have meta-analyzed evidences obtained from studies that were particularly conducted in Ethiopia. Therefore, this study did not require approval from ethical committee.

Consent for publication

Not applicable.

Availability of data and materials

No additional data are required; all information is clearly presented in the main manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Authors' contributions

MK: Conception of research protocol, study design, literature review, data collection, data extraction, data analysis and interpretation, and drafting manuscript. EA, BG and FM,: literature review, data collection and extraction, and reviewing manuscript. All authors have read and approved the manuscript.

Acknowledgment

We are very grateful to the University of Gondar (UoG), Ethiopia for providing a scholarship for the corresponding author. We also like to acknowledge the University of Gondar librarians.

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Tables

Due to technical limitations, Tables 1 - 3 are only available for download from the Supplementary Files section.

Figures

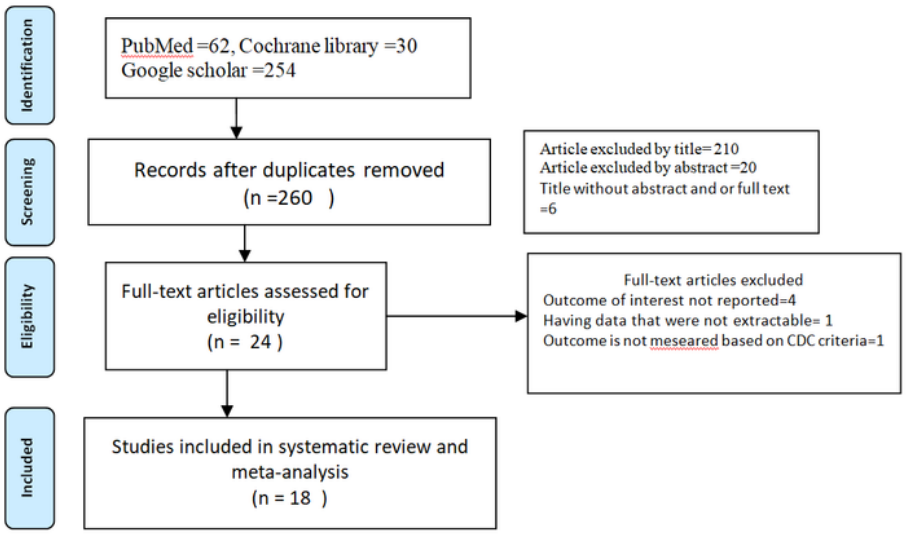


Figure 1

Flow chart shows the study selection process

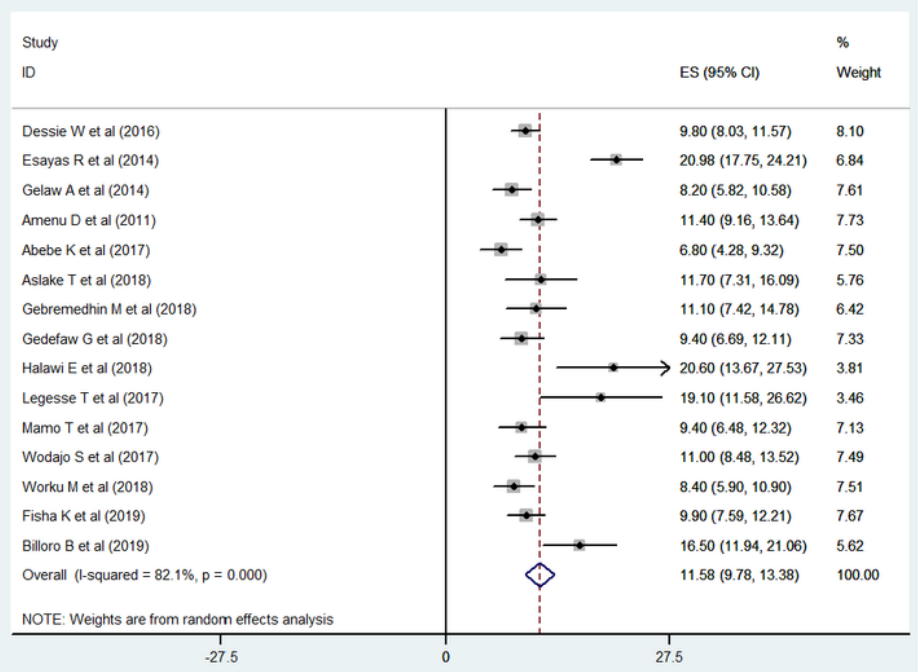


Figure 2

Forest plot of the pooled prevalence of SSI rate with corresponding 95% CIs

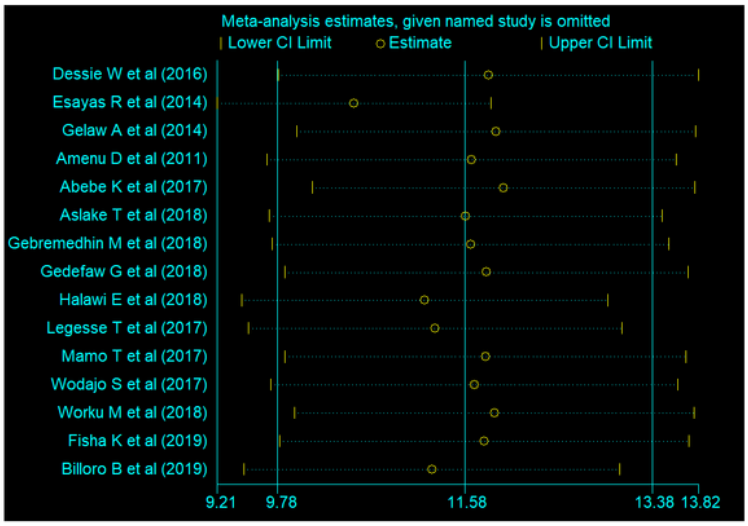


Figure 3

The sensitivity analysis showed the pooled prevalence of SSI rate when the studies omitted step by step

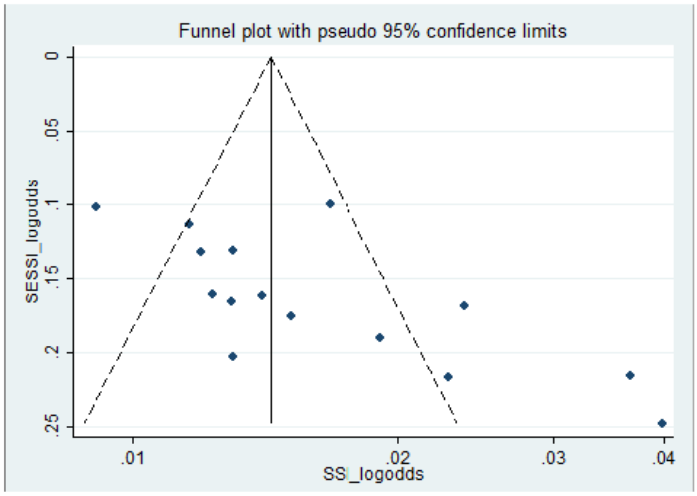


Figure 4

Funnel plot for publication bias, SSI Log odds (log of proportion) represented in the x-axis and standard error of log proportion in the y-axis

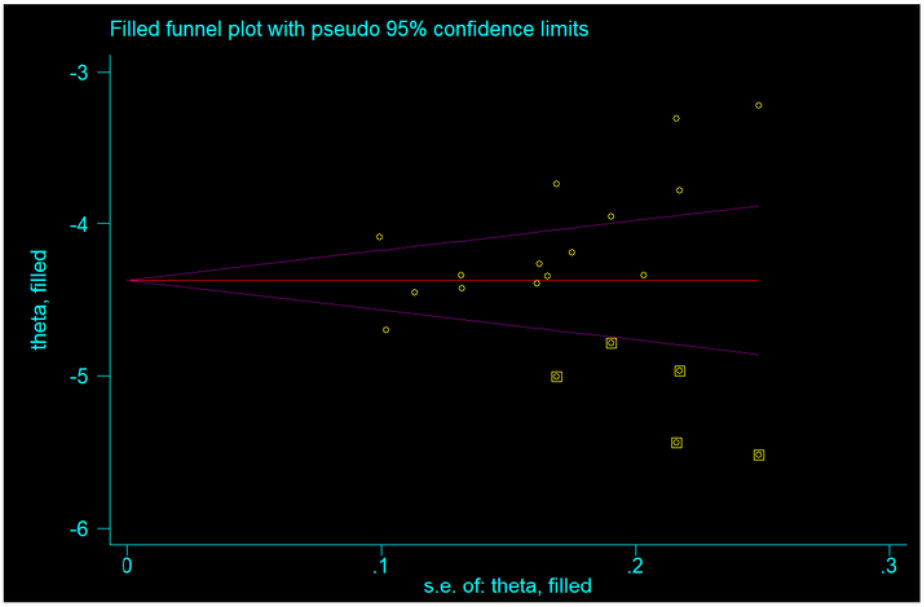


Figure 5

Funnel plot of trim and fill analysis

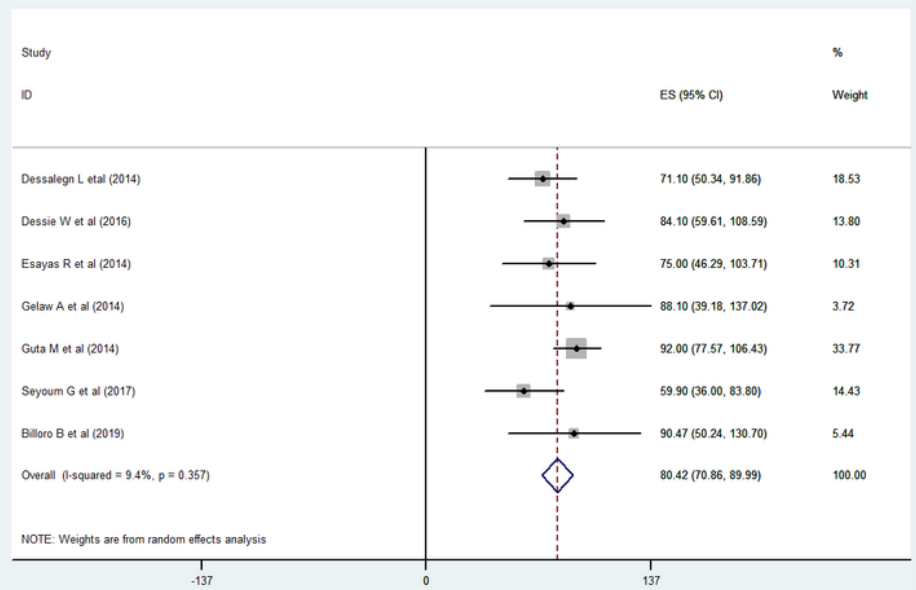


Figure 6

Forest plot of the prevalence of culture positive SSI with corresponding 95% CIs

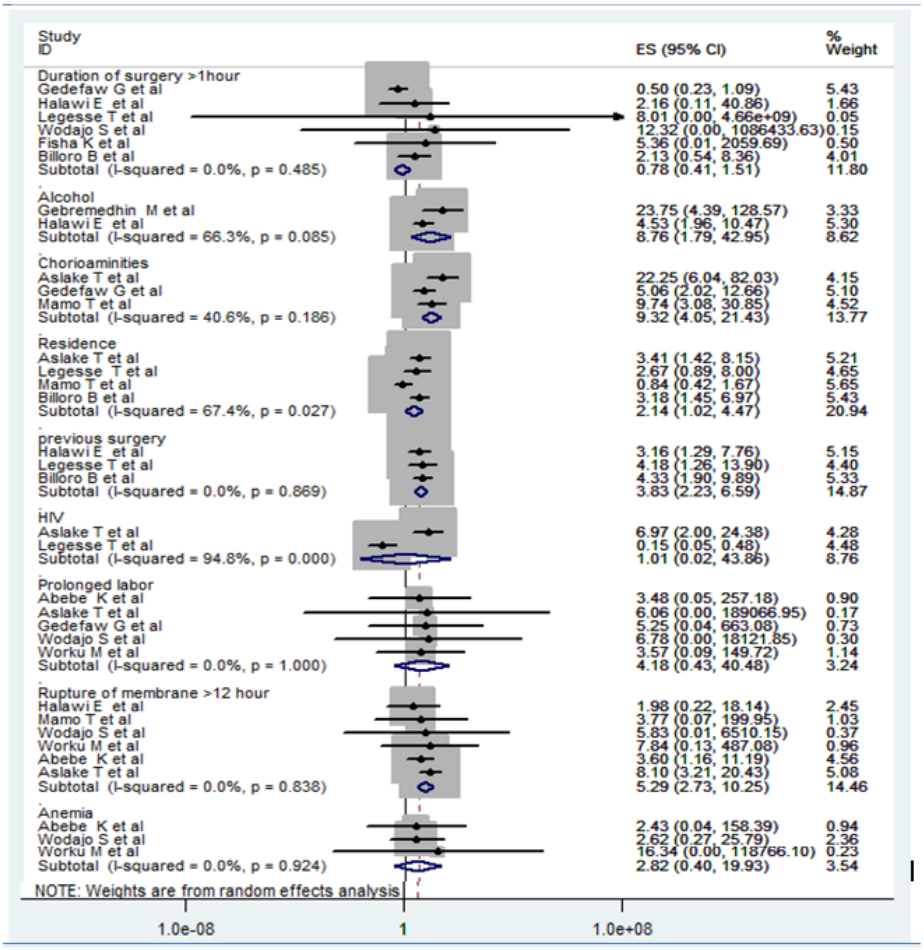


Figure 7

The pooled effects of drinking an alcohol, chorioaminities, residence, previous surgery anemia, prolonged labor, duration of surgery > 1hour, HIV and rupture of membrane >12 hour on SSI

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2Mizan.pdf
- Table1Mizan.pdf
- Table3Mizan.pdf