ORIGINAL RESEARCH

Do Post-debridement Cultures have a Role in Reduction of Infection in Open Fractures? Report of 166 Cases and Literature Review

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Abstract

Objective: To evaluate the role of post-debridement cultures in the prevention of future infection following open fractures.

Design: Retrospective Cohort Study and Literature Review.

Setting: Division of Orthopaedic Surgery, Sultan Qaboos University Hospital, Academic and tertiary health care, Muscat, Oman.

Participants: A total of 166 patients from a cohort study and 539 patients from the literature review with open fractures. There were 640 cumulative patients fit the inclusion and exclusion criteria.

Intervention: Using predetermined inclusion and exclusion criteria, data on all open fractures were gathered from the electronic health system of a single institution between 2010 and 2019. PubMed and Embase electronic databases were also searched for relevant articles relating to post-surgical debridement culture and its correlation with future infection.

Main outcome measures: Assessing the benefit, role of post-debridement cultures in the prevention of future infection following open fractures.

Results: Combining the results of this retrospective cohort study and previously published data, there were 640 Gustilo-Anderson grades II and III open fractures which had post-debridement screening. Eighty-eight patients (13.8%) developed an infection, out of which 16 had positive post- debridement cultures (18.2%). Only four grew similar organisms at screening and infection stages, two of which had different antibiotic resistance patterns at the infection stage. Seventy-two fractures had negative post-debridement screening swabs (81.8%). Of the 59 (9.2%) fractures with positive screening only four (6.8% of the infected fractures) developed later deep infection. All these 59 cases had culture-guided antibiotic treatment, with or without surgical debridement.

Conclusion: Although the bacterial growth of post-debridement cultures is low, post-debridement screening as part of a comprehensive management protocol may have a role in reducing deep infection in open fractures. This is particularly the case in Gustilo and Anderson type 3 open fractures, the risk of infection is high. The poor association between organisms isolated from screening and those from subsequent deep infection may mean that the later infective organisms have been acquired from a secondary colonisation source after the debridement.

Level of evidence: III

Keywords: Culture swabs, Infection, Open fractures, Post-debridement.

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Introduction

The incidence of infection following open fracture fixation can reach as high as 47%.[1] It disrupts the patient's life significantly and drains healthcare system financially.[2] Iliaens et al. found that fracture-related infections resulted in an eight times increase in direct healthcare costs, patients missed four times more days of work, and reported significantly lower quality of life scores than age, sex, and fracture-matched patients without infection.[3]

Measures used to mitigate the risk of infection include obtaining bacterial culture specimens (swabs or tissue) after the first surgical debridement.[4] However, many authors and recent guidelines have recommended against this practice.[2,5–8] On the other hand, other surgeons find surveillance helpful in identifying potential pathogens and in guiding the treatment plan.[9] A number of studies have tried to correlate the bacteria grown at different stages—pre-debridement and post-debridement results—to subsequent infections.[9–14] However, predicting which wound will develop an infection and the role of surveillance remain subjects of debate. This is due partly to a lack of a standard surveillance method, the significant number of unplanned procedures, and the observed heterogeneity in study designs of the published literature.[15]

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Table 1: Search strategy of PubMed and Embase databases

1)	Open fracture: "fractures, open"[MeSH Terms] OR ("fractures"[All Fields] AND "open"[All Fields]) OR "open fractures"[All Fields] OR ("open"[All Fields] AND "fracture"[All Fields]) OR "open fracture"[All Fields]	28,476
2)	Infection: "infect"[All Fields] OR "infectability"[All Fields] OR "infectable"[All Fields] OR "infectant"[All Fields] OR "infectants"[All Fields] OR "infected"[All Fields] OR "infecteds"[All Fields] OR "infectibility"[All Fields] OR "infectible"[All Fields] OR "infecting"[All Fields] OR "infection's"[All Fields] OR "infections"[MeSH Terms] OR "infections"[All Fields] OR "infection"[All Fields] OR "infective"[All Fields] OR "infectiveness"[All Fields] OR "infectives"[All Fields] OR "infectivities"[All Fields] OR "infects"[All Fields] OR "pathogenicity"[Subheading] OR "pathogenicity"[All Fields] OR "infectivity"[All Fields]	3,689,855
3)	Culture: "culture"[MeSH Terms] OR "culture"[All Fields] OR "cultures"[All Fields] OR "culture's"[All Fields] OR "cultured"[All Fields] OR "culturing"[All Fields] OR "culturings"[All Fields]	11,482
4)	Debridement: "debride"[All Fields] OR "debrided"[All Fields] OR "debridement"[MeSH Terms] OR "debridement"[All Fields] OR "debridements"[All Fields] OR "debrides"[All Fields] OR "debriding"[All Fields] OR "debridment"[All Fields] OR "debridments"[All Fields]	37,176
Total		496

The very low positive surveillance results and the high infection rates, especially in Gustilo and Anderson grade III open fractures, demand better quantitative and qualitative evaluation of the literature. In this study, a retrospective cohort study of open fractures from a single institution along with the review of published literature was carried out. The aim of this study is to seek if open fracture surveillance if performed in a standardised manner, has a role in the prevention and treatment of infection after open fracture fixation.

Materials and Methods

Search Strategy

After obtaining institutional review board approval, this retrospective study was conducted to trace all patients admitted with open fractures for the period between 2010 and 2019.

For the literature review, the research question, inclusion, and exclusion criteria for individual studies were established prior to searching the databases. Online databases (PubMed and Embase) were used to find literature related to post-debridement culture swabs and their efficacy in predicting infection in the setting of open fracture. The search was conducted on 28 September 2021, without any restriction on language or date of publication. Details of keywords used and article yields are presented in Table 1.

Inclusion and Exclusion Criteria

All patients older than 18 years of age with an open fracture requiring wound debridement and fixation were included. Surgical procedures were carried out by qualified orthopaedic surgeons. We excluded all cases that exceeded 48 hours between injury and surgery, patients who died before wound closure, and those who did not complete the follow-up period. Patients who underwent amputation during the index admission were also excluded.

All included cases received antibiotics per hospital protocol and had follow-up in the fracture out-patients clinic for at least 6 months before discharge. The Centre for Disease Control and Prevention (CDC) definition of wound infection as an infection within 90 days of surgery presenting with: Fever (>38°C), a sinus, purulent discharge, spontaneous dehiscence, local inflammation, evidence of infection involving the deep tissue with one or more isolated microorganism or requiring reoperation and surgical debridement.[16] The same inclusion and exclusion criteria have been used for literature review analysis.

Study Chart Review

Data were gathered from the electronic health system for all admitted patients with open fractures for the period between 2010 and 2019, including patient demographics, site of fracture, Gustilo and Anderson classification of the fracture, time from injury to debridement, type of antibiotic given, results of post-debridement cultures, and if available, subsequent wound cultures.

Surgical Protocol

All patients with an open fracture were evaluated in the emergency department. At the initial evaluation, the wounds were cleared of gross contamination using normal saline, dressed in sterile gauze and splinted. The patients received intravenous 1.5 gm cefuroxime in addition to tetanus prophylaxis.

In the operating room (OR), a thorough debridement of the open fracture was carried where indicated, the wound was extended along fasciotomy lines or in accordance with a standard surgical approach to the region. All foreign and necrotic material was meticulously removed, and tissues were assessed for viability by colour, bleeding, and muscle contractility. The wound was irrigated 6–9 litres of normal saline using low-pressure pulse lavage.

Following debridement, four swab samples are taken from the bone and surrounding soft tissue for cultures including deep recesses in grade III fractures. Sampling grades I and II fractures were left to the discretion of the operating surgeon based on the clinical scenario and the condition of the tissues at the time of surgery. Fractures were then stabilised using definitive internal or external fixation.

Primary wound closure at index surgery, without skin tension, was performed when possible. In only a few cases, primary soft tissue coverage using local fasciocutaneous flaps was possible due to the absence of regular access to plastic surgery support in our hospital. Otherwise, topical negative pressure therapy (VAC, KCI, San Antonio, TX, USA) was applied and the patient was taken back to the OR after 48–72 hours for further debridement and four fresh culture swabs were taken at the end. This process is repeated until definitive wound coverage is obtained. Wounds that have grown pathogens were started on sensitivity-guided intravenous antibiotics and repeated debridement until three consecutive sets of negative culture swabs are obtained prior to definitive soft tissue coverage. The antibiotics were continued till the wound was closed or definitive coverage was done. All patients have been followed and traced for infection development for a minimum of 6 months.

Data Extraction

The literature review produced 496 potentially eligible articles. In the first reviewing stage, titles and abstracts were screened, as

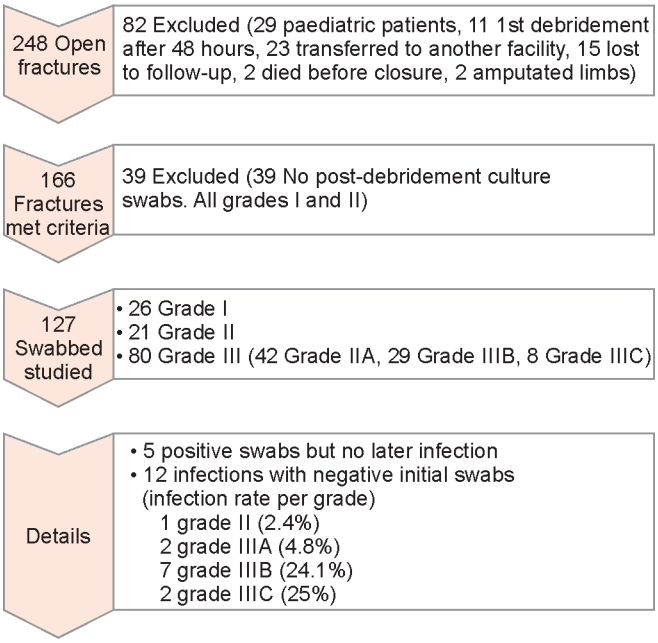

Fig. 1: Flowchart of the elimination process of cases to the final study group

well as titles and abstracts of crossover references. Four studies satisfied all inclusion and exclusion criteria. Two independent reviewers performed full-text review of the four eligible studies. However, only two reported the intervention initiated based on the surveillance culture results.[17,18] The authors of the other two studies were contacted for these details but unfortunately, did not respond.[7,9] Therefore, these two studies were excluded as well. These included study and publication information (author, year of publication, study design, level of evidence, and sample size), patient data (age, sex, and clinical features), and surgical and swab culturing details (procedures performed, technique, and approach), as well as complications, infection, and follow-up.

Study Analysis

Categorical data were concise using percentages and Chi-squared tests or Fisher's exact test, whichever was most appropriate. Continuous variables such as means and standard deviations or medians and interquartile ranges were examined using the Student's *t*-test and analysis of variance or Mann–Whitney *U* test as appropriate. All data were entered into SPSS program for Windows version 22 (SPSS, Chicago, IL, USA) which was used for subsequent statistical analysis.

Results

An institutional search has identified 248 open fractures during the specified study period, from which only 166 cases (12 females) fulfilled the inclusion criteria (Fig. 1). The mean age was 33.9 years (18–85 years). The average time from injury to surgical wound debridement was 13 hours (1–48), whereas the average wound closure time was 1.2 days (0–19 days). Lower limbs involvement was more common than the upper limbs with 136 cases (79.5%).

Culture swabs were taken from 127 patients with 127 open fractures after initial debridement out of 166. All the 39 patients who had not been swabbed had Gustilo and Anderson fracture grades I and II and have been excluded from further analysis in this study.

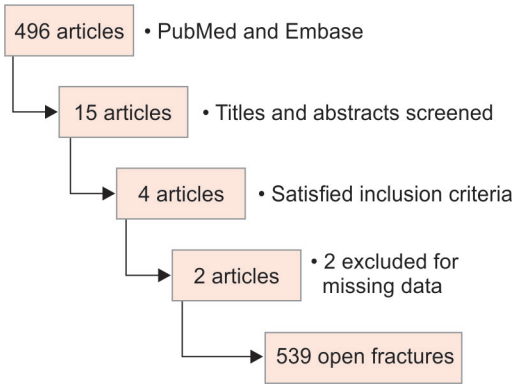

Fig. 2: Flowchart illustrating the article screening process of the literature

The Gustilo and Anderson grades in the 127-study group were as follows: Grades I and II were 26 (20.2%) and 21 (16.5%), respectively. Grade III were a total of 80 (63%) cases: 42 cases (52.5%) of grade IIIA, 29 cases (36.3%) of grade IIIB, and 8 cases (10%) of grade IIIC. Grade I patients were excluded from further analysis as none of them had any positive cultures or developed later infection.

Of the 101 swabbed patients, microbial growth was found only in 10 patients (9.9%). Five cases (5%) grew pathogenic organisms none of which developed later infection as appropriate sensitivity-guided antibiotics and surgical management were initiated in a timely manner. The grown organisms were mainly gram-negative, such as *Enterobacter cloacae, Klebsiella pneumonia, Bacillus cereus, and Candida*. Only one isolate (*Bacillus cereus*) showed resistance to most cephalosporins but was sensitive to clindamycin and vancomycin. All the remaining isolates shown sensitivity to cephalosporins, quinolones, and aminoglycosides without any drug resistance. The other five (5%) positive cultures after initial debridement showed normal skin flora and the wound healed uneventfully without any further intervention. On the other hand, 12 fractures (11.9%) developed later infection, where none of the isolates demonstrated multidrug resistance and all required surgical intervention after discharge from the hospital. Eleven of the infected cases were in Gustilo and Anderson grade III fractures and one was in grade II fracture. None of these cases had positive post-debridement cultures.

A total of 539 open fractures from two studies were included in the literature review (Fig. 2).[17,18] Positive cultures after debridement were found in 54 fractures (10%), only four of which developed later infection caused by the same organism. The rest responded to culture-guided therapy. Seventy-six fractures (14.1%) developed infection, 72 of which had negative surveillance cultures raising the possibility of either an undetected primarily acquired dormant pathogen or a secondarily acquired infection. It is worth noting that each of the other studies used different surveillance methods. Lenarz et al. state that aerobic and anaerobic cultures were obtained by swabbing the bone and local tissue directly at the site of the fracture only 19 whereas in Hao and A-Qin Peng study soft tissue was collected from around the fracture sites.[17]

Combining the results from our retrospective cohort study and literature review, there were 640 grades II and III open fractures, of which 88 (13.8%) became infected and had been screened. Of those infections, 16 had positive cultures post-debridement (18.2%). Only four grew similar organisms at screening and infection stages, two of which had different antibiotic resistance patterns at the infection

stage. Seventy-two fractures that became infected had negative post-debridement screening swabs (81.8%).

From the combined data, 59 (9.2%) fractures had a positive screening with only four (6.8% of the infected fractures) developing deep infection later. It is important to note that in all those 59 cases, culture-guided antibiotic treatment with or without surgical debridement was administered following the positive screening.

Discussion

The results of this retrospective cohort study have shown that post-debridement culture yielded bacterial growth in only 10% (10/101 Gustilo and Anderson grades II and III fractures) of fractures. Only five of these were pathogens. However, none of these fractures developed a later infection as culture-guided specific antibiotics were administered with or without further surgical debridement. Twelve (12%) fractures developed later in infection, all of which had negative screening cultures. It is possible that either the screening protocol was inadequate, or the source of the infective organism was not at the initial injury. These observations are further confirmed when our data are combined with those from the two studies included in this literature review. Out of a cumulative total of 640 Gustilo and Anderson grades II and III screened fractures, there were 59 (9.2%) positive screening cultures. As appropriate sensitivity-guided antibiotic and surgical treatment was initiated based on these results, only four patients (6.8% of the infected fractures) developed deep infection caused by the same initial organism. In two cases the organism has developed antibiotic resistance. Out of 16 patients with positive screening results that developed later deep infection, 12 (75%) patients had completely different organisms indicating that the initial organisms responded to the initial therapy but developed later infection from a different source, for example, nosocomial. Again, 84 out of the 88 patients who developed deep infection had either negative screening cultures (72 fractures) or were positive for a different organism (12 fractures). This fact can be explained by two possibilities: (1) dormant undetected pathogen from the initial injury, or (2) the eventual infective organisms were acquired further down the line rather than at the initial injury. It is not known how many of the culture-positive fractures would have gone on to develop later infection if left untreated. It is equally unrealistic to assume that sensitivity-guided antibiotics and wound debridement are universally efficacious in preventing later infection. However, the fact that only four out of 59 culture-positive fractures developed infection points towards a possible contributory role played by the culture-guided preventive measures undertaken.

Many studies attempted to establish the concordance between screening and eventual infective organisms. They found disappointingly low concordance, thereby concluding that screening was of no value.[7,17] However, it should be remembered that screening is usually undertaken to prevent the development of serious conditions, such as breast or cervical cancer, and in open fractures, osteomyelitis; not concordance. Our results indicate that post-debridement screening is quite successful in this regard. The significant infection rate seen in patients with negative post-debridement screening should draw attention to failures in either screening or open fracture management protocols. Many of these fractures undergo repeated debridement procedures. Lenarz et al. found that infected fractures underwent a significantly higher number of surgical debridement procedures than the non-infected ones.[18] Hao and A-Qin Peng noted that none of the organisms isolated at screening showed multidrug resistance, whereas 60.8% of those grown from infected wounds were multidrug resistant.[17]

In a retrospective review of 245 open fractures, Lee J investigated the usefulness of both pre- and post-debridement specimens and concluded that they were of no value.[7] D'Souza et al. prospectively studied the role of pre- and post-debridement culture swabs in 108 cases of open tibial fractures.[9] In contrast, they found that both specimens were helpful with the pre-debridement specimens having greater sensitivity and the post-debridement specimens having greater specificity, and reported an accuracy of 77% and odds ratio of 4.9 (27/51, 52.94%) for the latter. Of note is their 47% infection rate for all the Gustilo and Anderson grades which is much higher than those reported in other series, including this one. The high concordance rate suggests a progression from contamination to infection and ineffective or inadequate preventive intervention. Lenarz et al. reported a low positive post-debridement culture rate and very low overall wound infection rates following a rigorous structured open fracture management protocol.[18] They argued that the positive cultures helped to guide further wound management by guiding further antibiotic regimen, surgical debridement, and timing of wound closure, depending on the energy of injury and clinical picture. Our experience is very similar to theirs in that none of the patients whose screening swabs grew pathogens developed a later infection. Infection was pre-empted by appropriately guided antibiotic and surgical management in these patients.

Clearly, this significant risk of infection development merits a closer look and further study of this area. Preoperative antibiotics, surgical debridement, and copious washout resulting in weakened and reduced microbial wound load, in combination with inadequate sampling, delays in specimen processing, and the use of standard culture media and time (rather than enriched prolonged cultures) are some of the factors that might account for the high negative results. Tissue death and cell necrosis due to hypoperfusion and hypoxia along with prolonged periods of exposed deep structures create an ideal area for microbial growth leading to later infection. In addition, it is possible that the pathogen responsible for wound infection may have originated elsewhere, for example, nosocomial or haematogenous source.[7,19]

While it might be argued that post-debridement screening should be abandoned because of its low sensitivity, it should be remembered that the human and economic burden of established musculoskeletal infection far outweighs those of screening.[3] One approach is to improve pathogen detection if indeed there is a high false-negative rate. The adoption of a more aggressive combined approach of radical debridement, post-debridement screening, standardisation of culture obtaining protocols, fracture fixation, and immediate soft tissue cover, followed by culture-guided antibiotics for the positive cultures, would theoretically minimise the risk of nosocomial contamination and lower the overall infection rate.[20–23] Another area that needs to be explored is the role of newer technologies such as next-generation DNA sequencing. While these have greater sensitivity to finding bacterial genetic products, their clinical usefulness has not been evaluated yet.

Despite the qualitative and quantitative hurdles related to studying this difficult condition, our study has some strengths. The pooling of the data has enhanced the numbers that allowed us to find some trends. The clear management protocol, a minimum of 6-month follow-up, and strict inclusion and exclusion criteria are additional positive attributes.

The limitations of this study include its retrospective design, a relatively small number of patients over a long-time-interval, and the small number of published studies that met the inclusion criteria which are all retrospective in design.

In conclusion, this report shows that post-debridement screening as part of a comprehensive management protocol maybe helpful in preventing deep infection in open fractures. This is particularly the case in Gustilo and Anderson type III open fractures the risk of infection is high.

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