How effective are drain tip cultures at predicting surgical site infections after hip arthroplasty?

Akira Toga (akira.toga@gmail.com)
Edogawa Hospital: Edogawa Byoin https://orcid.org/0000-0001-5692-768X
Ayush Balaji
Edogawa Hospital: Edogawa Byoin
Osamu Hemmi
Edogawa Hospital: Edogawa Byoin
Ken Ishii
IUHW Mita Hospital: Kokusai Iryo Fukushi Daigaku Mita Byoin
Shigeyuki Tokunaga
Edogawa Hospital: Edogawa Byoin
Shojiro Katoh
Edogawa Hospital: Edogawa Byoin
Ryoichi Izumida
Edogawa Hospital: Edogawa Byoin

Research Article

Keywords: bipolar hip arthroplasty (BHA), drain tip culture, revision total hip arthroplasty, surgical site infection, total hip arthroplasty (THA)

Posted Date: July 9th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-683668/v1

Abstract

Background

Postoperative surgical site infections (SSIs) are a common complication of surgical procedures; however, the use of drain tip cultures to diagnose SSIs in patients is controversial. The objective of this study was to evaluate the efficacy of drain tip cultures for the prediction of postoperative SSIs in patients recovering from hip arthroplasty.

Methods

The data was compiled from 1,204 patients over a 15-year period. Statistical analysis was performed to evaluate the diagnostic value of drain tip culture in determining surgical site infection. We also used this data to evaluate whether preexisting conditions such as hypertension or diabetes affected the probability of a patient getting an SSI.

Results

Drain tip cultures were positive in 12 of 1,112 cases of primary hip arthroplasty, but only one of these 12 patients were ultimately diagnosed with an SSI (sensitivity, 12.5%; specificity, 99.0%; p = 0.0834). Results from postoperative drain tip cultures performed in patients undergoing revision arthroplasty included two false positives and three false negatives; interestingly, no true positives were detected in any of the revision arthroplasty cases we evaluated (sensitivity, 0%; specificity, 97.8%; p = 0.9355).

Conclusions

Our results indicate that drain tip cultures have no statistically significant predictive value for the diagnosis of post-operative SSIs and thus should not be used as a primary diagnostic or predictive tool for SSIs. We recommend that other diagnostic tools for the postoperative diagnosis of SSIs be explored. Standardized guidelines should therefore be established to improve the predictive value of alternative methods.

Introduction

Surgical drains are inserted after total hip arthroplasty (THA) and bipolar hip arthroplasty (BHA) procedures to prevent the formation of a hematoma at the surgical site. Bacterial cultures from the tips of the drainage tubes are routinely performed after drain removal, but the efficacy of such drain tip cultures for the detection and diagnosis of postoperative surgical site infection (SSI) remains unclear. SSIs are perioperatively diagnosed using samples taken from the synovial capsule; however, drain tip culture is the primary method for diagnosing SSI postoperatively due to the undesirable nature of invasive sampling.

Although the incidence of SSI after hip arthroplasty is between 1–3%, the complications of SSIs associated with this procedure are often severe and require immediate intervention [1–3]. It is therefore important to evaluate the effectiveness of the diagnostic tools and protocols used to diagnose SSI after hip arthroplasty.

Several previous studies have documented specific correlations between the results of drain tip cultures and the incidence of SSIs after total knee arthroplasty and spinal surgery [4]. However, these studies only included a small number of patients and drain tip samples, and thus the likelihood of statistical errors was high. Petsatodis *et al.* [5] determined that a minimum of 1,000 drain tip cultures would be required for an accurate conclusion regarding the efficacy of drain tip cultures for diagnosing SSIs after hip arthroplasty. Because only one study to date has achieved such a large sample size, the efficacy of drain tip cultures remains controversial. Achieving a clear conclusion therefore requires increasing the availability of data while maintaining standard surgical procedures.

The purpose of this study was to evaluate the effectiveness of drain tip cultures for predicting and diagnosing SSIs in patients who underwent hip arthroplasty, with the goal of obtaining a large enough sample size for a robust and accurate assessment. To that end, we performed a retrospective analysis of drain tip cultures from 1,087 primary THA patients, 25 primary BHA patients, and 92 patients who underwent revision arthroplasties between 2005–2019 at our hospital. Using our data, we tested the hypothesis that drain tip cultures are not an adequate predictor of SSI.

Materials And Methods

Literature search

We performed a literature search (MEDLINE) to identify published reports from 1989 to 2020 that examined the use of drain tip cultures to predict SSIs after hip arthroplasty. The search keywords included “drain tip culture,” “surgical site infection,” and “hip,” which resulted in only one relevant study [6]. From the sources cited in this publication, we identified an additional six studies that were directly relevant to our work. This literature review was conducted to understand the conclusions of past studies about the predictive value of drain tip cultures.

Participants and procedures

We performed a retrospective evaluation of findings from 1,112 of the 1,159 patients who underwent primary hip arthroplasty at our hospital over the past 15 years, as well as 92 patients who underwent revision hip arthroplasty. Forty-seven cases that did not include records of drain tip cultures were eliminated from further consideration. Patients were between 25–94 years of age (average: 65.9 years) and included 232 males (20.8%) and 880 females (79.1%). The primary indications for hip arthroplasty included osteoarthritis (895 cases, 80.5%), idiopathic necrosis of the femoral head (102 cases, 9.2%), and other conditions including rheumatoid arthritis and osteonecrosis (115 cases, 10.3%). There were 105 patients with diabetes, 462 patients with hypertension, and 654 patients with an abnormal body mass index (BMI) above 25 or below 18.5.

All surgical procedures were performed using either a posterior approach or an anterolateral supine approach by one of two surgeons using the same aseptic techniques. Specifically, we used the same asepsis protocol and antibiotic regimen in all cases, as well as the same range of implant types and a standardized drain removal protocol to control for as many variables as possible. The asepsis protocol for these procedures included preoperative scrubbing with iodopovidone (Betadine) and draping. Cefazolin (1.0 g) and Amikacin (200 mg) were administered intravenously 30 min before surgery and then every 12 hours for three days after surgery. Cephalexin (250 mg) was taken orally four times a day for the subsequent seven days.

Surgical sites were cleaned with pulsed lavage both before and after implantation of the prosthesis. The fascia was closed using a standard closure technique. Before closure, the operative site was copiously irrigated with iodopovidone, which was also reapplied to the incision site using a sterile sponge. A catheter with a 3 mm diameter was inserted under the fascia lata at the time of closure to promote drainage and infused with a solution of 10 mL 0.75% anapeine, 10 mL 10% tranexamic acid, and 40 mg gentamicin. Sterile technique was maintained through the insertion and removal of the catheter. The wound was covered using a water- and film-proof dressing with a transparent hydrogel pad. The closed suction drainage system, which was clamped shut during surgery, was opened two hours after surgery to allow for adequate suction and was eventually removed 48 hours after surgery.

After removal, the catheter was cut approximately 2 cm from the tip and submitted to the laboratory for culturing. Catheter samples were submitted in a sterile spitz with saline and then centrifuged for 10 min at 3500 rpm. The supernatant was decanted after centrifugation and the sample was smeared onto chocolate agar (carbon dioxide culture), liquid agar (aerobic culture), blood agar (anaerobic culture), bromothymol blue agar (aerobic culture), and Gifu anaerobic semi-fluid medium. All cultures were incubated at 37°C for 24 hours. Samples with visible bacterial growth were then Gram-stained, and samples without visible growth were cultured for one extra day. Additional biochemical tests to identify specific bacterial species were performed on any culture that produced visible bacterial growth. Samples in which no bacterial growth was observed even after an additional day of culturing were considered negative for infection.

To validate the results from the tip cultures, surgical sites were inspected post-operatively for signs of SSI by a member of the healthcare staff according to guidelines from the Centers for Disease Control (CDC) [8]. The specific CDC criteria used for the diagnosis of SSI included (1) development of symptoms within 30 days after the procedure, (2) evidence for infection extending to the skin or subcutaneous tissue at the incision site, (3) detection of purulent drainage, and (4) liquid or tissue collected aseptically at the incision site that provided documentation of infection by bacterial culture. We improved upon the CDC guidelines by diagnosing an SSI based on (1) the isolation of a bacterial pathogen in conjunction with (2) local pain or tenderness, swelling, redness, heat, and (3) elevated serum levels of C-reactive protein (CRP). In cases where the diagnosis remained unclear, we consulted multiple physicians and reached a collective decision, thereby ensuring the reliability of the diagnosis and decreasing the chance of a misdiagnosis.

Results from all patients in this 15-year study were compiled in Microsoft Excel® spreadsheets and analyzed for evidence that were part of our criteria using keywords including “elevated temperature,” “inflammation,” “swelling,” “CRP,” and “redness.” The language used in the spreadsheet was consistent across all patients and agreed upon by the research team and the inputting physician. We calculated the correlation between positive drain tip cultures and SSI diagnoses using a one-tailed Fisher's exact test with a confidence interval of 95% (i.e., the null hypothesis was rejected if $p < 0.05$). We also calculated the positive predictive value, which measures the effectiveness of a test at predicting a certain condition. In our case, we measured whether drain tip culture can accurately predict an SSI when it occurs. We therefore used the positive predictive value as an indicator for effectiveness, as our goal was to determine the prognostic value of positive drain tip cultures for the diagnosis of SSI.

Results

Of the 1,112 patients who underwent primary hip arthroplasty at our hospital from 2005–2019, twelve patients had positive drain tip cultures (Table 1) and eight patients (0.72%) were suspected to have a postoperative SSI. However, only one SSI case was associated with a positive drain tip culture. Of the seven SSI cases with negative tip culture results, four (0.36%) required washing and surgical debridement. All eight SSI cases were diagnosed as superficial. Based on these results, the sensitivity of drain tip culture for postoperative SSI was 12.5% and the specificity was 99.0%, with a positive predictive value of 8.3% and a negative predictive value of 99.4%. A Fisher’s exact test performed on these data showed that there was no statistically significant correlation between drain tip culture results and the onset of an SSI ($p = 0.0834$).In the single case of suspected SSI with a positive drain tip culture, the drain tip culture was positive for methicillin-resistant *S. epidermidis*. The other 11 patients with false-positive drain tip cultures had no symptoms or indications of SSI, and their drain tip cultures were positive for bacteria that are part of the native skin flora, which may not result in infection. The bacterial strains detected in these false positive drain tip cultures included *Staphylococcus epidermidis* (n = 3), *S. cohnii* (n = 2), and *Escherichia coli* (n = 2; Table 2).

Table 1
Correlation between postoperative SSI and the incidence of positive drain tip cultures from patients who underwent primary hip arthroplasty from 2005 to 2019. The p-value was 0.0834, indicating that there was no statistically significant correlation.

	Number of patients with SSIs*	**Number of patients without SSIs**
Positive cultures	1	11
Negative cultures	7	1093
Total	**8**	**1104**
***All SSIs diagnosed in this patient cohort were superficial in nature.**		

Table 2
Species identified in drain tip cultures from patients who underwent primary hip arthroplasty at our hospital from 2005 to 2019.

Bacteria	**Number of culture-positive drain tips (total n = 12)***
Staphylococcus epidermidis	3
Staphylococcus cohnii	2
Escherichia coli	2
Staphylococcus haemolyticus	1
Acinetobacter lwoffi	1
Methicillin-susceptible S. aureus	1
Enterobacter cloacae	1
Methicillin-resistant S. epidermidis	1
Fungi	1
* One patient returned to 2 bacteria in their culture result.	

In addition to obtaining samples from patients undergoing primary hip arthroplasties, we also performed drain tip cultures in 92 patients who underwent revision hip arthroplasties. Neither of the two patients with positive drain tip cultures were diagnosed with an SSI (Table 3), resulting in a drain tip culture sensitivity of 0.0%, a specificity of 97.8%, a positive predictive value of 0.0%, and a negative predictive value of 96.7%. Overall, there was no statistically significant correlation between the results of drain tip culture and the incidence of SSI in patients that underwent revision hip arthroplasties (One-tailed Fisher's exact test, $p = 0.936$). However, due to the modest sample size, Fisher’s exact test may not provide a decisive conclusion regarding the effectiveness of tip culture for predicting SSI in these patients. The two positive drain tip cultures were positive for *E. coli* and *Burkholderia cepacia*, respectively (Table 4). These false-positive results suggest that detection of these bacteria, which are components of the normal skin flora, may not necessarily indicate infection.

Table 3
Correlation between postoperative SSI and the incidence of positive drain tip cultures who underwent revision hip arthroplasty from 2005 to 2019. The p-value was 0.936, indicating that there was no statistically significant correlation.

	Number of patients with SSIs*	**Number of patients without SSIs**
Positive cultures	0	2
Negative cultures	3	87
Total	**3**	**89**
* One case of SSI after revision arthroplasty was deep in nature.		

Table 4
Bacteria identified in drain tip cultures from patients who underwent revision hip arthroplasty at our hospital from 2005 to 2019.

Isolated Bacteria	**Number of culture-positive drain tips (total n = 2)**
Escherichia coli	1
Burkholderia cepacia	1

Table 5
Statistical evaluation of the use of drain tip cultures to predict SSIs after primary or revision hip arthroplasty data in patients [5–7].

Outcomes	**Primary arthroplasty (N = 1112 patients)**	**Revision arthroplasty (N = 92 patients)**
Sensitivity	12.5%	0.0%
Specificity	99.0%	97.8%
Positive Predictive Value	8.3%	0.0%
Negative Predictive Value	99.4%	96.7%
P-Value	0.0834	0.936

To determine whether preexisting patient factors affected the chance of developing SSI, we also evaluated the incidence of SSI in relation to various patient characteristics including age, gender, hypertension, diabetes, steroid use, and BMI (Table 6). However, none of these factors were statistically significantly correlated with the development of an SSI.

Table 6
Incidence of positive drain tip cultures in relation to patient characteristics and pre-existing conditions. No statistically significant correlations were observed.

		SSI	No-SSI	P-Value
Gender	Male	3	229	0.2223
	Female	5	875	
Age	Above 65	4	588	0.5143
	Under 65	4	473	
Hypertension	Hypertensive	4	458	0.4188
	Non-hypertensive	4	673	
Diabetes	Diabetic	1	104	0.5583
	Non-Diabetic	7	973	
BMI	Normal BMI	4	476	0.4603
	Abnormal BMI	4	650	
Steroid Use	Steroid User	0	21	0.8558
	Non-steroid User	8	1064	

Discussion

There has been much recent debate on the utility of drain tip cultures for predicting and diagnosing postoperative SSIs. Studies published prior to 2004 concluded that drain tip culture results were positively correlated with SSI diagnoses in cases of total hip arthroplasty. However, these studies all had small sample sizes (approximately 100 patients), making the conclusions of these retrospective analyses controversial, as small sample sizes can sometimes lead to fallacious results. In 2009, Petsatodis *et al*. [5] noted that a statistically significant evaluation would require a cohort of no fewer than 1,000 patients. Toward this end, in 2015, Takada *et al*. [6] evaluated the relationship between drain tip cultures and SSIs in 1,380 patients who underwent hip arthroplasty. Interestingly, they found no significant correlation between the results of drain tip culture and the incidence of SSI using diagnostic criteria similar to the criteria we used here.

Our study, which included 1,112 patients who underwent primary hip arthroplasty, agrees with the results of previous studies that do not support using routine drain tip culture after hip replacement to diagnose postoperative infection [5, 6, 9]. The low positive predictive value suggests that the prognostic value of drain tip cultures is minimal, the likelihood of false-negative results is high, and, overall, that this test is not effective for predicting or diagnosing an SSI in postoperative patients.

The false-positive results in the data could be the result of drain tip contamination during the process of drain tip removal, transport, or culturing. Drain tip contamination has not been emphasized in other studies; however, based on the type of bacteria we found and the lack of clinical findings indicative of an infection, we suggest that drain tip contamination is a possible cause of false-positive culture results. Relying on the results of drain tip cultures could therefore lead to the unnecessary use of antibiotics, thus increasing the risk of side effects and the costs of healthcare.

Based on the low prognostic and diagnostic value of drain tip cultures, we recommend that alternate techniques be evaluated for the prediction and diagnosis of SSIs. It is critical to recognize that the total cost of performing the 1,204 drain tip cultures in our study was at a minimum US$3,688, with positive results incurring additional costs. The costs associated with drain tip cultures will increase as the number of people undergoing hip arthroplasty increases, raising additional questions about the feasibility of drain tip culture.

We also evaluated the incidence of SSI with patient age, gender, BMI, and history of hypertension, diabetes, and steroid use. Age, gender, and the tested comorbidities were not statistically significantly correlated with the development of SSI. However, preexisting conditions that we did not assess here may still impact postoperative outcomes. For example, previous geriatric or bariatric surgery may lead to higher incidences of postoperative complications due to the potential degradation of the patients' immune system. Understanding the relationships between patient comorbidities and the incidence of SSI may allow for patient-specific SSI screening procedures to be introduced in the future.

There are limitations associated with all the studies considered here, including the present study. First, all studies were retrospective in nature, although in our case the use of a standard and uniform clinical protocol throughout the study period mitigated potential confounds associated with variation among surgeons or procedures. Second, all SSIs diagnosed in patients undergoing primary hip arthroplasty were superficial in nature, meaning that the infection only involved the skin or subcutaneous tissue and did not extend down to the muscle, fascia, or the organ space. We identified only one case of deep tissue infection in a patient who underwent revision hip arthroplasty. It is therefore unclear from our results whether drain tip cultures were effective at predicting deep tissue or organ/space SSIs. Third, we recognize that it is difficult to compare across studies because of variation in postoperative antibiotic protocols, asepsis techniques, implant types, and surgical approaches.

A fourth limitation is that the timing of drain removal may have an impact on the risk of contamination. For example, we cannot exclude the possibility that drain tip cultures were contaminated by skin flora, which may not result in infection; skin flora contamination is likely to have contributed to findings reported in all similar studies that have been published to date [10, 11]. The length of time that the drain remains in the operative site could also affect the likelihood of developing an SSI and the risk of skin flora contamination of the drain tip culture [12]. It is therefore important to standardize the time at which the drain is removed.

Other problems include the lack of universal guidelines for the diagnosis and prevention of SSIs and the additional expense of drain tip cultures, which may act as a barrier to their clinical use [13]. In addition, given the low incidence of SSI associated with hip arthroplasty procedures, an ideal study would include a substantially larger patient cohort in which a significant number of patients tested positive for SSI. A larger study would provide a more definitive conclusion about the prognostic and diagnostic value of drain tip cultures. Because drain tip cultures are also routinely used in spinal procedures and knee arthroplasty, continuing to evaluate the effectiveness of drain tip cultures is important for the broader field of orthopedic surgery.

Given the present studies and the general lack of statistical support for the routine use of drain tip cultures, other diagnostic tools should be explored as potential alternatives. Such tools may include screening for hematoma, as previous studies have observed a correlation between the incidence of hematoma and SSIs, or diagnostic tools such as physical examination [14].

Conclusions

In our data from the primary and revision hip arthroplasties performed at our hospital from 2005–2019, we found no correlation between drain tip culture results and the incidence of postoperative SSI. Furthermore, the low positive predictive value of drain tip cultures also suggests a correspondingly low efficacy for the diagnosis of SSI. Based on these results, drain tip cultures should not be routinely used as a primary tool for the prediction and diagnosis of SSIs. The costs incurred with positive cultures, coupled with the high rates of false-positive results, further decreases the clinical utility of this modality. In the cases in which the drain tip culture came back positive, most of the detected bacterial species were normal flora, which may not have resulted in infection. Our results, as well as those from other studies, indicate that other diagnostic tools should be explored as alternatives to drain tip cultures.

Abbreviations

SSI – Surgical Site Infection

THA – Total Hip Arthroplasty

BHA – Bipolar Hip Arthroplasty

CDC – Centers for Disease Control

BMI – Body Mass Index

E.Coli – Escherichia coli

S. epidermidis. - Staphylococcus epidermidis

CRP – C-reactive Protein

RPM – Rotations per minute

g - grams

mg - milligrams

min - minutes

mm - millimeter

mL - milliliters

Declarations

ACKNOWLEDGMENTS

The authors would like to thank Medical Journal Editors (MJE) and Wiley Editing Services for assistance with the editing of our manuscript. This assistance was funded privately by the authors.

DATA AVAILABILITY

The datasets generated and/or analysed during the current study are not publicly available due to confidential patient information but an anonymized version can be made available from the corresponding author on reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest with respect to the work presented herein.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

AUTHORSHIP

All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

AUTHOR CONTRIBUTION

Akira Toga: contributed to the design and implementation of the research, to the analysis of the results, to the presentation of the results, and to the writing of the manuscript.

Ayush Balaji: contributed to the design and implementation of the research, to the analysis of the results, to the presentation of the results, and to the writing of the manuscript.

Osamu Hemmi: contributed to the acquisition of the data, discussed the results, and commented on the manuscript.

Ken Ishii: discussed the results and commented on the manuscript.

Shigeyuki Tokunaga: discussed the results and commented on the manuscript.

Shojiro Katoh: discussed the results and commented on the manuscript.

Ryoichi Izumida: conceived of the presented idea, discussed the results, and commented on the manuscript.

COMPLIANCE WITH ETHICS GUIDELINES

This study was approved by the review board at our hospital and was performed in accordance with the Helsinki Declaration. All study participants provided informed consent for study and publication prior to being enrolled in the study.

References

1. Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. The Journal of Bone Joint Surgery British volume. 2005;87-B:844–50.
2. Wilson J, Charlett A, Leong G, McDougall C, Duckworth G. Rates of Surgical Site Infection After Hip Replacement as a Hospital Performance Indicator: Analysis of Data From the English Mandatory Surveillance System. Infection Control Hospital Epidemiology. 2008;29:219–26.
3. López-Contreras J, Limón E, Matas L, Olona M, Sallés M, Pujol M. Epidemiology of surgical site infections after total hip and knee joint replacement during 2007–2009: a report from the VINCat Program. Enfermedades Infecciosas y Microbiología Clínica. 2012;30:26–32.
4. Yamada T, Yoshii T, Egawa S, Takada R, Hirai T, Inose H, et al. Drain Tip Culture is Not Prognostic for Surgical Site Infection in Spinal Surgery Under Prophylactic Use of Antibiotics. Spine [Internet]. 2016;41:1179–84. [cited 2021 Jul 1 ;:. Available from:.
5. Petsatodis G, Parziali M, Christodoulou AG, Hatzokos I, Chalidis BE. Prognostic value of suction drain tip culture in determining joint infection in primary and non-infected revision total hip arthroplasty: a prospective comparative study and review of the literature. Arch Orthop Trauma Surg. 2009;129:1645–9.
6. Takada R, Jinno T, Koga D, Hirao M, Muneta T, Okawa A. Is Drain Tip Culture Prognostic of Surgical Site Infection? Results of 1380 Drain Tip Cultures in Total Hip Arthroplasty. The Journal of Arthroplasty [Internet]. 2015 [cited 2021 Jul 1];30:1407–9. Available from: https://pubmed.ncbi.nlm.nih.gov/25770862/.

7. Overgaard S, Thomsen NO, Kulinski B, Mossing NB. Closed suction drainage after hip arthroplasty. Prospective study of bacterial contamination in 81 cases. Acta Orthopaedica Scandinavica [Internet]. 1993 [cited 2021 Jul 1];64:417–20. Available from: https://pubmed.ncbi.nlm.nih.gov/8213118/.
8. Berríos-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surgery [Internet]. 2017;152:784. Available from: https://jamanetwork.com/journals/jamasurgery/fullarticle/2623725.
9. Weinrauch P. Diagnostic value of routine drain tip culture in primary joint arthroplasty. ANZ journal of surgery [Internet]. 2005 [cited 2021 Jul 1];75:887–8. Available from: https://pubmed.ncbi.nlm.nih.gov/16176233/.
10. Willett KM, Simmons CD, Bentley G. The effect of suction drains after total hip replacement. The Journal of Bone and Joint Surgery British Volume [Internet]. 1988 [cited 2021 Jul 1];70:607–10. Available from: https://pubmed.ncbi.nlm.nih.gov/3403607/.
11. Sørensen AI, Sørensen TS. Bacterial growth on suction drain tips. Prospective study of 489 clean orthopedic operations. Acta Orthopaedica Scandinavica [Internet]. 1991 [cited 2021 Jul 1];62:451–4. Available from: https://pubmed.ncbi.nlm.nih.gov/1950489/.
12. Girvent R, Marti D, Muñoz JM. The clinical significance of suction drainage cultures. Acta Orthopaedica Belgica [Internet]. 1994 [cited 2021 Jul 1];60:290–2. Available from: https://pubmed.ncbi.nlm.nih.gov/7992605/.
13. Sankar B, Ray P, Rai J. Suction drain tip culture in orthopaedic surgery: a prospective study of 214 clean operations. International Orthopaedics [Internet]. 2004 [cited 2021 Jul 1];28:311–4. Available from: https://pubmed.ncbi.nlm.nih.gov/15316674/.
14. Saleh K, Olson M, Resig S, Bershadsky B, Kuskowski M, Gioe T, et al. Predictors of wound infection in hip and knee joint replacement: results from a 20 year surveillance program. Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society [Internet]. 2002 [cited 2021 Jul 1];20:506–15. Available from: https://pubmed.ncbi.nlm.nih.gov/12038624/.