Infection Control & Hospital Epidemiology (2023), **44**, 631–637
doi:10.1017/ice.2022.112

SHEA

Original Article

The utility of routine autologous bone-flap swab cultures in predicting post-cranioplasty infection

Tuan Hoang MD[1], Nick Daneman MD[1,2], Jerome A. Leis MD[1,2], Eric A. Coomes MD[1], Marion Elligsen BScPhm[3], Connie Colavecchia MLT[4], Alison Halliday MLT[4], Yulia Lin MD[4,5], Leodante da Costa MD[6] and Philip W. Lam MD[1,2]

[1]Department of Medicine, University of Toronto, Toronto, Ontario, Canada, [2]Division of Infectious Diseases, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada, [3]Department of Pharmacy, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada, [4]Transfusion Medicine & Tissue Bank, Sunnybrook Health Sciences Centre, Toronto, Ontario Canada, [5]Division of Hematology, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada and [6]Division of Neurosurgery, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

Abstract

Objective: To evaluate the utility of autologous bone-flap swab cultures performed at the time of cranioplasty in predicting postcranioplasty surgical site infection (SSI).

Design: Retrospective cohort study.

Participants: Patients undergoing craniectomy (with bone-flap storage in tissue bank), followed by delayed autologous bone-flap replacement cranioplasty between January 1, 2010, and November 30, 2020.

Setting: Tertiary-care academic hospital.

Methods: We framed the bone-flap swab culture taken at the time of cranioplasty as a diagnostic test for predicting postcranioplasty SSI. We calculated, sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios.

Results: Among 282 unique eligible cases, 16 (5.6%) developed SSI after cranioplasty. A high percentage of bone-flap swab cultures were positive at the time of craniectomy (66.7%) and cranioplasty (59.5%). Most organisms from bone-flap swab cultures were *Cutibacterium acnes* or coagulase-negative staphylococci (76%–85%), and most SSI pathogens were methicillin-susceptible *Staphylococcus aureus* (38%). Bone-flap swab culture had poor sensitivity (0.07; 95% CI, 0.01–0.31), specificity (0.4; 95% CI, 0.34–0.45), and positive likelihood ratio (0.12) for predicting postcranioplasty SSI.

Conclusion: Overall, autologous bone-flap swab cultures performed at the time of cranioplasty have poor utility in predicting postcranioplasty SSI. Eliminating this low-value practice would result in significant workload reductions and associated healthcare costs.

(Received 7 February 2022; accepted 6 April 2022; electronically published 5 May 2022)

Cranioplasty procedures are carried out to repair a skull vault defect by implanting an autologous bone-flap or custom synthetic prosthesis.[1] The procedure provides protection of the underlying brain and restores the brain dynamics within a closed cavity. Consequently, cranioplasty helps avoid recurrence of brain damage, protects the patient from possible repeated brain injury, and improves brain energy metabolism.[1]

Autologous bone flaps (ABFs) provide not only a cosmetic but also cost-effective solution for cranioplasty.[2] In addition, ABFs decrease the risk of excessive immune response to foreign materials.[3] Surgical site infection (SSI) rates following cranioplasty with ABF have ranged from 6% to as high as 26%.[2,4–17] A systematic review by Yalda et al[15] showed that the SSI risk is comparable between autologous bone flap and synthetic materials.

Intraoperative routine bone-flap cultures have been used in many neurosurgical centers to screen for microbial contamination before cryopreservation or reimplantation.[4,16,18,19] A survey of practice in major Australian neurosurgical centers showed that 68% of hospitals obtained bone-flap biopsy or swabs for microcontamination studies.[20] Some studies over the last decade have questioned the utility of bone-flap swabs in predicting and preventing postcranioplasty infection with autologous bone flap.[13,16,18,20] Misinterpretation of a bone-flap culture result may lead to unnecessary use of antibiotics, discarding bone flaps, and increased use of synthetic prostheses.

Routine bone-flap swab sampling continues to occur at some large neurosurgical centers, including our own. We are unaware of prior studies that have systematically evaluated the utility

Author for correspondence: Philip W. Lam, E-mail: philip.lam@sunnybrook.ca
Cite this article: Hoang T, *et al.* (2023). The utility of routine autologous bone-flap swab cultures in predicting post-cranioplasty infection. *Infection Control & Hospital Epidemiology*, 44: 631–637, https://doi.org/10.1017/ice.2022.112

of bone-flap swab culture in a clinically meaningful fashion.[4,13,16,18] In this study, we evaluated the utility of autologous bone-flap swab taken at the time of cranioplasty in predicting postcranioplasty SSI by framing the swab culture as a diagnostic test. In addition, we evaluated the utility of bone-flap swabs taken at the time of craniectomy in predicting postcraniectomy SSI. Finally, we examined the concordance between craniectomy and cranioplasty bone-flap cultures.

Methods

Study setting and procedures

Sunnybrook Health Sciences Centre is a 678-bed, academic health sciences center in Toronto, Ontario, Canada. It has been long-standing practice at our institution to obtain routine bone-flap swab cultures following craniectomy and before cranioplasty procedures. For craniectomy procedures, aerobic and anaerobic swabs taken from the explanted bone flap are sent to the microbiology laboratory for bacterial culture. When coagulase-negative staphylococci are isolated from culture, the specific organism is not reported unless it is *Staphylococcus lugdunensis*. The bone flap is labelled, packaged, and sent to the tissue bank for storage. Upon arrival at the tissue bank, the bone flap is accessioned and stored in a freezer at −80°C. The neurosurgeon is informed of any positive bone-flap culture results, and the decision to discard the bone flap is left to their discretion. At the time of autologous bone-flap cranioplasty, the bone flap is retrieved from the tissue bank. Aerobic and anaerobic swabs are taken before the bone flap is soaked in povidone-iodine 10% solution for a minimum of 15 minutes prior to reimplantation. Intravenous cefazolin is the antibiotic of choice as surgical prophylaxis in craniectomy and cranioplasty procedures.

Study design

We conducted a single-center retrospective cohort study of all patients undergoing craniectomy (with bone-flap storage in the tissue bank), followed by delayed autologous bone-flap replacement cranioplasty between January 1, 2010, and November 30, 2020. Patients were excluded from the study if there was evidence of pre-existing bone-flap infection at the time of initial craniectomy or bone-flap replacement cranioplasty, if they had neither swab taken for craniectomy nor cranioplasty procedures, or if they were lost to clinical follow-up after cranioplasty.

Data collection

A list of patients meeting the inclusion criteria were identified through an institutional surgical database. Additional information for each patient was collected through manual chart review: prior cranioplasty infection, diabetes, immunocompromised status, indication for craniectomy, duration of hospital stay prior to cranioplasty, time between craniectomy and cranioplasty procedures, the use of adjunctive synthetic materials for cranioplasty, and cranioplasty complications (shunt placement intraoperatively, postcranioplasty shunt placement due to hydrocephalus, postoperative seizure, postoperative hematoma requiring evacuation). Antibiotic use after cranioplasty in response to positive bone-flap culture results, and involvement of infectious diseases consultation were also recorded.

To assess for possible selection bias (ie, whether bone flaps were being discarded due to positive culture results), all bone flaps received by the tissue bank were reviewed during the same period, and all discarded bone flaps were reviewed to determine the reason for doing so.

Variables of interest and statistical analysis

The bone-flap culture result was the primary exposure variable. The outcome variable of interest was postcranioplasty SSI.[21] Assessment for SSI via chart review was performed for all patients from their index procedure up until August 31, 2021. Each patient would therefore have at least 9 months of follow-up time. We chose a longer follow-up time for SSI than that used by the CDC National Healthcare Safety Network (NHSN) definition[21] to better detect delayed-onset infections caused by indolent organisms (eg, coagulase-negative staphylococci and *C. acnes*). The other criteria for determining SSI otherwise followed NHSN criteria.[21] The organisms isolated from bone-flap cultures and surgical site infection operative sampling were also recorded.

The utility of a bone-flap culture in predicting SSI was determined by framing the bone-flap culture result as a diagnostic test. When calculating the operating characteristics, we considered 2 scenarios: (1) a "true positive" defined as a positive bone-flap culture and presence of SSI regardless of the organisms isolated, and (2) a "true positive" defined as positive bone-flap culture and presence of SSI in which the same organism was isolated. A 2 × 2 contingency table was constructed, and the following test characteristics were calculated using the totals in each quadrant: sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio, and negative likelihood ratio. Each bone-flap culture result paired with the corresponding surgical site infection outcome served as the unit of analysis. If no cranioplasty bone-flap culture was available, the corresponding craniectomy bone-flap culture was used as a surrogate. Similar analyses were applied to evaluate craniectomy bone-flap culture in predicting postcraniectomy SSI. All statistical analyses were performed using Microsoft Excel software (Microsoft, Redmond, WA) and R statistical software (R Foundation for Statistical Computing, Vienna, Austria). This study received approval from our institutional research ethics board.

Results

In total, 282 patients met the inclusion criteria for the study, of which 16 cases of postcranioplasty SSI were identified, which resulted in the postcranioplasty SSI rate of 5.6% (Fig. 1). Patient characteristics stratified by presence of SSI are summarized in Table 1. Patient and operative factors were similar between the 2 groups.

Cranioplasty bone-flap swab cultures and SSI pathogens

Most craniectomy (66.7%) and cranioplasty (59.5%) bone-flap swabs were culture positive, and these proportions were similar between patients who did and did not develop SSI (Table 2). Analysis of the organisms isolated from bone-flap cultures showed that ∼15% of positive cultures were polymicrobial. Among the positive cultures, *Cutibacterium acnes* and coagulase-negative staphylococci (CoNS) were the predominant organisms; they appeared in >75% of positive cultures in both craniectomy and cranioplasty bone-flap swabs.

Comparison of organisms isolated from bone-flap cultures and subsequent SSI specimens from the same patient demonstrated

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press

Table 1. Characteristics of Patients Undergoing Cranioplasty, Including Those With and Without Surgical Site Infection

Characteristic	No Surgical Site Infection (N = 266)	Surgical Site Infection (N = 16)	*P* Value
Age, median y [IQR]	47.0 [31.0–57.0]	42.5 [26.8–49.0]	.21
Sex, no. (%)			.71
Female	96 (36.1)	7 (43.8)	
Male	170 (63.9)	9 (56.2)	
Diabetes, no. (%)	12 (4.5)	1 (6.2)	1.00
Immunocompromised, no. (%)	17 (6.4)	2 (12.5)	.62
Indication for craniectomy, no.			.98
Aneurysm	9 (3.4)	1 (6.2)	
Astrocytoma	1 (0.4)	0 (0.0)	
Intracerebral hemorrhage	30 (11.2)	2 (12.4)	
Intracranial abscess	1 (0.4)	0 (0.0)	
Meningioma	4 (1.5)	0 (0.0)	
Subarachnoid hemorrhage	8 (3.0)	1 (6.2)	
Subdural hematoma	9 (3.4)	0 (0.0)	
Stroke	36 (13.5)	2 (12.5)	
Trauma	168 (63.2)	10 (62.5)	
Previous SSI	0	0	
Synthetic materials included, no. (%)	49 (18.4)	4 (25)	.75
Interval between craniectomy and cranioplasty, median d [IQR]	136.5 [66.3–204.8]	105 [70–175.8]	.36
Duration of hospitalization prior to cranioplasty, median d [IQR]	0 [0–6.75]	0 [0–22]	.60
Cranioplasty complications, no.			.73
Hematoma requiring evacuation	5 (1.9)	0 (0.0)	
Seizure	11 (4.1)	0 (0.0)	
Shunt placement due to hydrocephalus	4 (1.5)	0 (0.0)	
Positive craniectomy bone-flap swab culture, no./total (%)	172/260 (66.2)[a]	12/16 (75)	.61
Positive cranioplasty bone-flap swab culture, no./total (%)	149/255 (58.4)[b]	11/14 (78.6)[c]	.22
Infectious disease consultation (%)	45 (16.9)	16 (100.0)	<.001

Note. IQR, interquartile range; SSI, surgical site infection.
[a]In 6 cases, a bone-flap swab was not collected during craniectomy.
[b]In 11 cases, a bone-flap swab was not collected during cranioplasty.
[c]In 2 cases, a bone-flap swab was not collected during cranioplasty.

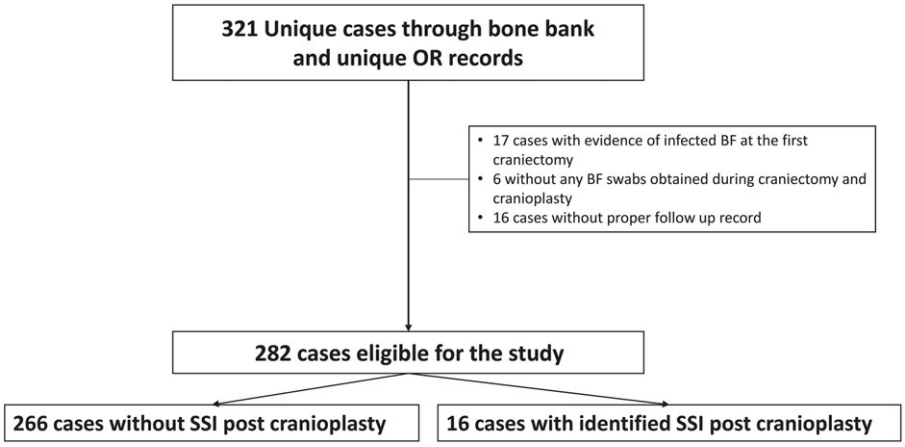

Fig. 1. Flow chart describing information obtained in the study population. Note. BF, bone flap; OR, operating room; SSI, surgical site infection

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press

Table 2. Microorganisms of Bone-Flap Swab Cultures at the Time of Craniectomies and Cranioplasties

Organisms from Bone-Flap Swab Cultures at Time of Craniectomy	Frequency, No. (%)	Organisms from Bone-Flap Swab Cultures at Time of Cranioplasty	Frequency, No. (%)
Craniectomy culture (N = 276)[a]		**Cranioplasty culture (N = 269)[b]**	
Negative	92 (33.3)	Negative	109 (40.5)
Positive	184 (66.7)	Positive	160 (59.5)
Polymicrobial	28 (15.2)	Polymicrobial	17 (17.5)
C. acnes	126 (59.4)	*C. acnes*	95 (52.4)
CoNS	54 (25.5)	CoNS	43 (23.8)
E. faecalis	5 (2.4)	*Aerobic spore forming bacilli*	10 (5.5)
Aerobic spore forming bacilli	4 (1.9)	*MSSA*	5 (2.8)
Diphtheroid bacilli	4 (1.9)	*Diphtheroid bacilli*	4 (2.2)
B. cereus	2 (0.9)	Viridans group streptococci	3 (1.7)
Corynebacterium	2 (0.9)	*B. cereus*	2 (1.1)
E. cloacae	2 (0.9)	*E. faecalis*	2 (1.1)
P. granulosum	2 (0.9)	*Microbacterium spp*	2 (1.1)
S. mitis	2 (0.9)	*Peptostreptococcus asaccharolyticus*	2 (1.1)
P. mirabilis	1 (0.5)	*Candida parapsilosis*	1 (0.6)
Acinetobacter spp	1 (0.5)	*C. sporogenes*	1 (0.6)
Anaerococcus octavius	1 (0.5)	*Corynebacterium*	1 (0.6)
Penicillium species	1 (0.5)	*E. coli*	1 (0.6)
Roseomonas gilardii	1 (0.5)	*K. Pneumoniae*	1 (0.6)
S. capitis	1 (0.5)	*M. saccharophilum*	1 (0.6)
S. anginosus	1 (0.5)	*Micrococcus luteus*	1 (0.6)
S. salivarius	1 (0.5)	*P. granulosum*	1 (0.6)
Viridans group streptococci	1 (0.5)	*S. epidermidis*	1 (0.6)
		S. lugdunensis	1 (0.6)
		S. marcescens	1 (0.6)
		S. saccharolyticus	1 (0.6)
		S. sanguinis	1 (0.6)

Note. CoNS, coagulase-negative *Staphylococcus* (non–*S. lugdunensis*); MSSA, methicillin-susceptible *Staphylococcus aureus*.
[a]In 6 cases, a bone-flap swab was not collected during craniectomy.
[b]In 13 cases, a bone-flap swab was not collected during cranioplasty.

poor concordance (Table 3). Although most organisms from bone-flap cultures were *C. acnes* and CoNS, most SSI pathogens were *Staphylococcus aureus* (6 of 16, 38%) (Table 3). We excluded from the organism-specific analysis 2 postcranioplasty SSIs in which no definitive pathogen was identified. Among the 14 postcranioplasty SSIs with a definitive pathogen identified, only 1 case had an exact microorganism match to the bone-flap culture (Table 3).

Utility of bone-flap swab cultures at the time of cranioplasty in predicting postcranioplasty SSI

A 2×2 contingency table was created to calculate the utility of bone-flap swab cultures in predicting postcranioplasty SSI (Table 4). When considering a "true positive" as positive bone-flap culture and presence of SSI in which the same organism was isolated, the sensitivity was 0.07 (95% CI, 0.01–0.31) and the specificity was 0.40 (95% CI, 0.34–0.45). The PPV was 0.006 (95% CI, 0.001–0.03) and the NPV was 0.89 (95% CI, 0.82–0.93). Accordingly, the positive and negative likelihood ratios were 0.12 and 2.32.

When considering a "true positive" as a positive bone-flap culture and the presence of SSI regardless of the organisms isolated, the sensitivity of the test was 0.86 (95% CI, 0.6–0.96), whereas the specificity remained unchanged at 0.40, (95% CI, 0.34–0.45). The PPV and NPV were 0.07 (95% CI, 0.04–0.12) and 0.98 (95% CI, 0.92–0.99), respectively. The positive likelihood ratio of postcranioplasty SSI using bone-flap culture as a diagnostic test was 1.43, and the negative likelihood ratio was 0.35.

Utility of bone-flap swab culture at time of craniectomy in predicting postcraniectomy SSI

A similar analysis was carried out for post-craniectomy SSI, using craniectomy bone-flap culture as a diagnostic test (Table 4). When considering identical bone-flap culture and SSI pathogens, the sensitivity of bone-flap culture was 0.07 (95% CI, 0.01–0.30) and

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press

Table 3. Comparative Organisms of Craniectomy and Cranioplasty Bone-Flap Swab Cultures Versus Post-cranioplasty SSI

Case	Craniectomy BF Culture	Cranioplasty BF Culture	SSI Pathogen(s)	SSI Depth[a]
1	CoNS, *C. acnes*	. . .	MSSA	Organ-space
2	Negative	*C. acnes*	CoNS, *Corynebacterium, C. albicans*	Organ-space
3	*C. acnes*	*C. acnes*	MSSA	Organ-space
4	*C. acnes*	Negative	CoNS	Superficial
5	CoNS	. . .	CoNS	Organ-space
6	*C. acnes*	CoNS	*K. pneumoniae,* diphtheroid bacilli	Organ-space
7	*C. acnes*	Negative	MSSA	Organ-space
8	*C. acnes*	*C. acnes*	*E. aerogenes*	Organ-space
9	*C. acnes*	*C. acnes*	MSSA	Organ-space
10	Negative	MSSA	MSSA, *P. aeruginosa*	Organ-space
11	*CoNS, E. faecalis*	CoNS	CoNS, *E. faecalis,* diphtheroid bacilli, yeast	Superficial
12	Negative	Negative	. . .	Organ-space
13	CoNS	CoNS	*P. aeruginosa*	Organ-space
14	CoNS	viridans group streptococci, aerobic spore-forming bacilli	MSSA, *E. cloacae*	Organ-space
15	*C. acnes*	Diphtheroid bacilli	*P. mirabilis*	Organ-space
16	Negative	*C. acnes*	. . .	Superficial

Note. CoNS, coagulase-negative *Staphylococcus* (non–*S. lugdunensis*); MSSA, methicillin-susceptible *Staphylococcus aureus*.
[a]SSI depth was classified according to NHSN criteria.[21]

Table 4. Utility of Bone-Flap Swab Cultures in Predicting Postcranioplasty and Postcraniectomy SSIs

Scenario	True Positive	True Negative	False Positive	False Negative	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	+LR	−LR
Cranioplasty bone-flap swab cultures predicting postcranioplasty SSI										
Exact organism match between bone flap and SSI culture	1	106	160	13	0.07 (0.01–0.31)	0.40 (0.34–0.45)	0.006 (0.001–0.03)	0.89 (0.82–0.93)	0.12	2.32
Any positive bone flap and SSI culture	12	106	160	2	0.86 (0.6–0.96)	0.40 (0.34–0.45)	0.07 (0.04–0.12)	0.98 (0.93–0.99)	1.43	0.35
Craniectomy bone-flap swab cultures predicting postcraniectomy SSI										
Exact organism match between bone flap and SSI culture	1	86	179	14	0.07 (0.01–0.30)	0.32 (0.27–0.38)	0.005 (0.001–0.03)	0.86 (0.78–0.91)	0.10	2.91
Any positive bone flap and SSI culture	9	86	179	6	0.6 (0.36–0.80)	0.32 (0.27–0.38)	0.05 (0.03–0.09)	0.93 (0.86–0.97)	0.88	1.25

Note. CI, confidence interval; LR, likelihood ratio; PPV, positive predictive value; NPV, negative predictive value.

specificity of the test was 0.32 (95% CI, 0.27–0.38). The PPV and NPV were 0.005 (95% CI, 0.001–0.03) and 0.86 (95% CI, 0.78–0.91), respectively. The positive likelihood ratio of postcraniectomy SSI using bone-flap culture as a diagnostic test was 0.10; the negative likelihood ratio was 2.91.

Organism concordance between positive craniectomy and cranioplasty bone-flap cultures

Among 263 patients with matched craniectomy and cranioplasty bone-flap swab, there were only 88 cases (33%) with an exact culture match between craniectomy and cranioplasty bone-flap swabs. 47 (53.4%) of matched cultures between cranioplasty and craniectomy bone flap were negative. The only matched organisms between craniectomy and cranioplasty bone-flap cultures were *C. acnes* and CoNS (42% and 4.5% of matched cranioplasty and craniectomy bone-flap cultures, respectively).

Impact of positive bone-flap swab culture on antibiotic use, infectious disease consultation, and decision to discard

All 16 patients with postcranioplasty SSIs received a consultation by the infectious disease service and were treated with prolonged antibiotics (at least 3 weeks with a maximum of 6 weeks) (Supplementary Table S1 online). All antibiotics were targeted towards the SSI pathogens and not organisms isolated from the bone-flap swab culture taken before SSI onset. All patients achieved clinical cure of infection. There were 2 cases where

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press

patients were treated with empirical antibiotics based solely on positive bone-flap cultures at the time of cranioplasty. In both cases, bone-flap cultures grew *C. acnes*. No other cases of positive bone-flap cultures, in the absence of signs of infection, were prescribed antibiotics postoperatively.

Management of bone flaps in tissue bank

During the 10-year review period, there were 173 bone flaps discarded from the bone bank. Most discarded bone flaps (155 of 173, 90%) were due to patient death, infected flaps at the time of craniectomy, extensive craniodefect, or storage beyond 2 years from index craniectomy. Also, 8 bone flaps (4.6%) were discarded due to positive bone-flap swab taken at the time of craniectomy. Furthermore, 5 of these bone-flap cultures grew *C. acnes*, whereas the remainder grew CoNS. These patients eventually underwent cranioplasty with synthetic materials.

Discussion

Routine bone-flap swabs taken during craniectomy and cranioplasty exhibited poor diagnostic test characteristics when used to predict postneurosurgical SSI. This finding persisted even with a more lenient definition of a "true positive" result, in which growth of any organism was used. Most bone-flap cultures were positive, and most grew commensal skin flora such as *C. acnes* and CoNS; the most common SSI pathogen was *Staphylococcus aureus*. Moreover, craniectomy and cranioplasty bone-flap cultures obtained from the same patient demonstrated poor organism concordance, despite minimal handling between the two procedures. We suspect that the organisms isolated from routine bone-flap swabs represent contamination or colonization, which are eradicated after soaking with povidone-iodine solution prior to reimplantation.

Our study adds to the growing literature questioning the utility of routine bone-flap swabs.[4,5,13,16,18] The overall postcranioplasty SSI rate with autologous bone flap was 5.6%, which is on the lower end of the reported SSI rates in the literature (5%–26%).[2,4–17] In a small prospective study (with 84 cranioplasties, 52 with ABF and 32 with polymethymethacrylate) in 2008, Cheng et al[4] showed that there was no significant association between swab-culture results and postcranioplasty infection status. Similar results were observed in a larger prospective cohort study (with 372 bone flaps) by Chiang et al[18] in 2011. These researchers showed that 50% of intraoperative bone-flap cultures were positive, with mainly skin flora including *C. acnes* and CoNS.[18] Electrophoresis analysis of *C. acnes* isolated from these bone-flap swabs showed multiple genotypes, suggesting contamination derived mainly from patients.[18] Again, there was no association between positive bone-flap culture and SSI, and reimplanting bone flaps with positive cultures did not increase the risk of SSI after cranioplasty ($P = .80$).[18] A large retrospective study (with 754 cranioplasties) in 2016 by Morton et al[13] at Harborview Medical Center (Seattle, WA) also showed no significant difference in the postcranioplasty infection rates among sterile ABF (7%) and positive ABF (8%).[13] The limitations of prior studies include possibility of selection bias (eg, bone flaps may have been discarded due to a positive result). Moreover, none of the prior studies examined antibiotic use after cranioplasty in response to positive bone-flap cultures.

Our study is among the first to formally examine the diagnostic utility of bone-flap cultures in predicting postcranioplasty SSI.[16] Recently, Yeap et al[16] reported a similar poor predictive value of swab cultures. Their study, however, reported a much lower rate of positive bone-flap cultures (6%–7%), contradicting previous studies.[16] This difference may be related to variations in bone-flap handling, swab technique, and microbiological culturing methods. Moreover, almost half of cranioplasties examined in their cohort did not have bone-flap cultures, which may have introduced an element of selection bias.[16] The strengths of our study include the consistency of bone-flap swabs being performed in all patients, with only 2% of procedures where swabs were not done. More importantly, our study accounted for potential selection bias by assessing reasons that bone flaps were discarded from the tissue bank. Very few bone flaps were discarded due to a positive bone-flap culture result, and of those that were discarded, the organisms were not significantly different than those identified for bone flaps that were reimplanted. We also examined antibiotic use after cranioplasty and found a low incidence of use in the absence of infection. This finding, combined with a low SSI incidence even in the presence of positive bone-flap cultures, supports the position that antibiotics are not indicated unless there are clear signs or symptoms concerning for infection. Furthermore, the prolonged timeframe for SSI follow-up in our study allowed for detection of indolent infections that may have presented with delayed onset of symptoms. Finally, our study included a sensitivity analysis to assess the utility of bone-flap swabs not only in predicting SSI from the same pathogen but also from any other pathogen as well.

Relying on bone-flap culture results may lead to unnecessary antibiotic use and discarding of autologous bone flaps, which can lead to increased patient harm and system costs. Discontinuation of this practice would result in reduced workload in the operating room, tissue bank, and for microbiology laboratory staff, as well as reduced associated healthcare costs and improved patient quality of care. Based on our findings, removal of this culture information would have minimal impact on the management of postneurosurgical infections because these infections are generally treated with prompt broad-spectrum antimicrobial therapy. Of the 16 postcranioplasty SSI cases identified in this cohort, antimicrobial therapy directed against the pathogens causing SSI (rather than the organisms isolated from bone-flap swabs) resulted in cure, which further supports the idea that the organisms isolated from routine swabbing of bone flaps are inconsequential.

Our study had several limitations. This was a single-center, retrospective study, and these findings may not be applicable to centers where antiseptic bone-flap handling practices differ, although our findings have been congruent with previously published studies on this topic. Secondly, some patients may have presented to a different institution with a surgical site infection, which would not have been captured through this chart review. This was likely infrequent because patients are closely followed by their neurosurgeon at our hospital for any complications that occur. Finally, this study was underpowered to allow for subgroup analyses, but it is biologically plausible that patient or operative factors could change the test characteristics of a bone-flap culture result.

Overall, this study suggests that routine autologous bone-flap cultures do not predict postcranioplasty SSI, given their poor concordance between bone-flap swab organism and SSI pathogen. Eliminating this low-value practice could result in significant workload reductions and associated healthcare costs.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2022.112

Acknowledgments.

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press

Financial support. No financial support was provided relevant to this article.

Conflicts of interest. J.A.L. has received financial support from Choosing Wisely Canada for the Using Antibiotics Wisely campaign. All other authors report no conflicts of interest.

References

1. Aydin S, Kucukyuruk B, Abuzayed B, Aydin S, Sanus GZ. Cranioplasty: review of materials and techniques. *J Neurosci Rural Pract* 2011;2: 162–167.
2. Prolo DJ, Burres KP, McLaughlin WT, Christensen AH. Autogenous skull cranioplasty. *Neurosurgery* 1979;4:18–29.
3. Meyer H, Khalid SI, Dorafshar AH, Byrne RW. The materials utilized in cranial reconstruction: past, current, and future. *Plast Surg* 2021;29: 184–196.
4. Cheng Y-K, Weng H-H, Yang J-T, Lee M-H, Wang T-C, Chang C-N. Factors affecting graft infection after cranioplasty. *J Clin Neurosci* 2008; 15:1115–1119.
5. Chen Y, Zhang L, Qin T, Wang Z, Li Y, Gu B. Evaluation of neurosurgical implant infection rates and associated pathogens: evidence from 1118 postoperative infections. *Neurosurg. Focus* 2019;47:E6.
6. Huang Y-H, Yang T-M, Lee T-C, Chen W-F, Yang K-Y. Acute autologous bone flap infection after cranioplasty for postinjury decompressive craniectomy. *Injury* 2013;44:44–47.
7. Inamasu J, Kuramae T, Nakatsukasa M. Does difference in the storage method of bone flaps after decompressive craniectomy affect the incidence of surgical site infection after cranioplasty? Comparison between subcutaneous pocket and cryopreservation. *J Trauma Inj Infect Crit Care* 2010; 68:183–187.
8. Iwama T, Yamada J, Imai S, Shinoda J, Funakoshi T, Sakai N. The use of frozen autogenous bone flaps in delayed cranioplasty revisited. *Neurosurgery* 2003;52:591–596.
9. Jin S, Kim S-D, Ha S-K, Lim D-J, Lee H, You H-J. Analysis of the factors affecting surgical site infection and bone flap resorption after cranioplasty with autologous cryopreserved bone: the importance of temporalis muscle preservation. *Turk Neurosurg* 2018;28:882–888.
10. Liang ES, Tipper G, Hunt L, Gan PYC. Cranioplasty outcomes and associated complications: a single-centre observational study. *Br J Neurosurg* 2016;30:122–127.
11. Matsuno A, Tanaka H, Iwamuro H, *et al.* Analyses of the factors influencing bone graft infection after delayed cranioplasty. *Acta Neurochir (Wien)* 2006;148:535–540.
12. Moreira-Gonzalez A, Jackson IT, Miyawaki T, Barakat K, DiNick V. Clinical outcome in cranioplasty: critical review in long-term follow-up. *J Craniofac Surg* 2003;14:144–153.
13. Morton RP, Abecassis IJ, Hanson JF, *et al.* Predictors of infection after 754 cranioplasty operations and the value of intraoperative cultures for cryopreserved bone flaps. *J Neurosurg* 2016;125:766–770.
14. Sundseth J, Sundseth A, Berg-Johnsen J, Sorteberg W, Lindegaard K.-F. Cranioplasty with autologous cryopreserved bone after decompressive craniectomy. Complications and risk factors for developing surgical site infection. *Acta Neurochir (Wien)* 2014;156:805–811.
15. Yadla S, Campbell PG, Chitale R, *et al.* Effect of early surgery, material, and method of flap preservation on cranioplasty infections: a systematic review. *Neurosurgery* 2011;68:1124–1130.
16. Yeap M-C, Chen C-C, Chen C-T, *et al.* Predictive value of swab cultures for cryopreserved flaps during delayed cranioplasties. *World Neurosurg* 2021. doi: 10.1016/j.wneu.2021.09.111.
17. Zanaty M, *et al.* Complications following cranioplasty: incidence and predictors in 348 cases. *J Neurosurg* 2015;123:182–188.
18. Chiang H, *et al.* Clinical significance of positive cranial bone flap cultures and associated risk of surgical site infection after craniotomies or craniectomies: clinical article. *J Neurosurg* 2044;114:1746–1754.
19. Bhaskar IP, Inglis TJJ, Bowman J, Lee GYF. Microbial contamination assessment of cryostored autogenous cranial bone flaps: should bone biopsies or swabs be performed? *Acta Neurochir (Wien)* 2013;155:367–371.
20. Bhaskar IP, Zaw NN, Zheng M, Lee GYF. Bone flap storage following craniectomy: a survey of practices in major Australian Neurosurgical centres: Bone flap cryopreservation methods. *ANZ J Surg* 2011;81:137–141.
21. National Healthcare Safety Network. Surgical site infection (SSI) event. Centers for Disease Control and Prevention website. https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf. Published 2021. Accessed April 19, 2022.

https://doi.org/10.1017/ice.2022.112 Published online by Cambridge University Press