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REVIEW

Systematic Review of Heel Puncture-Related Osteomyelitis of the Calcaneus in Newborn Infants

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ABSTRACT

Introduction: Heel puncture (HP) in neonates can result in osteomyelitis if done non-aseptically or with incorrect technique. This study summarizes clinical experience with heel puncture-related osteomyelitis of the calcaneus (HP-CO) in newborns.

Methods: We systematically reviewed studies that examined HP-CO in newborn patients using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Our search included the PubMed, Embase, and Cochrane Library databases until December 31, 2023. We used the National Institutes of Health (NIH) assessment scale to evaluate the quality of our analyzed studies.

Results: This study analyzed 15 neonatal calcaneal osteomyelitis (CO) cases due to HP conducted in six countries from 1976 to 2016. The average age of the cases was 8.87 ± 6.13 days, with an average birth weight of 2367.27 ± 947.59 g. The infants had undergone an average of 9.00 ± 8.90 HP, with 93.33% exhibiting swelling. *Staphylococcus aureus* was present in 80% of cases. Beta-lactam antibiotics were used, with satisfactory outcomes in 53.33% of cases. However, in seven cases, three patients had flatfoot due to calcaneal deformity, and other complications were observed in some patients after 7–8 years.

Conclusions: This study offers valuable insights into a rare condition, including its epidemiology, clinical and laboratory characteristics, and treatment options for infants with HP-CO. To prevent the risk of osteomyelitis in this vulnerable group of patients, increasing awareness and maintaining strict aseptic techniques is necessary. We recommend that infants presenting with tenderness, redness, purulent discharge, erythema, or fever and with a history of repeated HP and swollen ankles should be evaluated for suspicion of osteomyelitis.

A graphical abstract is avilable for this article.

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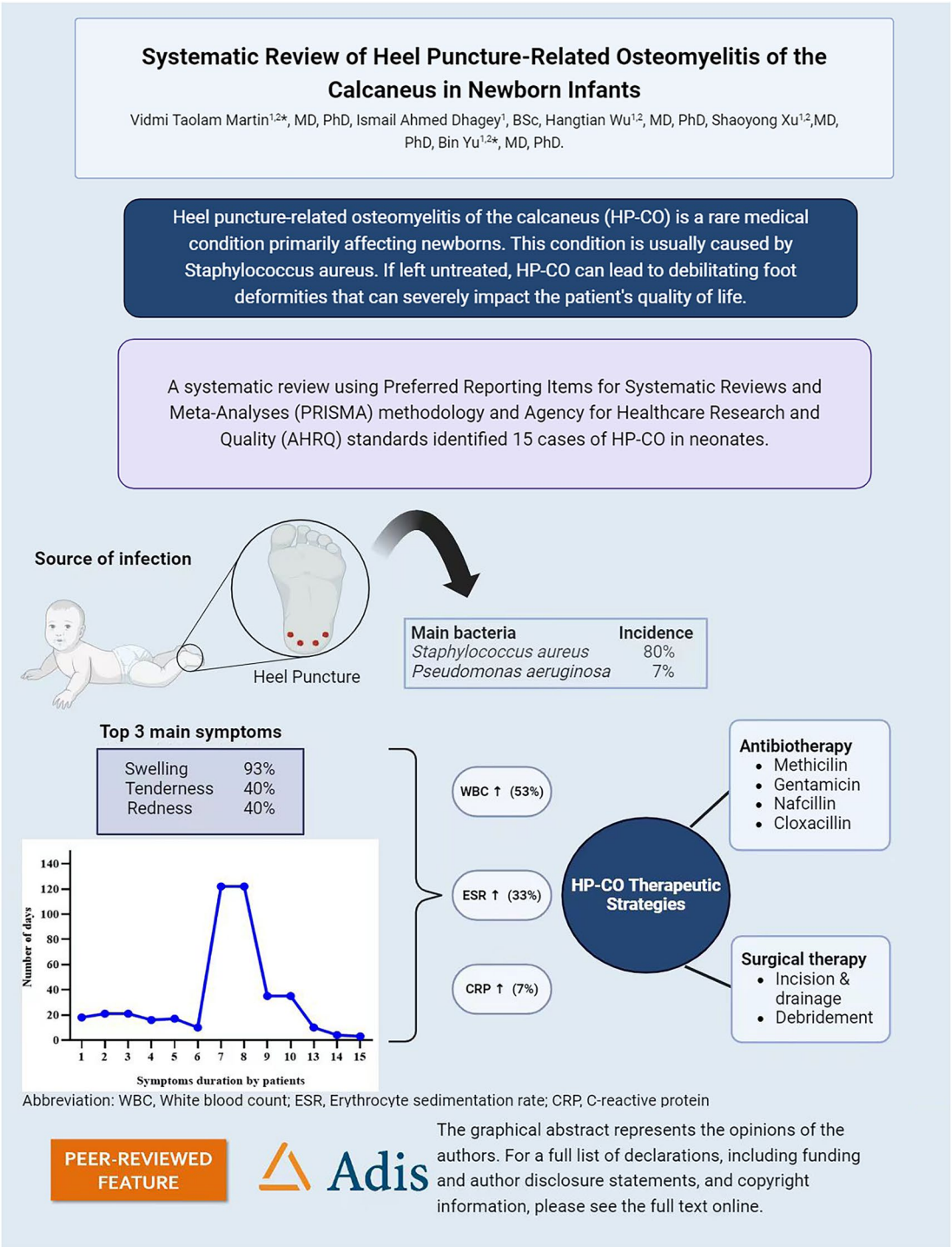
Graphical Abstract:



Abbreviation: WBC, White blood count; ESR, Erythrocyte sedimentation rate; CRP, C-reactive protein

PEER-REVIEWED FEATURE

The graphical abstract represents the opinions of the authors. For a full list of declarations, including funding and author disclosure statements, and copyright information, please see the full text online.

Keywords: Heel puncture; Calcaneal osteomyelitis; Newborn infants; Guthrie test; Bone infection

Key Summary Points

Why carry out this study?

Blood samples from newborns in neonatal units are often collected by puncturing the baby's heel.

Although this procedure is generally harmless, it can sometimes lead to neonatal osteomyelitis of the calcaneus. This study summarizes clinical experience with heel puncture-related osteomyelitis of the calcaneus (HP-CO) in newborns.

What was learned from this study?

The most common surgical interventions to treat this condition involve incision and drainage.

Methicillin, gentamicin, nafcillin, and cloxacillin are the most frequently used antibiotics to treat the infection.

However, the clinical efficacy of these treatments is still unsatisfactory, with an overall incidence of complications of 47%.

DIGITAL FEATURES

This article is published with digital features, including a graphical abstract, to facilitate understanding of the article. To view digital features for this article, go to https://doi.org/https://doi.org/10.6084/m9.figshare.25328848.

INTRODUCTION

Heel puncture (HP) is a common method used to obtain blood samples from neonates in neonatal units [1]. However, this seemingly harmless procedure can sometimes lead to neonatal osteomyelitis of the calcaneus (CO). Compared to osteomyelitis in other bones, osteomyelitis of the calcaneus is a rare condition with an incidence rate of between 3% and 11% [2]. It can develop after HP as a result of either local spread of infection from the surrounding soft tissue to the bone or direct inoculation by the lancet, despite following an aseptic technique [3]. Unfortunately, there is very little peer-reviewed literature on CO as a complication of HP, and no recent reports have been published. This lack of research limits the knowledge of this condition, especially in low-income countries with limited medical facilities, leading to underestimation of this unusual complication. Therefore, this study aims to summarize clinical experience with cases of heel puncture-related osteomyelitis of the calcaneus (HP-CO) in newborn infants.

METHODS

Study Design and Identification

Three authors (VTM, IAD, and HW) independently reviewed PubMed, EMBASE, and Cochrane Library databases to find studies published from database inception until December 31, 2023, in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. The search term of ("osteomyelitis" OR "osteitis" OR "bone infection") AND ("calcaneal" OR "calcaneus" OR "heel") AND ("Guthrie test" OR "heel prick test" OR "capillary blood collection") was used. Two authors (HW and SX) independently reviewed the references of the retrieved publications for any relevant articles. Out of 2361 articles identified (Fig. 1), we assessed only 35, including case reports, short reports, case series, conference abstracts, clinical correspondence, letters to the editor, and retrospective studies. We then included only full English texts of single case reports and short report studies involving individual cases of HP-CO in newborn infants, regardless of the sufficiency of the data provided. The data resulting from this review are summarized in this article. We did not require ethics committee approval as all the data we used are publicly available.

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Inclusion and Exclusion Criteria

This research aimed to document occurrences of calcaneal osteomyelitis (CO) in newborn infants due to heel puncture (HP). Cases without bacterial culture results, biomarker levels, or radiographic imaging were excluded. Neonatal CO cases without a diagnosis of HP-related osteomyelitis were also excluded.

Data Collection

The study examined basic demographic, clinical, and treatment-related information (as listed in Table 1), diagnostic modality outcomes, and summary points (Table 2). Means, standard deviation, or range of variables were calculated only if specified for cases of HP-CO.

Risk of Bias Assessment

Two independent reviewers (VTM and IAD) assessed the potential for bias using the National Institutes of Health (NIH) quality assessment tool for case series studies/case reports [4]. Since all of the studies included were in the form of a case report, certain items in Table S1 were not applicable, including items 3, 4, 6, and 8. Therefore, to meet the Agency for Healthcare Research and Quality (AHRQ) standards, items 1, 6, and 7 must be present. If all three factors are present, the study is considered "good." If two factors are present, it is considered "fair." However, if only one factor is present, the study is deemed "poor" or of "insufficient quality." Each reviewer independently provided a score for each study, and a total score was obtained for each category.

Statistical Analysis

Descriptive statistics were used to present the data. The mean and standard deviation were used to express continuous variables.

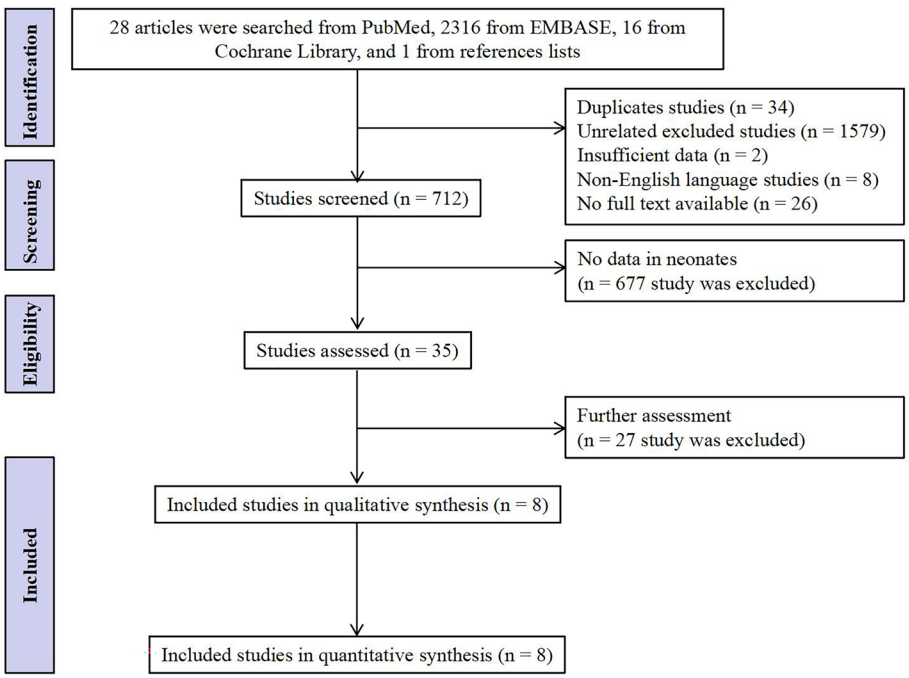


Fig. 1 Flowchart of the screening process used to exclude or retain studies for the review of heel puncture-related osteomyelitis of the calcaneus in newborn infants

Table 1 Demographic, clinical, and treatment-related information of the studies included in the analysis

Study	Country	Patients	Sex/age (days)	BW (g)	GA (weeks)	MOD	Side	HP	Symptoms	SD (days)	Organism	FU (months)	Intervention
Lilien, 1976 [5]	USA	2	B/5	2040	36	VB	L	6	Swelling, tenderness, purulent discharge	18	*S. aureus*	1.84	PO oxacillin Debridement + methicillin IV
			B/10	1710	34	VB	L	12	Swelling, erythema, fever, tenderness, purulent discharge	21	*S. aureus*	1.84	Methicilin IV + kanamycin IM
Canale, 1981 [6]	USA	3	B/1	NA	29	VB	R	30	Swelling (fluctuant mass)	21	*P. aeruginosa*	30	Debridement + sequestrectomy + carbenicillin + gentamycin IV
			B/1	NA	28	CS	R	16	Swelling and cellulitis	16	*S. aureus*	48	Nafcillin + gentamycin Debridement + nafcillin
			B/1	2080	36	VB	R	16	Swelling and cellulitis	17	*S. aureus*	48	Nafcillin + gentamycin + debridement
Goldberg, 1981 [12]	Israel	1	G/6	3100	36	VB	R	3	Swelling and erythema	10	Negative culture	1.38	Cephalothin IV + gentamycin IV + PO cephalexin

Table 1 continued

Study	Country	Patients	Sex/age (days)	BW (g)	GA (weeks)	MOD	Side	HP	Symptoms	SD (days)	Organism	FU (months)	Intervention
Borris, 1986 [8]	Denmark	2	G/22	1180	32	CS	R&L	10	Purulent discharge (right heel), swelling and redness (both heels)	122	*S. aureus*	84	Incision + drainage + methicillin + kanamycin + lincomycin
			G/9	1200	Preterm	VB	R	+[a]	Tenderness	122	*S. aureus*	84	Erythromycin IM
Gjurić, 1992 [9]	Croatia	2	G/10	2520	Full term	VB	R	1	Purulent discharge, swelling and redness	35	*S. aureus*	1.15	Drainage + methicillin IV
			G/10	3910	Full term	VB	L	1	Purulent discharge, swelling and redness	35	*S. aureus*	1.15	Drainage + methicillin IV

Table 1 continued

Study	Country	Patients	Sex/age (days)	BW (g)	GA (weeks)	MOD	Side	HP	Symptoms	SD (days)	Organism	FU (months)	Intervention
Abril, 1999 [7]	Spain	3	G/7	NA	NA	NA	L	NA	Pain, swelling, fever edema, erythema	NA	*S. aureus*	96	Drainage + cloxacillin IV
			B/10	1600	NA	NA	L	17	Tenderness, fever	NA	NA	96	Cloxacillin IV
			G/17	3100	Full term	VB	L	3	Tenderness, swelling, fever	4	*S. aureus*	96	Drainage + cloxacillin IV
Yüksel, 2007 [10]	Turkey	1	G/17	NA	Full term	VB	L	1	Redness/erythema, swelling and tenderness	10	*S. aureus*	1.5	Drainage + cefazolin + gentamicin + bone curettage
Tural, 2016 [11]	Turkey	1	G/7	3600	Full term	VB	R	1	Redness/erythema, swelling, edema, fever	3	*S. aureus*	NA	Drainage + mupirocin ointment + sulbactam/ampicillin IV + PO Augmentin

BW birth weight, *GA* gestational age, *MOD* mode of delivery, *HP* number of heel punctures, *SD* symptom duration, *FU* follow-up, *IV* intravenous, *IM* intramuscular injection, *PO* per os, *USA* United States of America, *B* boy, *G* girl, *VB* vaginally born, *CS* C-section, *L* left, *R* right, *S. aureus Staphylococcus aureus*, *P. aeruginosa Pseudomonas aeruginosa*, *NA* not available

[a]Several heel punctures (number not specified)

Table 2 Diagnostic modalities results and summary points of the included studies

Study	Patients	Bacterial culture results	Biomarkers levels	Radiographic imaging	Summary points
Lilien, 1976 [5]	2	Cultured pus sample was found to have CoPS	NA	An X-ray showed erosion of the left calcaneus, indicating osteomyelitis	Neonates contracted infections from heel punctures. In case 2, positive blood culture may be due to manipulation of the infected area. Management involves antibiotics and abscess drainage
Canale, 1981 [6]	3	Pus was found during aspiration. Case 1 had *P. aeruginosa*, case 2 had *S. aureus* in blood cultures, and case 3 had *S. aureus* growth during surgery	Case 1&2: NA Case 3: WBC ↑	X-ray results: Case 1: Osteomyelitis in right os calcis. Case 2: Soft-tissue swelling and periosteal elevation in os calcis, distal, and proximal tibia. Case 3: Periosteal elevation in proximal femur on repeat X-ray	Swollen lower limbs in newborns may indicate heel infection. Antibiotics may be prescribed, but surgery may be necessary if there is no improvement within 48 h. Repeated heel pricks can cause bone infections, so orthopedic surgeons must advise caution
Goldberg, 1981 [12]	1	No organisms were identified from blood cultures or the heel puncture site	WBC ↑ ESR ↑	A bone scan showed exaggerated uptake in the right calcaneus and distal tibia. X-ray 10 days later revealed an osteolytic lesion in the posterior portion of the right calcaneus, indicative of osteomyelitis	Antibiotic therapy, when given immediately, is successful. Routine X-rays of the healed os calcis are seen in 2–3 months. Prophylactic treatment is strongly advised
Borris, 1986 [8]	2	Pus was discharged from the right heel, and culture revealed growth of *S. aureus*, which was coagulase-negative in case 1. In case 2, a culture grew *S. aureus*	NA	X-ray of the calcaneus revealed osteomyelitis in the right heel in case 1, while in case 2, the bone was unaffected	Neonatal infection caused growth issues in both patients. Early radiographic examination missed bone involvement in case 2. Children under 4 years with calcaneus osteomyelitis should be monitored for hind foot growth problems

Table 2 continued

Study	Patients	Bacterial culture results	Biomarkers levels	Radiographic imaging	Summary points
Gjurić, 1992 [9]	2	Case 1: *S. aureus* from heel abscess culture on day 9. Case 2: *S. aureus* from pus and sterile blood culture on day 7	Case 1: WBC ↑ Case 2: WBC ↑	Case 1: X-ray findings of right calcaneal osteomyelitis on day 9 of illness Case 2: X-ray signs of osteomyelitis of left calcaneus and talus on day 7 of illness	Two newborns got infected during neonatal screening due to a heel puncture that penetrated the bone. To prevent this, follow guidelines for heel puncture sites in infants
Abril, 1999 [7]	3	*S. aureus* was found to be growing in the drainage cultures	Case 1: WBC ↑, ESR ↑ Case 2: NA Case 3: WBC ↑, ESR ↑	Initial X-rays for these patients were normal. Follow-up technetium scans for cases 2 and 3 showed increased uptake in the calcaneus	Deformity of the calcaneus can lead to flatfoot despite treatment. To avoid this complication, a strict aseptic technique is required for neonatal heel puncture
Yüksel, 2007 [10]	1	*S. aureus* grew in the pus culture, while the blood culture was negative	WBC ↑, ESR ↑, CRP –	An osteolytic lesion on the posterior part of the left calcaneus was found on an X-ray of the heel, suggesting osteomyelitis. An MRI later confirmed this diagnosis	Improper sterile technique during the first heel puncture in healthy neonates may lead to calcaneal osteomyelitis. To prevent this, use lateral parts of the heel and avoid central and posterior areas
Tural, 2016 [11]	1	*S. aureus* was detected in nasal swab culture of the patient and her mother	WBC ↑, ESR ↑, CRP↑	The X-ray revealed a bone lesion on the calcaneus that suggests the presence of osteomyelitis Ultrasound found a 24 × 11 mm fluid sac with heavy content on the back of the right foot MRI showed tissue defect, edema, inflammation, and contrast enhancement in the same foot	Calcaneal osteomyelitis should be considered as a probable diagnosis in neonates with heel swelling after undergoing invasive procedures such as the Guthrie test

CoPS coagulase-positive *Staphylococcus aureus*, *NA* not available, *P. aeruginosa Pseudomonas aeruginosa*, *S. aureus Staphylococcus aureus*, *WBC* white blood count, *ESR* erythrocyte sedimentation rate, *CRP* C-reactive protein, *MRI* magnetic resonance imaging

↑ = Increase

– = Normal

Dichotomous variables were expressed as percentages. Statistical analysis was conducted using SPSS 21.0.

RESULTS

This review examined 15 cases across eight eligible studies conducted in six countries from 1976 to 2016, with an increase in eligible studies in 1981 and 1999. The countries included in the study were the USA [5, 6], Spain [7], Denmark [8], Croatia [9], Turkey [10, 11], and Israel [12]. The USA had the highest number of cases reviewed (62.50%), followed by Denmark and Croatia (25.00% each) and Israel (12.50%).

Based on 15 cases from eight included studies, the boy-to-girl ratio was found to be 1:1.5, with six boys and nine girls. The average age of all the cases was 8.87 ± 6.13 days (range 1–22 days). The mean age for boys was 4.67 ± 4.41 days (range 1–10 days), and for girls it was 11.67 ± 5.61 days (range 6–22 days). More than 70% of the patients were born by vaginal delivery, and the average birth weight of all cases ranged from 1180 to 3910 g (mean 2367.27 ± 947.59 g). The overall mean gestational age ranged from 28 to 36 weeks (mean 33 ± 3.42 weeks).

Upon admission, the medical history of the infants showed that they had undergone several heel punctures, ranging from 1 to 30 (mean 9.00 ± 8.90); 93.33% of these newborns exhibited swelling, redness in 40% of cases, and pain in 6.67% on both their left and right heels (50% each). During the physical examination, only 33.33% of the infants had a fever, while the skin on the affected heel was oedematous in 13.33% of cases and showed cellulitis in 13.33% of cases, with marked erythema in 33.33% and tenderness in 40%. A purulent discharge was observed in 33.33% of cases, with an overall symptom duration ranging from 3 to 122 days (mean 33.38 ± 40.52 days).

The following diagnostic methods were used to determine inflammation markers upon admission: bacterial cultures (93.33%), white blood count (WBC) (53.33%), erythrocyte sedimentation rate (ESR) (33.33%), and C-reactive protein (CRP) (13.33%). Radiologic investigations included X-rays (100% of cases) and magnetic resonance imaging (MRI) (13.33% of cases).

In eight cases at admission, the WBC ranged from 14.9×10^9 to 20.6×10^9/L (mean 18.15 ± 2.05). In five cases, the ESR values ranged from 25 to 40 mm/h (mean 35 ± 7.07). Only two cases had available data for CRP values (24 and 510 mg/L). Bacterial cultures revealed *Staphylococcus aureus* in 80% of cases and *Pseudomonas aeruginosa* in 6.67% of cases and were taken from purulent discharge from the heel, blood culture, and nasal swab culture.

Initial X-rays revealed abnormalities in 73.33% of cases (11/15), followed by MRI in 13.33% (2/15), and the time elapsed between symptom onset and hospitalization ranged from 3 to 17 weeks in eight cases (mean 7.84 ± 4.71 weeks).

Surgical Interventions

Out of 15 cases, 11 patients (73.33%) underwent surgery. The surgical interventions included incision and drainage (46.67%), irrigation and debridement (20%), irrigation and debridement + sequestrectomy (6.67%).

Antibiotherapy and Outcome

Based on the last follow-up evaluation, a satisfactory outcome was determined for the patients. Asymptomatic patients were identified if they showed no clinical symptoms during a routine X-ray, MRI and/or biomarker-level examination (Table 2). In this study, only one patient out of 15 missed a follow-up. Even though that individual's follow-up information was unavailable, the authors noted that the heel lesion had completely resolved and the acute phase reactants were normal at the end of the treatment [11].

This study covers four decades of literature, and treatment efficacy may have improved over time. Outcomes may vary across countries. Thirteen cases of intravenous antibiotic treatment lasted from 1 to 6 weeks (average 3.47 ± 1.46 weeks). However, in one case where an antibiotherapy ointment was used, the treatment duration was within 1 week. In four cases of oral antibiotic treatment, the duration ranged

from 1 to 3 weeks (average 2.28 ± 1.08 weeks). In three reported cases of intramuscular antibiotic treatment, the duration was 1 week (average 1.29 ± 0.14 weeks). Beta-lactam antibiotics, such as methicillin, gentamicin, nafcillin, and cloxacillin, were commonly administered either intravenously or orally (Table 1).

In eight studies, the outcome was satisfactory in 53.33% of cases. However, in seven cases [6–8], three patients had asymptomatic flatfoot secondary to calcaneal deformity after neonatal calcaneal osteomyelitis. Clinical assessment showed normal tension of the Achilles tendon, but an abnormal shape of the calcaneus was noted after 7–8 years of follow-up in these patients. Two patients ended up with an almost identical calcaneus deformity. One patient had inequality in leg length, and another developed growth arrest of the hip. Therefore, the overall follow-up length ranged from 1.15 to 96 months (average 42.20 ± 41.46 months). Six patients had less than 2 months of follow-up, while eight had up to 30 months.

DISCUSSION

Neonatal units often perform heel punctures (HP) on newborns, especially premature children, to collect blood samples for analysis. However, the skin on a newborn's heel is thick, and the calcaneus is cartilaginous, which makes a strictly aseptic technique necessary to avoid the risk of osteomyelitis. This complication needs to be discussed more in the literature. It is recommended that HP in infants be no deeper than 2.4 mm to allow adequate blood flow without puncturing the calcaneus [3]. Repeated HP has been reported to cause osteomyelitis of the calcaneus (CO), so physicians must be diligent and aware of the possibility of infection originating in the heel [6, 7, 10].

The analysis of 15 cases from eight eligible studies showed that CO is more common in newborn girls. It typically occurs after a routine puncture for biochemical analysis, causing symptoms such as swelling, tenderness, and redness. The most common microorganism detected is *S. aureus*. Even after surgical treatment, the outcomes were still unsatisfactory. Complications include deformity of the calcaneus, asymptomatic flatfoot, and growth arrest of the hip. Therefore, it is essential to discuss these findings from different aspects.

It has been observed that microorganisms enter the calcaneus bone as a result of an infected HP, which happens when capillary blood is taken for neonatal screening. This condition is found in patients of all ages and sexes. However, it is more common in newborn girls, especially those born prematurely (60%). In all cases, the sole cause of CO was HP. However, a comprehensive report on the incidence of this condition and its clinical features with respect to age and sex is not yet available. It is well known that invasive medical procedures, prematurity, and low birth weight are some of the factors that can increase the risk of HP-CO [6, 12]. There was a difference in median age at diagnosis between newborn boys and girls. Girls were diagnosed at an average age of 12 days, while boys were diagnosed at an average age of 5 days. The finding aligns with the results of earlier studies conducted by Abril and their colleagues [7].

We observed that the number of girls over 10 days old who had HP-CO was significantly higher than that of boys, which may explain why girls were diagnosed at an older median age than boys. This study found that the median symptom duration was 33 days. However, other studies have reported a range of symptom durations, from 3 to 122 days. Tural et al. [11] reported a case of a female infant with HP-CO who received the Guthrie test on the seventh day after birth. Three days later, she experienced swelling, redness, and increased temperature at the puncture site but did not have a fever. The short interval between the test and symptoms may have been due to the patient's typical presentations of infection, both systematically and locally. In contrast, Borris and colleagues [8] reported a maximum symptom duration of 122 days in 9- and 22-day-old girls with CO, respectively. Such a wide range of symptom duration suggests this condition's high heterogeneity.

Our findings showed a similar distribution regarding the affected side distribution between both sides. The type of device or stylus used

for the puncture is unreported, but the mean HPs were during the first 7 days of life (range 4–10 days of life). The infants' heels had been punctured at least once (range 1–30 times) for blood samples during the initial hospitalization. Thus, these cases of osteomyelitis were secondary to the trauma of multiple HPs, which caused a soft tissue infection in a localized area of the heel pad.

We discovered that the symptoms and pathogen culture outcomes of the HP-CO cases we studied showed similarities and differences compared to previous CO reports in older children and adults [13, 14]. Among the included patients with HP-CO, the most common early symptom was soft-tissue swelling next to the affected bone, possibly due to the thickness of the skin in children's heels and the limited surrounding soft tissue of the calcaneus, which has poor blood supply. We also observed that the positive rate of sample culture was 86.67%, with *S. aureus* being the most common pathogen (80%). However, this HP-CO study also frequently detected *P. aeruginosa* (6.67%). The predominance of *S. aureus* in this study is consistent with studies that have identified it as the primary causative organism in hematogenous osteomyelitis of newborns [15, 16].

Next, we found that surgery remained the mainstay of the HP-CO treatment strategy, which accounted for 87% of all the patients with HP-CO. Nonetheless, the clinical efficacy was still unsatisfactory, with an overall incidence of complications of 47%. Regarding surgical treatments, there are four main strategies to consider. Incision and drainage involve draining pus from the affected area of the body. Debridement involves removing foreign objects and dead tissue from a wound to prevent infection and promote effective healing. Bone curettage involves scraping away bone with a curette. Finally, sequestrectomy is the surgical removal of a sequestrum, which can be done through either an intraoral or extraoral strategy, depending on the size and location of the lesion. We found that the risk of complications from treatment by debridement was higher than that managed by incision and drainage (50% vs. 43%). Surprisingly, the efficacy of debridement was even worse than that of incision and drainage. Patients who undergo debridement as a treatment for their wounds may experience more severe complications depending on various factors, such as the recovery time after the procedure, the severity of the wound, its location, and the type of debridement method used. Thus, the complication risk was higher. Also, considering the limited number of patients that had a calcaneal deformity, it suggested that HPs should not penetrate deeper than 2.5 mm to avoid contact with the calcaneus as the skin of the heel in children is thick [8] and the rare but possible complication of osteomyelitis, given that septic involvement of the calcaneal apophysis may produce early closure of this growth plate and, consequently, a calcaneal deformity [7]. Thus, the clinical efficacy of this surgical method needs to be reassessed by future studies.

When interpreting the results of our study, it is important to take into account its limitations. Firstly, the study population was limited in size, and there was a wide variation in follow-up time. Secondly, the evidence level was limited, as the studies were case reports, which may have led to publication bias. Thirdly, treatment efficacy has likely improved over time as a result of variation in the years and geographical settings of its administration. Such variances may lead to an underestimation of its effectiveness; therefore, to obtain a more precise estimate of its efficacy, we recommend performing stratified analyses in future investigations.

CONCLUSIONS

Heel punctures on newborns can cause calcaneus osteomyelitis (CO) if done repeatedly on one heel or without adequate aseptic technique. This can lead to abnormal bone growth or hind foot growth disturbance. Vigilance by clinicians is necessary when swollen lower extremities are present to detect signs of infection, indicating CO, and immediate treatment is crucial. This review aims to provide guidance

on diagnosing and preventing HP-CO and promoting accurate, timely treatments.

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Author Contribution. Vidmi Taolam Martin: Conceptualization, Methodology, Software, Writing- Original draft preparation. Ismail Ahmed Dhagey: Methodology, Software, Data curation, Writing- Reviewing and Editing. Hangtian Wu: Methodology, Visualization, Writing-Reviewing and Editing. Shaoyong Xu: Software, Data curation, Investigation. Bin Yu: Supervision, Writing- Reviewing and Editing.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Vidmi Taolam Martin, Ismail Ahmed Dhagey, Hangtian Wu, Shaoyong Xu, and Bin Yu declare they have nothing to disclose.

Ethical Approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

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