

Adult calcaneal osteitis: incidence, etiology, diagnostics and therapy

Fersenbeinosteitis beim Erwachsenen: Inzidenz, Ätiologie, Diagnostik und Therapie

Abstract

Calcaneal osteomyelitis presents a complicated situation. The specific anatomy of the os calcis and its surrounding soft tissues plays an important role in the planning and realization of the procedures needed in order to eradicate the osteomyelitic focus. The calcaneus represents a spongy bone; a fact that supports the development of an osteomyelitis. It is the strongest bone of the foot and is highly important for the biomechanical features of physiological walking. The surrounding soft tissues are thin and contain various important anatomical structures. These might be damaged during the treatment of the osteomyelitis. In addition the vascularization of the os calcis is delicate and may be compromised during the surgical osteomyelitis treatment.

Calcaneus osteomyelitis may be classified based on the routes of infection into exogenous and endogenous forms. Additionally from the clinical point of view acute and chronic forms may be distinguished from an early and a late infection.

Exogenous calcaneal osteomyelitis mostly is the result of an infection with *S. aureus*.

The treatment is equal to the therapy in other locations and based on:

- Eradication of the bone infection
- Sanitation of the soft tissue infection
- Reconstruction of bone and soft tissue

Especially the preservation and restoration of the soft tissue is important. Thus plastic surgical procedures play an essential role.

The main object of treatment is the preservation of a biomechanical functioning foot. This may be impossible due to the local situation. Calcaneotomy or even below knee amputation may be needed in those cases.

Keywords: calcaneus, osteomyelitis, etiology, incidence, diagnostics, therapy

Zusammenfassung

Die Fersenbeinosteitis ist eine seltene Entität. Sie konfrontiert den behandelnden Arzt mit einer Reihe komplizierter Probleme. Eine wesentliche Rolle spielt dabei die spezielle Anatomie des Calcaneus und seiner umgebenden Weichteile. Der Calcaneus ist beim Gehen und der daraus folgenden Lastübertragung vom Körper biomechanisch hoch belastet. Das Fersenbein ist ein spongiöser Knochen und bietet demnach gute Voraussetzungen für eine Erregerausbreitung. Der umgebende Weichteilmantel ist dünn, enthält aber auf engem Raum eine große Zahl wesentlicher anatomischer Strukturen. Die möglichst ungestörte Durchblutung des Calcaneus ist eine Voraussetzung für die erfolgreiche Therapie. Gerade diese wird aber bei den z.T. ausgedehnten chirurgischen Revisionsoperationen im Rahmen der Infektsanierung häufig kompromittiert.

A. H. Tiemann¹

G. O. Hofmann^{1,2}

M. Steen³

R. Schmidt³

1 Abteilung für Septische und Rekonstruktive Chirurgie, Klinik für Unfall- und Wiederherstellungschirurgie, BG-Kliniken Bergmannstrost Halle, Deutschland

2 Klinik für Unfall-, Hand- und Wiederherstellungschirurgie, Friedrich-Schiller Universität Jena, Deutschland

3 Klinik für Plastische- und Handchirurgie, Brandverletzenzentrum, BG-Kliniken Bergmannstrost Halle, Deutschland

Unterteilt wird die Calcaneus-Osteitis in eine exogene (posttraumatische/postoperative) Form und in eine endogene (hämatogene) Form. Mit Blick auf die klinische Relevanz unterscheidet man die akute von der chronischen und die Früh- von der Spätinfektion.

Ursächlich für die Entstehung der in diesem Artikel betrachteten exogenen Calcaneus-Osteitis sind im wesentlichen Staphylokokken.

Die Therapie basiert wie die Behandlung der übrigen Osteitiden auf:

- Infektisanierung am Knochen
- Infektisanierung an den Weichteilen
- Rekonstruktion von Knochen und Weichteilen

Gerade im Rückfußbereich muss eben diesem Erhalt bzw. der Rekonstruktion des Weichteilmantels wesentliche Aufmerksamkeit gezollt werden. Insofern haben die plastisch-rekonstruktiven Verfahren an dieser Stelle einen bedeutenden Stellenwert.

Oberstes Ziel der Behandlung ist initial der Erhalt eines funktionsfähigen, belastbaren Fußes. Ist dies nicht möglich kommen lokal ablativ Verfahren (Calcanektomie) ebenso wie die Unterschenkelamputation in Betracht.

Schlüsselwörter: Calcaneus, Osteitis, Ätiologie, Inzidenz, Diagnostik, Therapie

Introduction

The treatment of calcaneal osteitis (CO) represents a demanding challenge. Analog to the treatment of skeletal infections in other locations the objective is defined obviously [1]:

- Calming of the infection
- Reconstruction of the bone
- Reconstruction of the soft tissue
- Preservation or reconstruction of affected joints
- For the patient: "Back to normal life as fast as possible".

Anatomy

The special anatomic configuration of the calcaneus leads to some special problems during the treatment of CO:

- The calcaneus is one of the most stressed structures in terms of weight bearing and load transfer from the foot to the ground.
- The special combination of highly elaborated anatomical shape, high load transfer capacity and thin surrounding soft tissue. In case of trauma and or infection this combination leads to an extreme local vulnerability.

In their article from 2010 Fukuda et al. summarize the main qualities of the calcaneus [2]:

- The calcaneus is the most stable anatomical structure of the pedal skeleton. It is one vital part of the "lateral column" [3].
- During walking the calcaneus transfers axial energy to fore and hind foot [4].

- The special flexible calcaneal incorporation in the pedal skeleton allows the adjustment to the ground and thus walking on rough surfaces.
- Tendons and ligaments stabilizing the pedal skeleton insert at the calcaneus, including the strongest human tendon (Achilles tendon).

Aa. tibialis anterior, posterior and peronea ensure the calcaneal vascularization. These vessels are connected to each other and thus form angiosoms. The successful treatment of any calcaneal trauma or infection is based on the knowledge of the location of these interconnections [5]. The interconnections between Aa. tibialis anterior and posterior are located [2]:

- 5 to 7 cm above the ankle
- On ankle level
- Next to the achilles tendon

The venous drainage is based on the minor saphenous vein. According to Zwipp 2005 the vulnerability of the hind foot originates from [6]:

- Thin soft tissue layer at the medial and lateral calcaneal aspect.
- Special anatomical structure of the planta pedis.

Classification

There is no specific classification for CO. It is based on the established classifications for osteitis/osteomyelitis [7]:

- Type of infection (specific/non-specific)
- Portal of entry (endogenous – hematogenous/exogenous – post traumatic)
- Direction of expansion (centripetal/cetrifugal)

- Acuteness (acute/primary chronical/secondary
 chronical)
- Onset of symptoms (early infection/late infection)

According to Fukuda 2010 two special entities have to be differentiated [2]:

- Posttraumatic CO
- CO based on chronical pressure. In these cases CO is often accompanied by diabetes (“Charcot foot”) or appears in the course of Charcot Marie Struempels disease.

Incidence

Only a few articles deal with the incidence of CO. In 1992 Wang et al. put the number of CO to 7 to 8% of all bone infections based on studies of Feigin et al. in 1970 [8], [9]. In the literature often wound infection, soft tissue infection and bone infection will not be differentiated. Schildhauer et al. quantified the calcaneal rate of infections to 11% [10]. Aseptic necroses of the wound edge especially after extended lateral approaches to the calcaneus are described in the literature between 2 to 27.3% [11], [12], [13]. Delayed healing or postoperative infection may occur up to 25% [4], [14], [15], [16], [17], [18]. Postoperative hematoma may be detected between 2 to 5% [11], [19], [20]. In case of closed fractures deep wound infections or CO occurs in 1 to 4%, in case of open fractures up to 7% [11], [14], [16], [18], [20], [21]. Siebert et al. describe the ratio of infection up to 60% in case of open calcaneal fractures. Amputation may be proceeded in these cases up to 14% [22]. The rate of complications is raised 5 to 7 times in case of open calcaneal fracture [23].

Etiology

By analogy to bone infections in *altero loco* there exist various predispositioning factors for the establishment of CO [24]:

a. Local factors

- Extent of the local bone damage
- Extent of the local soft tissue damage
- Localization of the fracture
- Preexisting local problems (local circulatory disturbance etc.)
- Virulence of the pathogen

b. Systemic factors

- Diabetes mellitus
- Vasculitis
- Rheumatoid arthritis
- General circulatory disturbance
- Nicotine abuse
- Obesity
- Tumors

- Immune suppression
- Immune deficit

c. Iatrogenic factors

- Therapeutical performance
 - Time of intervention
 - Manipulation during fracture reposition
 - Intraoperative manipulation of bone and soft tissue
 - Surgical approach
 - Duration of the operation
- Osteosynthesis material and configuration
- Hygiene deficit

Pathogens

There is no *specific* CO pathogen. Staphylococci, especially *S. aureus* and *epidermidis* but even Streptococci remain the most frequent bacteria to be detected (80%) [24]. The rate of multi-resistant bacteria increases during the last years, a trend already described by Giske, Rice and Spellberg in 2008 [25], [26], [27]. Rice summarized these pathogens by the acronym ESCAPE (*Enterococcus faecium*, *S. aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter species*) [26]. In their 2008 study Aragón-Sánchez et al. found *S. aureus* in pedal osteitis in 51.3%. Multiresistancy could be detected in 36.8% of those infections [28]. Sometimes atypical pathogenes may be detected like:

- Mycobacteriae [29], [30]
- Brucellae [31]

Symptoms

As well as in other cases of osteitis/osteomyelitis the typical clinical symptoms may not be detectable. It is important to *think* of this entity as an option whenever the following circumstances apply:

- History of local hind foot injuries
- Hind foot operations
- Scars located at the hindfoot
- Paraclinical signs of infection combined with secreting pedal wounds

According to Chen the following symptom may occur in case of CO [24]:

- Reddening of the skin
- Hind foot pain
- Edematous swelling
- Toe walk (weight bearing on the fore foot)

Diagnostic investigations

Diagnostics of the CO is based on clinical and apparative findings and may be distinguished into the pre- and intra-operative phase.

Table 1: Algorithm for the CO imaging diagnostics

Imaging proceedings	Unknown patient		Known patient
	Central problem: Osteitis yes / no		Central problem: Infection exacerbated?
Step 1	Projection radiography Objective: Orienting examination	Step 1	MRI Objective: Evaluation of acuteness
		Step 2	Reevaluation: "dubious radiological result"
		Step 3: In case of "dubious radiological result"	PET-CT
Step 2	CT Objective: Planimetry, planning of the operation	Step 4	Projection radiography Objective: Basic imaging for planimetry
Step 3	MRI: Objective: Evaluation of acuteness and intramedullary extent of the infection	Step 5	CT: Planimetry
Step 4	Reevaluation: Diagnosis clear?		
Step 5 "IF NOT"	PET-CT		

a. Parameters analyzed in the preoperative phase:

- Patients medical history
- Symptoms
- Laboratory findings (i.e. white blood count, C-reactive protein). Not only the absolute value of leucocytes and C-reactive protein have to be analysed but also the course of those parameters. The absence of a normalization of the above named parameters f.e. after trauma or postoperatively may be an early sign of infection.
- Radiological examination (x-ray, CT, MRI, PET-CT)
The diagnostic imaging should deliver the radio morphologic correlate to the clinical and laboratory findings [32], [33]. It supports the physician's effort to create an exact map of the localization and extent of CO ("planimetry"). We created a special algorithm to coordinate the imaging methods in order to achieve the optimal result (Table 1).

b. Parameters analyzed intraoperatively:

- Microbiological samples
- Histological samples

The collection of microbiological *and* histological samples from the infected bone *and* soft tissue is the "gold standard" of the intraoperative diagnostics for infectious bone diseases. Infectious bone diseases are known for their occasionally small number of pathogens [34]. Thus the microbiological proof of an infection sometimes may be missing. The histological analysis may lead to the proper diagnosis in these cases.

Therapy

According to Hofmann 2004 the therapy of CO is, in analogy to osteitis/osteomyelitis in general, divided into 3 phases [35]:

- Phase I: Sanitation of bone and soft tissue (leads to calming of the infect)
- Phase II: Soft tissue reconstruction
- Phase III: Reconstruction of the bone.

Phase II and III may be processed parallel.
See Figure 1, Figure 2, Figure 3, Figure 4.

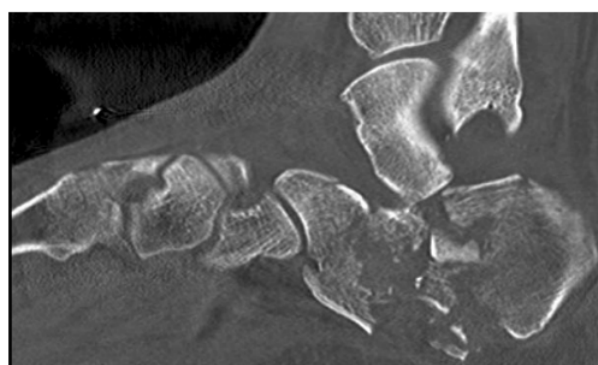


Figure 1: Initial lateral CT scan of 2° open calcaneal fracture ("Joint Depression" Type). March 2009. Initial conservative treatment. Early infection with the proof of *Acinetobacter baumannii*. After transferral achievement of biomechanical stability by an external fixator. Consequent local surgical debridement combined with local and systemical antibiotics led to infect calming and negative proof of bacteria in the former infection area. BUT: Remaining extended bone and soft tissue lesion.

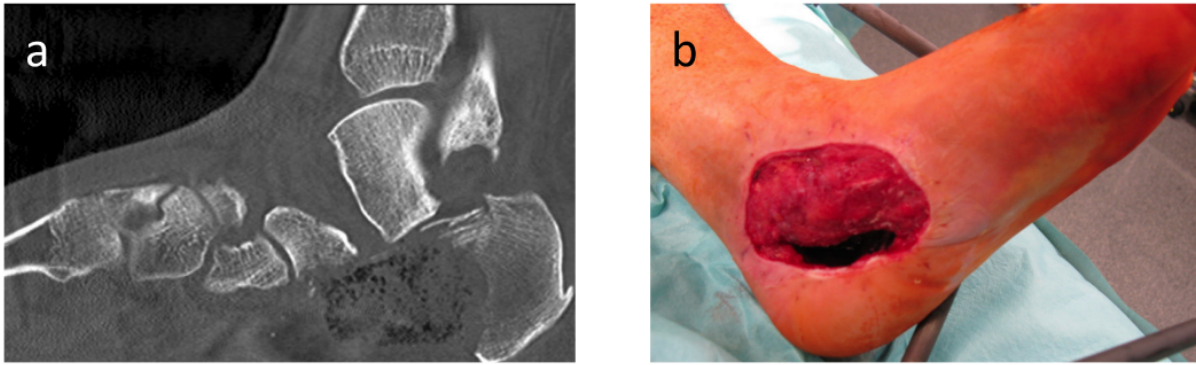


Figure 2: a. Lateral calcaneal CT scan after local surgical infect eradication. Extended calcaneal bone defect with additional destruction of the subtalar joint.
b. Clinical presentation of the remaining local soft tissue lesion.

Due to the extent of the bone and soft tissue lesion decision to proceed in a two step therapy. First: Reconstruction of the soft tissue. Second: Reconstruction of the os calcis.

The waiver of using a composite flap in a one step procedure in our opinion leads to a more accurate positioning of the bone graft due to the fact, that we do not have to focus on the perforator vessels connecting soft tissue and bone in these composite flaps.

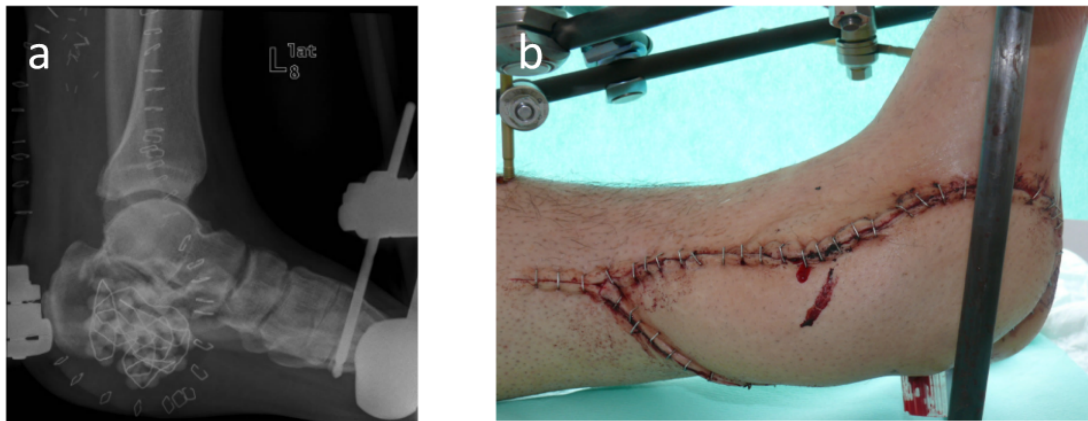


Figure 3: a. Projection radiographical lateral image of the os calcis. Antibiotic chain serves as a spacer for later implantation of bone graft.
b. Clinical presentation after closure of the soft tissue lesion by an ALT flap.

After a 3 months time period without any signs of recurrent infection a partial raise of the ALT flap was proceeded and a micro vascularized iliac crest bone graft was transplanted (anastomosed to the A. tibialis posterior). After bony assimilation of the graft complete weight bearing was achieved after furthes 4 weeks. Today's situation: Full weight bearing, subtalar arthrodesis, no walking canes, back to work in october 2010

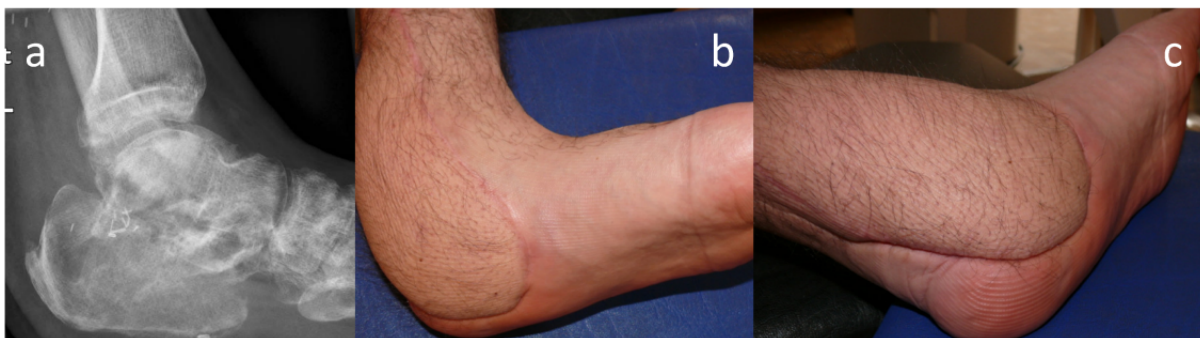


Figure 4: a. Lateral projection radiographical image after bony assimilation of the iliac crest graft and subtalar arthrodesis.
b. and c. Clinical healed up presentation

Phase I/surgery

Local surgical eradication of the infection site (bone in combination with the soft tissue) remains *the* basic therapeutical procedure. As mentioned above in contrast to infectious bone diseases in other locations the local layer of soft tissue is extremely thin at the hind foot. If this thin layer has to be resected in order to proceed radical local surgery the calcaneus is threatened vitally. Heier et al. postulated in 2003: "The extent of soft tissue damage determines the therapeutical result". This thesis drafted for open calcaneal fractures applies for CO as well [36]. In this respect the early soft tissue coverage plays an important role. The preservation of the calcaneus and thus a functional pedal anatomy is the main target during the infect sanitation. This is not always feasible. Depending on the local situation the spectrum of surgical procedures includes partial calcaneal resection, calcaneotomy and lower leg amputation (as an ultima ratio). According to Bollinger and Lehmann partial calcaneotomy is a decent alternative to lower leg amputation in cases of strictly local infection [37], [38]. In their study of 2008 Bragdon et al. supported this thesis. The authors mentioned, that partial calcaneal resection may be performed if the inflammatory process does involve less than 50% of the heel [39]. In these circumstances the sufficient hind foot blood supply seems to be the central problem [40], [41]. Syme-Amputation may also be performed in special cases.

Phase I/adjuvant therapy

Surgery is supported by application of antibiotics (systemic and/or local antibiotics). The correct selection depends on the pathogens proven at the infection site. Analogous to bone infections in other locations early or acute infections will be treated immediately after harvesting samples for the microbiological analysis (calculated antibiotic therapy).

The additional administration of dietary minerals and vitamins may be discussed [42], [43], [44].

Phase II/III

Exact planning in advance is a must before doing any reconstructive surgery. The following factors have to be analyzed:

- Extent of the calcaneal bone defect
- Localization of the calcaneal bone defect
- Extent of the soft tissue defect
- Localization of the soft tissue defect
- Additional involvement of the subtalar and calcaneocuboidal joint
- Subtalar arthrosis
- Calcaneocuboidal arthrosis

Depending on the size and localization of the calcaneal bone defect local cancellous bone plastic may be discussed as well as (microvascularized) bone grafts. Seg-

ment transportation by callotaxis plays a tangential role. Basic element of any reconstructive procedure is the biomechanical stability of the calcaneus (analogy to bone reconstructive procedures at another location). Stability may be achieved by using external fixators.

The status of the subtalar and calcaneocuboidal joint has to be analyzed critically. If those joints were involved and were damaged (by infection and/or resection) arthrodesis has to be discussed.

Phase II/III: Reconstruction of the calcaneus by micro vascularized bone graft

Though small calcaneal defects may be filled up by using cancellous bone grafts or corticospongious chips, this methods are not sufficient for defects bigger than 6 cm in diameter. In 2010 Schmidt et al. described the muscular and osteomuscular composite peroneus brevis flap for those defects [45]. Osteocutaneous free fibula transplantation as well as osteocutaneous flaps including the medial tibial condylus have been used successfully [46], [47].

Phase II/III: Reconstruction of the soft tissue

In case of small bone defects which could be filled up by using cancellous bone graft local pediculated muscular flaps may be proceeded. The soft tissue defects in these cases mostly originate from calcaneal osteosynthese and are located on the lateral face of the hind foot. Local flaps like mentioned above may solve these problems. Vacuum sealing of the wounds should only be a temporary bridging method, if the soft tissue can not be restored temporarily. If the soft tissue defect extends to the basis of the 5th metatarsal bone, one has to keep the raised number of flap apex necroses in mind. Local wound conditioning combined with later mesh graft may be feasible.

Locoregional pediculated flaps like M. abductor digiti minimi or M. abductor hallucis are mentioned in the literature and may also be useful for closing small soft tissue defects [48], [49].

In case of more extended soft tissue defects the pediculated fasciocutaneous suralis flap may be used. Once again in case of soft tissue defects extending to the dorsum of the foot necroses may occur in the distal 1/3 of the graft due to a reduced venous flow. This situation may lead to a venous swelling of the flap with resolving flap necrosis. In case of exposed extensor tendons on the dorsum of the foot, free microvascularized flaps should be discussed.

Free microvascularized flaps are also indicated in case of large soft tissue defects. We use the anterolateral upper leg flap which mostly is anastomosed to the A. tibialis anterior. A. dorsalis pedis we use as an exception due to its close position to the infection site.

Differential diagnosis

Tumors and tumor like lesions may mimic CO. 3% of all bone tumors are located in the foot. Soft tissue tumors outnumber bone lesions 10 times, malignant tumor benign tumors 5 times [50]. Therefore an analytic approach with prompt usage of the appropriate diagnostic features is a must in order to avoid further complications (Table 1).

Conclusion

CO is a rare entity. The therapy corresponds to the therapeutical approach to bone infections in other locations. It is based on:

- Local surgical eradication of the infected bone segment and its surrounding soft tissue
- Local and/or systemic application of antibiotics
- Usage of further supplementary therapies (f.e. application of trace elements)
- Preservation or reconstruction of the bone structure of the heel
- Preservation or reconstruction of the soft tissue surrounding the heel
- The special anatomical situation at the hind foot with just a thin covering soft tissue layer complicates the situation. Therefore soft tissue preservation or reconstruction as early as possible is of vital relevance.
- Ablative therapy should only be proceeded as an ultima ratio.

Notes

Competing interests

The authors declare that they have no competing interests.

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Corresponding author:

Prof. Dr. med. A. H. Tiemann
Abteilung für Septische und Rekonstruktive Chirurgie,
Klinik für Unfall- und Wiederherstellungschirurgie,
BG-Kliniken Bergmannstrost Halle, Merseburgerstr. 165,
06112 Halle, Deutschland, Tel.: 0345-1326632
andreas.tiemann@bergmannstrost.com

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