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Plantar calluses - pathogenesis, risk factors, prophylaxis, methods of treatment

Daria Marczak[1], dariamarczak1@wp.pl ORCID: https://orcid.org/0000-0003-2404-8001

Sławomir Liberski[1], liberski@o2.pl ORCID: https://orcid.org/0000-0002-6942-2506

Arkadiusz Migdalski[2], armigos@wp.pl ORCID: https://orcid.org/0000-0002-9835-5103

[1]Faculty of Medicine, Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University, M. Curie 9, 85-090 Bydgoszcz, Poland

[2]Department of vascular surgery and angiology, Faculty of Medicine, Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University, M. Curie 9, 85-090Bydgoszcz, Poland

Abstract

Calluses are one of the forms of cutaneous hyperkeratosis. The problem of their occurrence applies to people of all ages, with a special tendency among older people. The cause of their formation is local damage to the skin of feet secondary to the impact of excessive shear forces and pressure. Symptoms that accompany foot calluses, beyond the adverse cosmetic effect, are pain and abnormalities in gait and balance. Increased occurrence of calluses has been observed with other medical conditions, such as diabetes and rheumatoid arthritis, which is related to the synergistic effect of risk factors. Currently, in the treatment of foot calluses, local chemical agents are used to accelerate the exfoliation of excessively cornified layers of the skin, cryosurgery, electrosurgery, the use of orthoses and removal of calluses using a scalpel. In the case of unsatisfactory results, it also goes to advanced surgical treatment.

Keywords: callus, foot, hyperkeratosis

1. Introduction

Calluses are one of the manifestations of cutaneous hyperkeratosis. Most often they locate on the skin of the hands or feet [1]. The problem of occurrence of calluses applies to people of all ages [2]. Among older people, they are one of the most common causes of reported foot problems [1]. It is estimated that in the age group above 65 this problem occurs in 20-65% of people [2]. It has been proven that people with calluses are characterized with a feeling of lower quality of life [3]. Apart from the aesthetic defect, calluses are a frequent cause of pain, and in extreme cases may be a source of bleeding [4]. A correlation between their occurrence and disturbances of the walking pattern and the sense of equilibrium was also demonstrated [5]. People with diabetes may be predisposed to the formation of hard-healing foot ulcers [6]. Despite many efforts, the problem of the occurrence of calluses has not been sufficiently studied, which results in the lack of strictly defined therapeutic standards for individual groups of patients [7].

2. Pathogenesis

The peculiar structure of the human foot was shaped in response to the adoption of a vertical posture in the course of evolution. The feet are designed to bear the body weight when standing, walking, climbing stairs, running or jumping. While walking, 150% of the body weight rests on the foot, 370% while going down the stairs, and 800% during the fast run [8]. The surface of the foot's bones is not a flat one. It has haughtiness, the most important of which are located above the surface of the heads, as well as the bases of the metatarsus and phalanx, and the calcaneus. During movement, the increased pressure in places corresponding to these bone protrusions is transferred to the skin of the feet. It causes excessive shearing forces and compressive stress [5]. These phenomena lead to local irritation and mechanical damage to the skin of the feet [9]. In response, accelerated proliferation of keratinocytes of the stratum corneum occurs and at the same time the rate of skin exfoliation slows down [1]. This results in excessive accumulation of the stratum corneum, referred to as hoarseness, which, although being the body's defensive mechanism, increases the pressure at the place where it arises. Repetitive defects and defense mechanism in the form of hyperkeratosis lead to the formation of calluses [9]. This hypothesis was confirmed by the

studies where the higher tendency to form plantar calluses was observed in places where the measurements showed an increase in plantar pressure [5].

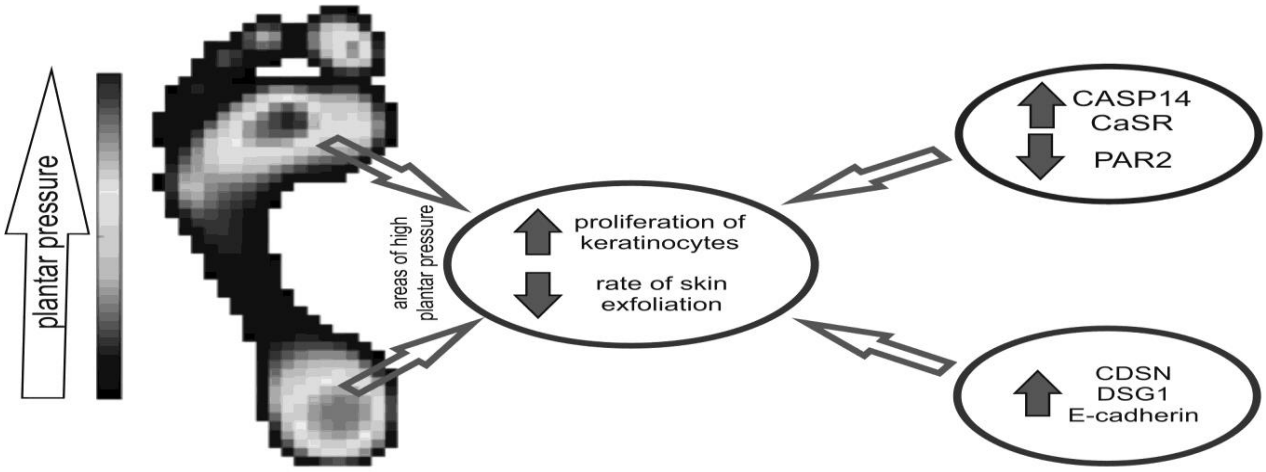

Figure 1. Pathogenesis of calluses.

Kim et al. conducted studies on the molecular basis of the formation of calluses. The samples were obtained from the back of the foot, plantar arch, and anterior heel area, which were then subjected to a cytological, histological, and molecular assessment, where the expression of genes involved in the processes of keratinization, adhesion of keratinocytes, and exfoliation of the epidermis was analyzed. The histological structure of the heel specimen showed changes corresponding to the process of incomplete keratinization, manifested by a smaller flattening of keratinocytes, as well as an increase in the thickness of the epidermis, expressed strongly in the stratum corneum. This was also confirmed by the increase in the Ki67 index, which is a marker of cellular proliferation. Increased expression of genes encoding factors involved in the differentiation of keratinocytes was observed, among others, caspase 14 (CASP14) and calcium-sensitive receptor (CaSR), as well as reduced expression of protease-activated receptors (PAR2) also involved in the formation of keratinocytes. In addition, an increase in the expression of adhesion factors has been demonstrated in, among others, CDSN, DSG1 and e-cadherin, which explains the delay in the process of stratum corneum exfoliation in the pathogenesis of cornea [1] (figure 1).

3. Risk factors

Factors that may be associated with high probability of calluses formation have been identified. A

commonly occurring risk factor is the use of improperly fitting footwear, especially tight or improperly made (low quality of materials, irregular shape). Foot and toe deformities and foot mobility disorders may also predispose to the formation of calluses. These abnormalities may occur in congenital deformations such as hollow foot, or be acquired as in the case of hallux valgus and mallet fingers, or secondary to diseases such as diabetes (especially complicated by neuropathy), as well as rheumatoid arthritis (RA). Other risk factors may be a high level of physical activity leading to mechanical overload of the foot, as well as the state after osteotomy surgery within the foot [6,9]. There was also a higher incidence of calluses in women, which is explained by the use of high heels, which is often less well-fitting [5]. It has also been proven that body weight can be positively correlated with plantar pressure values in patients with diabetes, which may predispose to calluses [10,11]. However, other authors suggest that a lower BMI level may be associated with the presence of a thinner layer of the plantar fat pad, which may be a factor favoring the formation of calluses [6].

Risk factors often co-exist with each other. Patients with diabetes are an extremely strained group of patients, which can serve as a model reflecting a multitude of factors occurring in one patient predisposing to the formation of calluses, which may interfere with each other. In diabetic patients complicated with neuropathy, both muscular dystrophy secondary to neuropathy as well as foot deformation secondary to this process are observed. In turn, disturbances of glycogen metabolism, which are also a secondary process to neuropathy, reduce the mobility of the joints. In addition, in the case of ill-chosen footwear in these patients synergism of adverse factors occurs, which can lead to hard-healing foot ulcers [6]. This was confirmed by studies in which patients with diabetes had an increase in plantar pressure [12]. It has been shown that the presence of hallux valgus and stigma is associated with an increase in pressure in the middle part of the forefoot, while the increase in pressure in the lateral parts of the forefoot positively correlated with an increased BMI [11]. Patients with rheumatoid arthritis (RA) are the second group of patients with significant risk of developing calluses. In the case of this disease secondary deformities of the feet are observed, as well as movement deficits of the joints, which, as noted earlier, predisposes to the formation of foot calluses[13].

4. Prevention

Undoubtedly, an important aspect in preventing the occurrence of calluses is proper care and apt hydration of the skin of the feet. Hyperkeratotic changes in the skin of the feet, such as corns and calluses, have been shown to have a 3-fold lower hydration level and nearly 2-fold lower elasticity

[14]. Prophylactic and therapeutic shoes can be used both on a daily basis and during physical activity. It may also be beneficial to use shoe inserts and orthoses [5]. In the presence of deformation of the foot that predisposes the formation of calluses, such as hallux valgus, surgical correction leads to regression of callous lesions, which may indicate an important role of early corrective intervention as a prophylactic factor in the occurrence of foot calluses [15]. However, when a patient has a disease that predisposes to the secondary formation of calluses in its course, such as diabetes, an essential element of prophylaxis to maintain the proper condition of the feet is adequate control of the underlying disease, in this case the level of glycaemia and regular medical visits including control of skin condition of the feet [16].

5. The effectiveness of therapeutic methods

Currently available options for treating foot calluses include the local use of chemicals to accelerate the exfoliation of calluses, cryosurgery, electrosurgery, the use of orthoses and scalpel debridement. In the case of ineffectiveness of these methods or significant complications, more advanced methods of surgical treatment are applied [17,18].

Before starting treatment, attention should be paid to worrying symptoms accompanying the calluses of the feet, eg difficult to heal wounds. The case of the location of a rare form of squamous cell carcinoma of the skin of the soles (Carcinoma cuniculatum) growing in the area of callus has been described [19]. When assessing the results of clinical trials demonstrating the effect of scalpel debridement on plantar pressure values, one should remember about the relatively low diagnostic value of pedobarography in the case of foot calluses [20].

5.1. Orthotic devices

Studies were carried out to assess the effect of orthotopic devices (minimum 7 hours per day) compared to standard podiatric care for callus morphology, changes in gait parameters and biomechanics of lower limbs. In addition, vascular flow in the patients' feet arteries were evaluated using Doppler ultrasound. Standard podiatric care included the removal of callous, skin deep layer calluses, and moisturizing, as well as the use of hypoallergenic insoles. The study group consisted of 20 people with foot calluses (15 women and 5 men) in the average age of 66 years. Observations were carried out for a period of 12 months, monitoring the condition of patients every 3 months. There was a statistically significant improvement ($p < 0.02$) in 16 of the 22 orthosis treated calluses with no adverse effects, while in the standard group of patients the vast majority of calluses

remained unchanged (23), condition of 7 worsened, and only in the case of two patients improved [18].

5.2. Treatment with topical preparations

Hashmi et al. conducted a study evaluating the effectiveness of three popular methods of treating foot calluses. Two of them - included local therapy with 40% solution of potasium hydroxide, and trichloroacetic acid, while the third method was invasive podological treatment consisting in scalpel debridement. Observation of each patient treated with one of the selected methods was carried out on 7th, 14th, and 21st day after the procedure. In all three groups, there was a significant reduction in pain and improvement in functionality. However, in terms of skin morphology assessment, podological treatment showed an advantage over other methods [2].
The topical use of urea-containing agents may result in improved hyperkeratotic states [16]. In a study conducted by Pham et al. after 4 weeks of using a cream containing urea (10%) and lactic acid (4%), a significant improvement was noted compared to placebo ($p < 0.01$) [21]. Similar results were obtained by Ademola et al. investigating the effect of applying a cream containing 40% urea compared to a cream containing 12.5% ammonium lactate on moderate and severe forms of hyperkeratosis of the skin of the feet in a group of 25 patients. After 2 weeks, the group using the cream containing urea showed a significant improvement in the clinical condition of the foot skin ($p < 0.05$) [22].

The method combining the use of an ointment containing kantharidine (1%), salicylic acid (30%), podophylline (5%), and removal with a scalpel was also evaluated. The study was carried out on a group of 72 patients, of which 65 had foot calluses. The follow-up time for each patient was 16 months on average. In 79.2% of cases, a positive treatment result was achieved after the first treatment session, while 8.3% required more than 2 treatment sessions (maximum 4) [7].

5.3. Scalpel debridement

In a 14-center study conducted on a group of 79 patients (34% of women versus 66% of men) aged 21 to 90 years, a significant reduction in pain after scalpel debridement was demonstrated. To determine the intensity of pain, a visual analog scale (VAS) with a span of 100 mm was used. The median of perceived pain before the procedure was 69 mm, while after the surgery it was reduced to 9.5 mm, which corresponds to a difference of 86% [23]. Differing results were obtained by Langdorf et al. who also studied the influence of scalpel debridement of calluses on pain reduction

with 100 mm VAS scale. Patients whose average age was 72.5 years (63% women) were divided into two groups. In the first group, the actual scalpel debridement of calluses was performed, while in the second group, this procedure was simulated using a blunt scalpel blade. The initial level of pain was estimated at 51 mm. The improvement of pain in both groups was demonstrated (with the predominance of pain relief in the group of real debridement), assessed immediately after the procedure, as well as after 1 and 3 weeks. After 5 and 6 weeks, the pain was similar, but lower than the initial pain in both groups. There was no statistically significant difference between the group of real or mock calluses' removal [24]. The CARROT study evaluated the effect of combining conservative therapy with the scalpel debridement of calluses compared to the use of conservative therapy alone in the treatment of pain associated with the occurrence of calluses in patients with RA. Conservative treatment included patient education, advice on the use of appropriate footwear, the use of orthoses, and emollients, as well as weekly rubbing of calluses with a file or pumice. Patients over 50 years of age participated in the study. 8 therapeutic visits were carried out and the study period was 18 months. The final results did not indicate significant differences in groups' perception of pain measured with the VAS scale, as well as in the change in gait parameters [25]. These results were in line with the conclusions of a study conducted by Woodburn et al., who showed only short-term, lasting 7 days, reduction of pain after debridement the calluses with a scalpel in patients with RA [26]. Also in an experiment conducted by Davys on a group of 38 patients, there was no statistically significant difference in pain reduction assessed on the VAS scale after 4 weeks ($P = 0.48$) from the procedure between patients who had the calluses removed with a scalpel and a group of patients, in which the surgery was staged. There was an improvement in gait parameters and reduction of plantar pressure ($P = 0.16$) at the calluses' location, however, these measurements also did not reach the statistical significance level [13]. Another study, among 17 diabetic patients with a total of 43 foot calluses, showed an average of 26% ($p < 0.001$) plantar foot pressure reduction in 37 of 43 treated areas after removal of the callus with a scalpel [27].

5.4. Laser treatment

In a study conducted by Balevi et al., the efficacy of callus care with the Er:YAG laser was evaluated. The participants of the study were 70 patients, including 32 women and 38 men aged 15-50 years. A total of 102 changes were treated, resulting in complete removal in 90.2% of cases, and partial in 9.8%. Only 16 patients required more than 1 therapy session, a maximum of 4 sessions were carried out for 2 patients. The most frequently observed complications were pain (14.2%), and post-inflammatory discoloration (2.8%). The relapse rate was estimated at 17.6% and the average time to recurrence was 18 weeks. In addition, 80% of patients declared complete satisfaction with

the therapeutic effects [17].

5.5. Application of osteotomies

The influence of a straight distal osteotomy of the metatarsal bones on the treatment of callosity unresponsive to other treatment methods was assessed. For the purpose of the study, 13 patients were selected (8 women and 5 men) at the average age of 48 years, in whom 25 calluses were found. The follow-up period was 7 years. Regression changes occurred in 92% of cases. In two cases, it was necessary to perform a second, oblique osteotomy. In 12 feet, there was a disturbance in the transverse arch architecture of the foot. The subjective evaluation of the procedure was positive in 60% of cases. The cosmetic effect of wound healing in 10 cases was below expectations [28]. Kitaoka et al. also evaluated the effectiveness of distal osteotomy in patients with calluses, in which other methods proved to be ineffective. The operation was performed on 19 patients (21 feet) at the average age of 59 years and the average duration of treatment effect was 4 years. A positive result was achieved in 76% of cases (16 feet) [29]. Another study demonstrated the efficacy of hallux valgus correction in the regression of accompanying foot calluses. The study involved 31 patients, hallux valgus and callus abnormalities were found on 40 feet. Abnormal keratosis and pain resolved in 80% of cases, while pain relief was reported in 12.5% of cases, but culluses were still present, while 7.5% of patients showed no improvement [15].

To the best of our knowledge, no clinical trials have been published to evaluate the use of cryosurgery and electrosurgery in the treatment of foot calluses. Improving the knowledge of the effectiveness of these methods by conducting appropriate tests is advisable in order to improve the methods of management in patients with calluses, especially in cases in which co-morbidities may further limit the range of available therapeutic methods.

6. Conclusions

The occurrence of foot calluses is often an underestimated problem, which, apart from the unfavorable aesthetic aspect, may have serious clinical implications in the form of pain, gait and balance disturbances, and in extreme cases, bleeding. In people suffering from diabetes, calluses can cause foot ulcers. Despite the research on many therapeutic methods, definite therapeutic standards for specific groups of patients are still not described. Further research leading to the deepening of knowledge about the causes of the formation of calluses and the effectiveness of individual therapeutic methods in selected groups of patients are recommended in order to learn the

appropriate treatment options for them.

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