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Management of First Metatarsophalangeal Joint Pain in Runners with Extracorporeal Shockwave Therapy and Physical Therapy

Behandlung von Schmerzen im ersten Metatarsophalangeal-Gelenk bei Läufern mittels Physiotherapie und extrakorporaler Stoßwellentherapie

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Summary

- **Problem:** The first metatarsophalangeal (MTP) joint can become painful in runners and limit ability to remain active. Extracorporeal shockwave therapy (ESWT) is a conservative treatment option for musculoskeletal disorders due to its proposed effect on tissue remodeling and pain modulation and is best combined with physical therapy (PT). We hypothesized that a portion of runners with first MTP pain treated with ESWT and PT would achieve functional improvements.
- **Methods:** Chart review identified 21 runners who received ESWT and PT for first MTP joint pain. Functional outcomes were quantified using the Foot and Ankle Ability Measure (FAAM) prior to and following treatment, and patients meeting minimally clinically important differences (MCID) was the primary outcome of interest. Each runner received a minimum of three sessions of ESWT over the MTP joint, and PT focused on intrinsic foot strengthening and joint mobilization.
- **Results:** MCID was achievable in either FAAM ADL and/or FAAM Sports subscales for 15 of 21 runners, of whom 9 of 15 (60%) met MCID in one or both subscales. FAAM Sports subscale improved from pre-treatment median of 12 to best post-treatment median of 23 (p=0.0049) after a median time of 3 weeks.
- **Discussion:** ESWT combined with PT may be an effective and well-tolerated treatment for runners with first MTP joint pain in whom other conservative management has failed. Most included runners treated with ESWT and PT had improved function.

KEY WORDS:
Foot, Running, Rehabilitation

Zusammenfassung

- **Problem:** Das erste Metatarsophalangealgelenk (MTP-1) kann bei Läufern schmerzhaft werden und die Aktivität einschränken. Die extrakorporale Stoßwellentherapie (ESWT) ist aufgrund ihrer Wirkung auf den Gewebeumbau und die Schmerzmodulation eine konservative Behandlungsoption für muskuloskelettale Beschwerden und wird am besten mit Physiotherapie (PT) kombiniert. Wir stellten die Hypothese auf, dass ein Teil der Läufer mit Schmerzen im MTP-1, die mit ESWT+PT behandelt wurden, funktionelle Verbesserungen erzielen.
- **Methoden:** In den Krankenakten wurden 21 Läufer identifiziert, die wegen Schmerzen im MTP-1 mit ESWT+PT behandelt wurden. Die funktionellen Ergebnisse wurden mit dem Foot and Ankle Ability Measure (FAAM) vor und nach der Behandlung quantifiziert, wobei das Erreichen der minimalen klinisch bedeutsamen Differenz (MCID) das primäre Outcome war. Alle Läufer erhielten mindestens 3 Sitzungen ESWT über dem MTP-1, und die PT konzentrierte sich auf die Stärkung der intrinsischen Fußmuskulatur und Gelenkmobilisierung.
- **Ergebnisse:** Bei 15 von 21 Läufern wurde der MCID entweder in der FAAM-ADL-Subskala und/oder der FAAM-Sport-Subskala erreicht, wobei 9 von 15 (60%) die MCID in einer oder beiden Subskalen erreichten. Die FAAM-Sport-Subskala verbesserte sich von einem Median von 12 vor der Behandlung auf einen Medianwert von 23 nach der Behandlung im Mittel nach 3 Wochen (p=0,0049).
- **Diskussion:** ESWT in Kombination mit PT kann eine wirksame und gut verträgliche Behandlung für Laufsportler mit Schmerzen im MTP-1 sein, bei denen andere konservative Behandlungen versagt haben. Bei den meisten Läufer, die wegen Schmerzen im MTP-1 mit ESWT +PT behandelt wurden, verbesserte sich die Funktion.

SCHLÜSSELWÖRTER:
Fuß, Laufen, Rehabilitation

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Introduction

The first metatarsophalangeal (MTP) joint serves a critical role in foot function. From a biomechanical perspective, the first MTP joint experiences loads up to 40 to 60 percent of body weight during a normal gait cycle and may exceed two to three times body weight during jogging or running (1). Pain and impaired mobility at the hallux limits generation of forward propulsive power, and therefore may contribute to major impairments in running performance. Clinical experience suggests that pain and functional limitations in first MTP mobility may also contribute to secondary injuries due to altered biomechanics in runners.

Initial management for painful pathologies involving the first MTP joint is largely supportive and focused on reducing pain, alleviating ›

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Table 1

Demographics and clinical characteristics.

ID	GENDER	AGE	SYMPTOM DURATION (MONTHS)	BMI	LATERALITY	TRAUMATIC?	CONCOMITANT SITES OF TREATMENT/DIAGNOSES
1	Female	28	18	22,7	Left	Yes	None
2	Female	38	12	25,75	Left	Yes	Left plantar fasciitis
3	Female	52	15	25,1	Right	Yes	Bilateral knee osteoarthritis
4	Male	51	36	Unspecified	Right	Yes	None
5	Female	53	"years"	18,42	Right	Yes	Bilateral hamstrings tendinopathy
6	Female	58	"years"	20,6	Left	No	Left hamstring tendinopathy
7	Female	40	22	27,95	Right	No	Unspecified right calf pain
8	Male	42	Unspecified	22	Left	No	Left abductor digiti minimi tendinopathy
9	Male	35	24	Unspecified	Right	No	Left iliotibial band syndrome
10	Female	23	6	23,4	Left	Yes	None
11	Female	30	20	21,3	Bilateral	No	Bilateral flexor hallucis longus tendinopathy, bilateral sesamoiditis
12	Male	33	43	24,07	Right	Yes	None
13	Female	39	Unspecified	Unspecified	Left	Yes	Bilateral plantar fasciitis, bilateral tibialis posterior tendinopathy
14	Female	55	10	20,8	Bilateral	No	Right tibialis posterior tendinopathy
15	Female	28	60	22,6	Left	No	Left sesamoiditis, left tibialis posterior tendinopathy
16	Male	43	1	22	Left	No	Left abductor digiti minimi tendinopathy
17	Male	61	“years”	21,54	Right	No	Right distal quadriceps tendinopathy
18	Female	48	Unspecified	19	Left	No	Left proximal hamstrings tendinopathy, left piriformis pain
19	Male	38	72	37,81	Left	No	Bilateral plantar fasciitis, bilateral tibialis posterior tendinopathy
20	Male	21	14	21,6	Bilateral	No	Bilateral sesamoid bone stress injury
21	Female	60	1	22,3	Bilateral	No	Bilateral Achilles tendinopathy, bilateral plantar fasciitis

joint stress, and improving function. These may include oral or topical analgesics, shoe modifications, and injections with either hyaluronic acid or corticosteroid. While not uniformly prescribed, physical therapy focused on intrinsic foot muscle strengthening, joint mobilization, and stability can be effective at reducing pain and addressing impairments (5, 8). Surgical treatment is considered for patients with persistent pain and dysfunction despite conservative treatment. Prior to surgery, patients are counseled on the possibility of persistent pain and prolonged activity restriction (generally 6-8 weeks) (1).

Extracorporeal shockwave therapy (ESWT) is a non-surgical treatment option for painful musculoskeletal conditions and allows for faster return to activity compared to other interventions (6). Radial-ESWT (R-SWT) propagates energy to target tissue from its contact point on the skin surface via a pneumatic or ballistic device. Focused-ESWT (F-SWT) generates higher energy sound waves from electromagnetic, electrohydraulic, and piezoelectric devices that concentrate force at a greater tissue depth compared to R-SWT (4). Shockwaves have been shown to induce cellular processes that promote blood flow and tissue remodeling (10, 11, 13). Radial and focused shockwaves may directly reduce musculoskeletal pain through proposed mechanisms: 1.) hyper-stimulating nociceptive fibers resulting in impaired propagation of the painful impulse (i.e. the gate-control theory), 2.) locally increasing pain-inhibiting substances, and 3.) altering of pain receptor cell membrane potential, thereby impairing transmission of pain signal (2, 6, 7).

Recent reviews have suggested ESWT may be effective for a variety of soft tissue, bone, and joint pathologies (6, 12). However, there is a paucity of literature to support the use of ESWT for first MTP joint pain. The purpose of this case series was to assess changes in functional outcomes after treatment with ESWT in conjunction with a physical therapy (PT) program focused on foot core strengthening and stabilization in a cohort of runners with first MTP joint pain. We hypothesized that most patients would achieve functional improvements following treatment with ESWT and PT.

Methods

Patients

Approval was obtained from our institution’s quality improvement chair and determined as exempt from IRB approval. A retrospective chart review was performed of all patients who received ESWT at a single outpatient sports medicine clinic for management of first MTP joint pain from August 2018 to April 2022. Clinical data obtained included demographic data, diagnosis, treatment characteristics, and functional outcomes. Inclusion criteria were: 1.) received ESWT for first MTP joint pain 2.) underwent concurrent foot core physical therapy 3.) performed running as physical activity or sport. Exclusion criteria included presence of systemic rheumatologic disease or not completing baseline or follow-up functional outcome measures.

Of initial 37 total patients who received ESWT for MTP joint pain, one was excluded due to systemic rheumatologic disease, 8 were excluded due to incomplete or absent functional outcome measures and 7 were excluded as they did not self-identify as runners. This resulted in 21 runners included in analysis (figure 1).

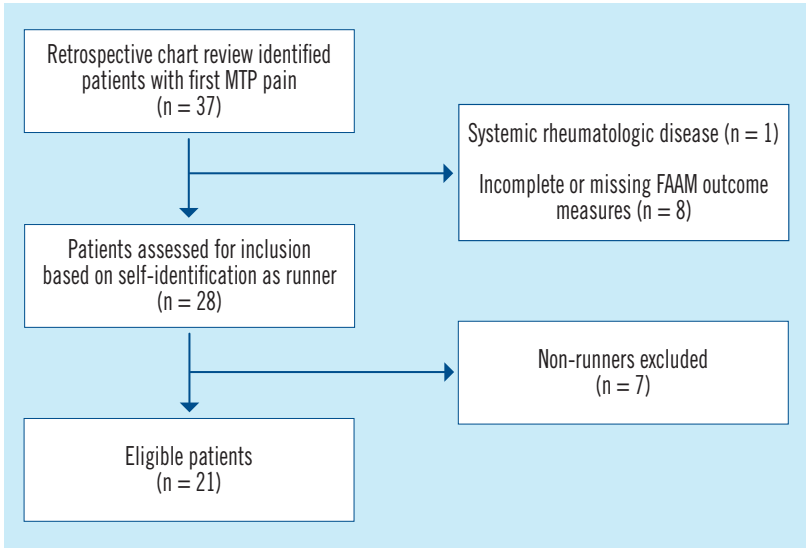

Figure 1

Data collection flowchart. FAAM=foot and ankle ability measure.

Functional Outcomes and Follow Up

Functional outcomes were completed by the patients at baseline and at follow-up visits using the Foot and Ankle Ability Measure (FAAM). The FAAM is an outcome measure divided into two subscales, Activities of Daily Living (ADL) and Sports. The ADL subscale ranges from 0 to 84 points (no limitations), while the Sports subscale ranges from 0 to 32 points (full performance).

The primary outcome measure of interest was meeting the Minimally Clinically Important Difference (MCID) for FAAM subscales of ADL and Sports. MCID in patients with lower leg, foot, and ankle pathology has been published to be an improvement of 8 points for the FAAM ADL subscale and an improvement of 9 points for the FAAM Sports subscale (3). Given that there are thresholds to meet MCID for FAAM subscales, MCID achievability was determined by baseline subscale scores. Patients with FAAM ADL baseline scores of 76 or less or FAAM Sports scores of 23 or less were considered to have potential to achieve MCID. Patients with FAAM ADL baseline scores greater than 76 or FAAM Sports scores greater than 23 were considered unable to achieve MCID as their maximal possible improvement was lower than the MCID thresholds. These patients were excluded in the primary analysis of proportion of patients meeting MCID to account for ceiling effects of treatment at high pre-treatment FAAM scores.

FAAM measures were collected on the date of first ESWT treatment, at follow-up visits, and after additional treatment with ESWT. Duration in weeks for the patient to achieve the highest FAAM composite scores was obtained via chart review. If a subject's FAAM outcomes were the same at more than one follow-up visit, the shortest follow-up time to achieve their highest FAAM score is reported. FAAM scores at follow-up times greater than or equal to 52 weeks were excluded from analysis, due to concerns that functional gains one year following initial treatment could not be fully accounted for by the treatment with ESWT and PT.

Shockwave Procedure

Patients received a minimum of three weekly ESWT sessions in the clinic of the senior author (A.S.T.) with additional sessions recommended based on treatment response at follow-up appointments. Patients received either F-SWT, R-SWT, or a combination of both (C-SWT). R-SWT treatments were performed using the Storz Extracorporeal pulse activation technology (EPAT®) device (Storz Medical, Tägerwilen, Switzerland). The R-SWT treatment included a minimum of 3000 counts of radial pressure waves at 2 to 3 bars at 12 to 15 Hz using different applicator heads. The F-SWT (Storz Duolith, Tägerwilen, Switzerland) was applied for minimum of 1000 pulses at minimum of 0.07 mJ over similar anatomic areas as the radial pressure device, targeting areas of pain (9). The entire first MTP joint capsule was explored during treatment, and treatment was applied to sites of maximal pain. Additional treatment was applied over secondary structures, including the tibial and fibular hallux sesamoid bones, flexor hallucis longus, and extensor hallucis longus to address components of pain arising from tendon actions on the first MTP joint.

No topical or regional anesthetic was applied. All patients were instructed to avoid NSAIDs and icing after treatment. Patients were concurrently prescribed PT. Activities including running were allowed as tolerated following each ESWT session unless pain was worse after treatment.

Number of treatment sessions needed was determined based on a combination of clinical judgment and response to treatment. Follow-up visits were generally scheduled in 6 to 8 weeks after the initial series of weekly ESWT treatment. At repeat clinic visits, further ESWT was offered to patients who did not report sufficient relief.

Physical Therapy and Manipulation

All patients were concurrently prescribed a PT regimen focused on the foot core principles and manual manipulation of the first MTP joint, with a protocol published previously (9). Briefly, foot core exercises include toe spreads, toe yoga, and doming. Toe spreads are done by repeatedly abducting and adducting the toes, thereby strengthening the abductor hallucis, among other foot intrinsic muscles (figure 2a). Toe yoga involves first extending the first MTP with the small toes on the ground, then alternating by holding the first MTP on the ground and extending the small toes (figure 2b). Doming involves engaging the foot's intrinsic muscles by stabilizing the toes and lifting the arch of the foot (figure 2c). These exercises were prescribed with graded progression into weightbearing and single-leg activities. Plyometrics were introduced to reinforce functional use of the first MTP joint to help return a patient to running. Manipulation of the first MTP joint primarily involved axial distraction followed by manual dorsal and plantar glides to improve flexion and extension at the joint. Patients were instructed in self-first MTP mobilization and range of motion exercises to perform daily at home. Foot extrinsic, especially calf, strengthening, and range of motion exercises were also prescribed.

Statistical Analysis

Median and interquartile ranges were calculated to characterize data. The Shaprio-Wilk test was performed to test the normality of FAAM ADL and FAAM Sports subscale scores and sho- ›

Table 2

Results. PT=physical therapy; ESWT=extracorporeal shockwave therapy; FAAM=Foot and Ankle Ability Measure; MCID=minimally clinically important difference; ADL=activities of daily living. *=Denotes achieved MCID.

ID	PRIOR TREATMENTS	NO. OF ESWT SESSIONS	ESWT CHARACTERISTICS	FAAM ADL MCID ACHIEVABLE?	FAAM ADL CHANGE	FOLLOW UP TIME TO BEST FAAM ADL (WEEKS)	FAAM SPORTS MCID ACHIEVABLE?	FAAM SPORTS CHANGE	FOLLOW UP TIME TO BEST FAAM SPORTS (WEEKS)
1	PT	4	4 focused: 0.25mJ, 3000 pulses	No	4	2	No	6	2
2	PT	5	5 focused: 0.25mJ, 1000 pulses	No	2	3	No	0	4
3	PT	5	5 focused: 0.15mJ, 1500 pulses	Yes	23*	18	Yes	12*	4
4	Self-directed PT	5	5 focused: 0.4 to 0.55 mJ, 2000 pulses	No	2	11	No	6	2
5	Steroid injection	6	6 combined: Radial: 15Hz, 2bar, 3000 pulses; Focused: 0.1mJ, 1000 pulses	Yes	11*	3	Yes	0	3
6	Previous bunionectomy	6	6 focused: 0.25mJ, 3000 pulses	Yes	3	4	No	1	4
7	PT, steroid injection, boot immobilization, rest	8	1 x Radial: 12Hz, 2bar, 3000 pulses. 7 x Focused: 0.15mJ, 2000 pulses	Yes	13*	10	Yes	10*	3
8	Unspecified	3	3 focused: 0.3mJ, 3000 pulses	No	-4	20	Yes	5	2
9	Unspecified	3	3 focused: 0.12mJ, 2000 pulses	No	4	2	Yes	13*	11
10	Steroid injection	6	6 focused: 0.15 – 0.2mJ, 2000 pulses	Yes	8*	28	Yes	12*	28
11	Steroid injection	3	3 focused: 0.25mJ, 1000 pulses	Yes	6	3	Yes	13*	3
12	Previous chevron osteotomy	4	4 focused: 0.25mJ, 3000 pulses	Yes	10*	5	Yes	0	5
13	Unspecified	5	5 focused: 0.2mJ, 1000 pulses	Yes	-4	2	Yes	-3	2
14	PT	6	6 focused: 0.2mJ; 1000 pulses	Yes	13*	13	Yes	3	13
15	Rest	5	5 focused: 0.15mJ; 1000 pulses	No	-2	14	Yes	-9	14
16	PT	3	3 focused: 0.3mJ; 3000 pulses	No	-4	2	Yes	3	2
17	Unspecified	3	3 focused: 0.25mJ; 1000 pulses	No	-7	2	No	0	2
18	Unspecified	4	4 focused: 0.12mJ; 1000 pulses	No	2	3	No	1	3
19	Orthotics	3	3 focused: 0.12mJ; 1000 pulses	Yes	8*	6	Yes	12*	6
20	Boot immobilization, orthotics	4	4 focused: 0.2 mJ: 1500 pulses	Yes	-16	3	Yes	-1	3
21	PT	3	3 focused: 0.1mJ; 1500 pulses	No	4	2	No	7	2

wed significant deviation from a normal distribution. Therefore, Wilcoxon signed-rank tests were used to compare baseline and follow-up FAAM ADL and FAAM Sports scores. To best observe the overall trend of treatment response in our cohort, patients who could not meet MCID were included in statistical analysis. Mann-Whitney test was conducted to compare the duration of follow-up between those who met MCID and those who did not meet MCID. A two-sided p-value <0.05 was considered statistically significant. Statistical analysis was performed using STATA Version 16 (StataCorp, LLC, College Station, Texas).

Results

Demographics

The cohort studied was primarily female gender (n=15, 71.4%), with median age 40 years old (IQR 33.5 to 51.5 years old) and BMI 22.2 kg/m^2 (IQR 21.2 to 24.3 kg/m^2). Eight patients (38%) attributed onset of symptoms following a prior traumatic injury to the affected first MTP joint. All patients had failed various alternative treatment strategies including boot immobilization, rest, physical therapy, steroid injection, and in some cases surgical intervention (table 1).

Outcomes

The MCID was achievable in the FAAM ADL subscale for 11 of 21 patients (based on baseline score of 76 or less). Seven of those 11 patients (63.6%) met MCID. The MCID was achievable in the FAAM Sports subscale for 14 of 21 patients (based on baseline score of 23 or less). Six of those 14 patients (42.8%) met MCID. MCID was achievable in either FAAM ADL and/or FAAM Sports subscales for 15 of 21 patients, of which 9 of 15 patients (60%) met MCID in one or both subscales.

FAAM Sports subscale improved from pre-treatment median of 12 (IQR 11 to 24) to final best post-treatment median of 23 (IQR 14 to 30), p=0.0049. FAAM ADL subscale was similar pre- and post-treatment, from pre-treatment score of 76 (IQR 51 to 81) to final best post-treatment median score of 74 (IQR 64 to 83) (table 2), p=0.109. Both best post-treatment FAAM ADL and Sports subscale scores were reached at median of 3 weeks (range 2 to 28 weeks). Descriptively, values were greater in 15 of 21 (71.4%) patients for the FAAM ADL subscale and 14 of 21 (66.7%) patients for FAAM Sports subscale. The values were higher in 17 of 21 (80.9%) patients in either FAAM ADL or FAAM Sports subscale.

Figure 2

Illustration of key foot exercises and shockwave therapy. 2a=toe spreads; 2b=toe yoga; 2c=foot doming, 2d=application of focused shockwave to first MTP joint.

One patient (patient 2) went on to pursue dorsal cheilectomy, and another patient (patient 20) opted for PRP after not achieving satisfactory results following initial ESWT.

Adverse Effects

One patient reported calf pain on the ipsilateral side beginning after initial shockwave treatment. A separate patient sustained a stress fracture of the third metatarsal on the ipsilateral side during progression to return to running. Otherwise, no significant adverse outcomes were observed.

Discussion

The purpose of this case series was to describe outcomes in a population of runners receiving ESWT combined with PT to treat first MTP joint pain. Most runners achieved functional improvement using FAAM measures in ADL and sports outcomes. ESWT was well-tolerated, and no significant adverse effects were reported directly from treatment. The results of our study suggest that ESWT may provide an effective and noninvasive alternative means of achieving functional gains in sport for runners who have failed initial conservative measures and who wish to avoid the relatively long period of rest required following more invasive treatment measures.

While ESWT is well described in a variety of soft-tissue musculoskeletal conditions, our findings add to the growing body of literature on the effects of ESWT on management of joint pain. ESWT exerts its effects through a variety of biological mechanisms to improve pain relief, regulate inflammation, and promote tissue healing. Existing literature suggests that functional benefits and pain relief from ESWT may last months to years after treatment (6, 12). The mechanism of the therapeutic effect of ESWT on the first MTP joint is unknown. It is possible that ESWT has an analgesic and tissue remodeling effect on the joint capsule and surrounding secondary structures including the sesamoid bones, the EHL, and FHL tendons. Further, anti-inflammatory and tissue remodeling effects induced by ESWT could reduce capsular stiffness and decrease pain signals at the joint. ESWT, in conjunction with PT, focused on intrinsic foot muscle strength, joint mobility, and stability may help patients improve function, and reinforce range of motion of the first MTP joint. The results from the current study provide relevant clinical rationale for treating first MTP pathology using ESWT in conjunction with foot core PT program. Future studies should compare ESWT with and without specific foot core PT to investigate the additive effect of focused PT on clinical outcomes.

While this report is the first published report describing outcomes with ESWT and foot core PT for management of first MTP joint pain, our report has limitations. The population treated was from a sports medicine clinic with an emphasis on running medicine, so many patients may seek treatment due to impairments with higher-level performance goals rather than ADL-related impairments. For example, one runner opted for surgical intervention due to refractory symptoms despite high baseline FAAM scores. Additionally, while most runners experienced gains using the FAAM ADL and Sports subscales, many did not achieve changes that met MCID in part due to high baseline scores (3). Out-of-pocket expense of ESWT may have contributed to selection bias and likelihood of improvements in this study. We included variable degrees of first MTP joint pathology and mechanism of injury. Runners had unique clinical courses in terms of prior treatments attempted and timeline to presentation for trial of ESWT. Many runners completed co-treatment with other sites in the lower extremity, which may have affected outcomes. Although all PT was prescribed to focus on foot core and range of motion work, we experienced heterogeneity of actual PT exercises due to concomitant PT at other sites, varying numbers of PT sessions, and multiple therapists being involved in patient care. Finally, follow-up times were not standardized, and our study included no control group. Future studies should aim to compare ESWT to a control intervention at standardized interval follow-up time points to better evaluate how physiological changes induced by ESWT translate to both short- and long-term clinical outcomes of ESWT in joint pathology. ›

This report is meant to serve as a description of the utility of ESWT in combination with foot core PT as an innovative conservative measure to treat first MTP joint pain in runners. These results may serve as rationale for further prospective investigation into the utility of ESWT in treatment of first MTP joint pain.

Conflict of Interest

The authors have no conflict of interest.

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