ARTICLE IN PRESS

Archives of Rehabilitation Research and Clinical Translation (2026) 000, 100626

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Rehabilitation Research and Clinical Translation

Archives of Rehabilitation Research and Clinical Translation 2026;000:100626

Available online at www.sciencedirect.com

Case Report

Safety and Feasibility of Early Aquatic Physical Therapy for Military Survivors of Gunshot Wounds and Blast Injuries: A Case Series

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KEYWORDS
Aquatic physical therapy;
Blast injury;
Early mobilization;
Feasibility;
Gunshot wound;
Infection prevention and control;
Rehabilitation;
Safety

Abstract This study evaluated the safety and feasibility of early aquatic physical therapy (APT) for gunshot wounds (GSWs) and/or blast injuries (BIs). Early aquatic physical therapy (eAPT) is defined as "therapy conducted within the first month after injury, considering the injury type, setting, and environment." APT facilitates the restoration of mobility and function after illness or injury. Although APT is helpful for patients with mobility issues, muscle weakness, and pain, its early use in high-functioning adults recovering from ballistic trauma remains underexplored. Usually, multidisciplinary rehabilitation occurs on land in sterile settings because of infection risks from GSWs and BIs. Water exercise offers a controlled, low-impact environment for recovery; however, precautions, particularly for infection prevention and control, are essential. Three case studies are described, all of whom received mobilization in water within their first month after injury. Two patients sustained only GSW, and a third experienced a combined GSW and BI. Participants also received conventional multidisciplinary treatment and were followed up for almost 7 months. Adverse events, feasibility, and functional improvements were assessed. Range of motion assessment, the manual muscle test, and the FIM instrument were used to evaluate progress. The eAPT program was feasible for all 3 patients who completed it. Noninfected open wounds were covered with waterproof dressings before eAPT, and assistance was provided and at the poolside, on steps, and during pool entry and exit using hoists. Exercises were performed at a safe water depth. No adverse events occurred, and patients showed clear functional improvements in and out of the water. eAPT appears to be a safe, feasible adjunct to early

List of abbreviations: APT, aquatic physical therapy; BI, blast injury; eAPT, early aquatic physical therapy; GSW, gunshot wound; MMT, manual muscle test; ROM, range of motion; VAS, visual analog scale.
Cite this article as: Arch Rehabil Res Clin Transl. 2026;000:100626

https://doi.org/10.1016/j.arrct.2026.100626

rehabilitation after complex ballistic or blast trauma, supporting further investigation into its broader clinical application.

Aquatic physical therapy (APT) is a well-established rehabilitation modality typically performed in heated therapeutic pools, where the physical properties of water—buoyancy, hydrostatic pressure, viscosity, and thermal effects—are used to facilitate movement and functional recovery.[1,2] These properties allow patients to engage in exercises that may not yet be possible on land because of pain, weakness, instability, or weight bearing restrictions. The buoyant environment reduces joint loading and perceived effort, while hydrostatic pressure assists venous return and edema control. The thermoneutral warmth of the water further promotes muscle relaxation, pain modulation, and autonomic regulation. Collectively, APT has demonstrated benefits including pain reduction, improved range of motion (ROM), enhanced endurance, and reduced physical and psychological stress.[3]

In this study, early APT (eAPT) is defined as "initiating water-based therapy within approximately one month of injury, after formal assessment of wound status, respiratory function, psychological readiness, and exclusion of contraindications." This timeframe intentionally precedes the conventional initiation period for aquatic rehabilitation after trauma and differs from standard orthopedic practice, where aquatic therapy is often delayed until wounds are fully healed and mobility limitations stabilized.

Gunshot wounds (GSWs) and blast injuries (BIs) represent complex, high-energy trauma patterns that require coordinated multidisciplinary management across acute, surgical, and rehabilitation phases.[4] Unlike typical orthopedic populations frequently referred for aquatic therapy, such as individuals with degenerative joint disease, postoperative joint replacement, or chronic lower back pain,[1] patients sustaining high-energy GSWs or BIs present with distinctive physiological and psychological challenges that introduce uncertainty regarding the safety and practicality of early immersion.

Tissue destruction after a GSW is determined not only by bullet trajectory but by kinetic energy transfer, which may result in extensive soft tissue disruption, cavitation, vascular compromise, contamination, and neurovascular injury. High-energy ballistic trauma commonly requires staged surgical intervention, prolonged antibiotic prophylaxis, and management of complex pain syndromes, including neuropathic pain and central sensitization. These factors, all observed within the present cohort, complicate conventional rehabilitation progression.[5-7] Similarly, BI mechanisms are multifactorial and include primary BI from the shockwave itself, secondary injury from shrapnel, tertiary injury from body displacement, quaternary injury such as burns or inhalation trauma, and quinary injury related to toxic exposure.[8-10] Advances in military body armor have shifted survivability and injury patterns toward extremities, resulting in increased limb trauma severity and rehabilitation burden.[5,11]

Such injury characteristics raise legitimate clinical concerns regarding early aquatic immersion. These include the risk of wound maceration or infection, respiratory compromise after thoracic injury or pneumothorax, hemodynamic tolerance of hydrostatic pressure, and the psychological readiness of patients who have been exposed to combat-related trauma. Consequently, despite evidence supporting APT in musculoskeletal and neurologic populations, its early application after high-energy combat trauma remains underexplored.

Rehabilitation after GSWs and BIs should be guided by the International Classification of Functioning, Disability and Health framework, which emphasizes the interaction between body structures and functions, activity limitations, participation restrictions, and contextual environmental and personal factors.[12,13] Physiotherapy algorithms based on this classification system have previously demonstrated benefit after GSWs and BIs, supporting structured, goal-oriented progression beyond isolated impairment management.[14,15] Within this framework, the therapeutic goals of eAPT include pain modulation, muscle relaxation, graded strengthening, restoration of ROM, postural control, and facilitation of functional independence to support reintegration into daily activities and occupational roles.[16]

The present study aims to evaluate the safety and feasibility of implementing eAPT during early rehabilitation after high-energy GSWs and BIs, considering all injury characteristics, environmental factors, clinical precautions, and patient tolerance. Safety is defined as the absence of adverse events, including wound infection or respiratory complications. Feasibility refers to the practicality of delivering eAPT within a hospital rehabilitation setting, reflected by patient adherence, completion of prescribed programs, and observed functional progress.

Methods

A case study design was selected to allow detailed clinical examination of individual rehabilitation trajectories after complex trauma, recognizing the heterogeneity and severity associated with GSWs and BIs.[17] Three male military patients injured during a mass casualty incident in October 2023 were included. Two sustained high-energy GSWs, and one sustained a combined high-energy GSW with tertiary BI.

All patients underwent multidisciplinary acute management prior to transfer to inpatient rehabilitation. Screening excluded traditional contraindications to aquatic therapy, including systemic infection, dermatologic conditions, or clinically infected wounds. Prior to eAPT initiation, each patient completed comprehensive physiotherapy assessment and participated in land-based rehabilitation to establish baseline mobility, strength, cardiopulmonary tolerance, and psychological readiness.

Fig 1 Three hydrotherapy pools at Sheba Medical Center. (A) A new pool featuring advanced technology, with a water depth of 120 cm and 2 underwater treadmills with adjustable pool floors; (B) a conventional hydrotherapy pool with 5 step levels (60, 85, 110, 135, and 160 cm) and retractable parallel bars on steps 4 and 5; (C) a heated swimming pool with non-slip floor tiles in shallow water of 90-120 cm, and a ninja gym in deep water of 130-170 cm.

A structured pre-entry screening was conducted before the first aquatic session, ensuring clear communication of swimming ability, wound status, injury-specific precautions, and emergency procedures with pool staff. Three indoor therapeutic pools (33—34°C), located within the rehabilitation hospital, were used (fig 1). Proximity to the wards facilitated logistical feasibility and rapid access to medical support if required.

Individual eAPT sessions of 30 minutes were prescribed 2 to 3 times per week, with additional independent sessions permitted for patients assessed as safe. Safety protocols included the use of waterproof transparent dressings (OpSite[a], Tegaderm[b]),[18] maintenance of Kinesio Tape[c] across sessions,[19] and exclusion of patients with indwelling pleural drains. Pool maintenance met clinical standards for chemical balance, temperature, and ventilation, after established hydrotherapy guidelines.[20] Showering before and after sessions was mandatory to support infection control.

Trauma-specific adaptations were incorporated, including gradual pool orientation for patients with acute stress responses and positional modifications to reduce respiratory load. All sessions were supervised by physiotherapists with postgraduate training in aquatic rehabilitation, supported by hydrotherapists and certified lifeguards.

Safety outcomes were defined as the absence of adverse events or secondary wound infection. Feasibility was evaluated through session adherence, program completion, and functional outcomes measured using the visual analog scale (VAS) for pain,[21] the manual muscle test (MMT),[22] joint ROM assessment,[23] and the FIM instrument.[24,25]

Ethical approval

The research was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Sheba Medical Center (Proposal No. 8808-21-SMC, February 13, 2022) and the Institutional Review Board of James Cook University, Townsville, Australia (May 22, 2022); ethics extension was approved (January 4, 2023).

Results

Case 1

A 22-year-old man sustained a high-energy GSW to the right shoulder and bilateral knees, with associated chest trauma. Emergency management included needle decompression for pneumothorax followed by pleural drain insertion. Additional injuries comprised a right scapular fracture, bilateral knee lacerations, and an open left patella fracture managed with open reduction internal fixation.

He was transferred to inpatient rehabilitation 6 days after surgery, presenting with significant bilateral knee edema, severe pain (VAS 7 of 10), and marked lower limb weakness (MMT 2-3 of 5).[26] A knee immobilizer was required during early eAPT sessions to prevent uncontrolled flexion and protect the surgical repair. eAPT commenced 18 days after injury.

Initially wheelchair-dependent and requiring full assistance for activities of daily living, he adapted rapidly to the aquatic environment, facilitated by prior swimming experience.

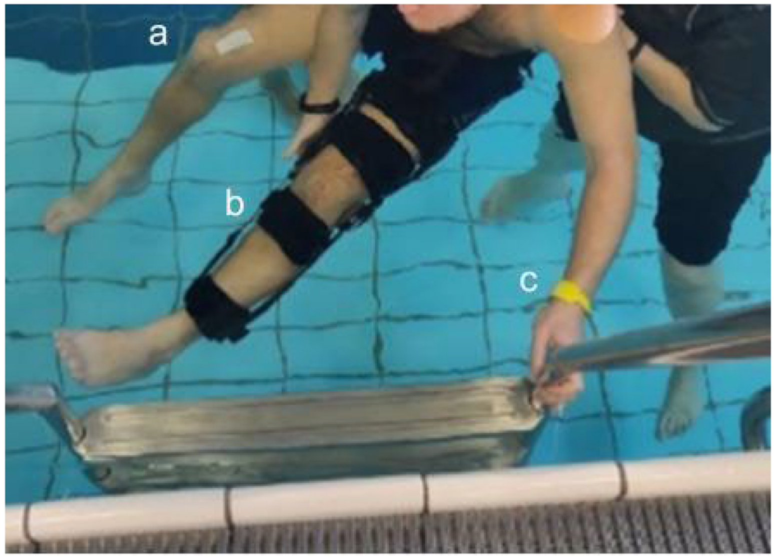

Fig 2 Case #1 - First hydrotherapy session, involving an assisted transfer from supine to upright, gradually lowering his left lower limb into the water. (A) Shows a small, noninfected wound covered with an OpSite dressing. (B) With knee flexion limited, the patient entered the water wearing a knee immobilizer. (C) Shows a yellow hospital inpatient wristband indicating the patient's fall risk on land.

During his first session, he independently ambulated across the pool (fig 1C) in deep water. Early therapeutic goals focused on partial weight bearing, pain reduction, and lower limb strengthening. Precautions included waterproof dressings, immobilizer use, and assisted pool entry and exit (fig 2).

Progressions included supported floating, vertical transfers, graded weight bearing gait, and active shoulder exercises despite residual chest expansion limitations (fig 3). Within 2 weeks, the patient achieved independent pool entry via steps. By 1 month postinjury, he demonstrated independent shallow water walking and short distance swimming.

After an arthroscopic knee manipulation at 17 weeks postinjury, pain reduced to VAS 4 of 10, knee ROM improved from 0° to 120°, and MMT progressed to 4 of 5. FIM scores improved from 101 to 112. He returned to active military duty on May 1, 2024.

Case 2

A 44-year-old man sustained a burst-fire (explosion) injury often classified within quaternary blast injuries resulting in a complex traumatic brachial plexus injury, rib fractures

Fig 3 Case #1 performing upper extremity active exercises in deep water. (A) Shows the patient's right shoulder protected with Kinesio Tape. (B) Illustrates infection prevention and control, with a small wound on the patient's right lower back covered with an OpSite dressing.

Fig 4 Case #2 (A) hospitalized at a nearby medical center 3 days after injury and (B) at Sheba Medical Center 9 days after injury.

(ribs 4-7), and severe lung contusion with pneumothorax requiring pleural drainage. Rib fixation surgery was performed 2 days after injury (fig 4A). Prior to rehabilitation transfer, he developed a deep vein thrombosis managed with anticoagulation and experienced left-sided hearing loss treated with corticosteroids.

After pleural drain removal (fig 4B), eAPT commenced 24 days postinjury. On admission, he presented with profound left upper limb weakness, neuropathic shoulder pain, and restricted ROM. Lower limb function remained intact, allowing independent pool entry via steps.

A progressive aquatic program prioritized core stability and lower limb strengthening (fig 1A) using an aqua bike, maintaining thoracic elevation to minimize respiratory strain (fig 5). As pulmonary tolerance improved, deeper water activities (fig 1C) were introduced for respiratory conditioning (fig 6). With pain improvement from VAS 8-9 of 10 to 2-3 of 10, shoulder ROM and strengthening exercises were incorporated.

He attended supervised sessions 2 to 3 times weekly and completed independent aquatic exercises daily. At 20 weeks, shoulder flexion improved from 30° to 150°, and MMT progressed from 2 of 5 to 4 of 5. Participation expanded

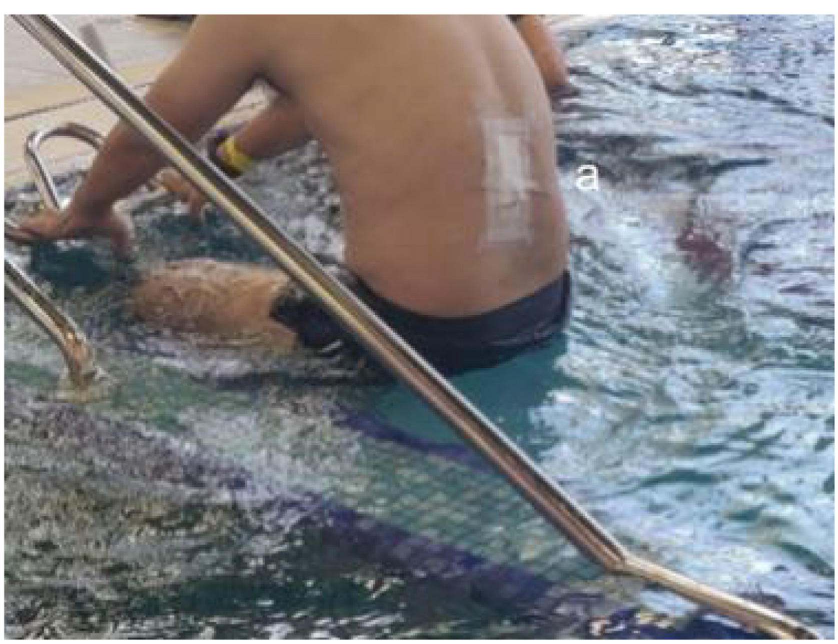

Fig 5 Case #2 exercises on an aqua bike during the first aquatic physical therapy session. (A) An OpSite dressing was applied to an open wound on the patient’s back to prevent and control infection.

Fig 6 Case #2 performing active exercises in deeper water at 1.20 m. (A) Kinesio Tape is used to protect the left shoulder (brachial plexus and median nerve injury). (B) A significant surgical scar is seen around the left scapula from surgery performed for fixation of fractured ribs 4-7.

to therapeutic swimming (fig 1C) and land-based treadmill training. FIM score improved from 115 to 120. He returned to work in a leadership role on February 1, 2024.

Case 3

A 53-year-old man sustained a high-energy GSW to the right calf, causing an open spiral tibia-fibula fracture (Gustilo type III)[27] (fig 7), with a retained projectile in the medullary canal. Surgical fixation and bullet removal were completed before transfer to rehabilitation 1 day postinjury. eAPT began 14 days after surgery. The patient was initially wheelchair-dependent (fig 8) but required only minimal assistance for pool entry. The pool's (fig 1B) stepped design (60-160 cm depth) and parallel bars enabled graded weight bearing progression. Early sessions at 135 cm depth used hydrostatic pressure to reduce edema. Pain was severe (VAS 9 of 10), and ankle ROM was limited.

Psychological readiness was challenged by posttraumatic stress disorder related to a previous injury. A false fire alarm triggered an acute stress response, highlighting the importance of trauma-informed care.

Fig 7 Gustilo type III fracture - open wound on the shin of Case #3 to be covered with OpSite before aquatic physical therapy.

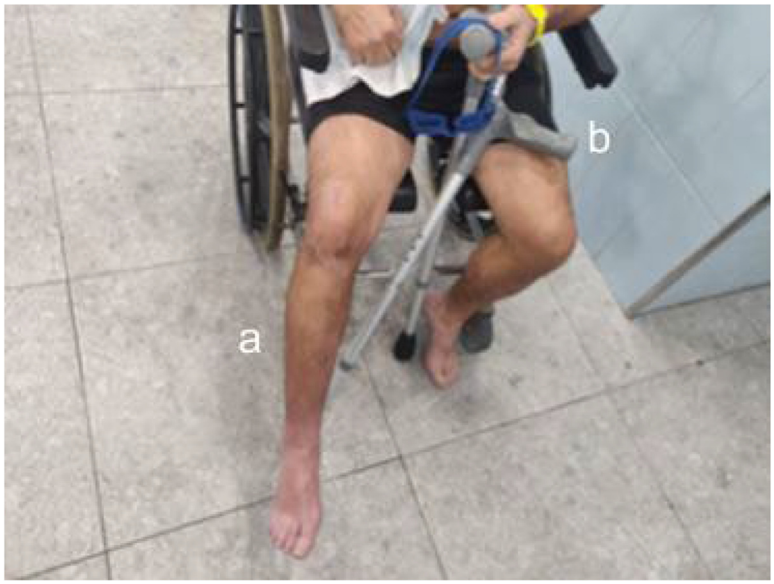

Fig 8 Case #3 is wheelchair-bound. (A) Indicates no weight bearing on the right lower extremity. (B) Indicates goggles and crutches for walking short distances in the pool area and a yellow hospital inpatient wristband demonstrating risk of falling.

Fig 9 Case #3 participating in aquatic exercises (right) and daily swimming therapy with a personal instructor (left).

Table 1 Summary table of patient details, injuries, and early aquatic physical therapy (eAPT) achievements. All 3 cases were male military personnel, injured October 7, 2023, in a mass casualty incident. Length of time each patient received APT is captured by eAPT starting date and date of return to active duty.

Case	Patient Details	Injuries	eAPT Implementation	Achievements With eAPT
#1	Age 22 y Initial surgery ORIF performed the day after injury at a specialized surgical center Transferred to SMC 6 d later eAPT initiation 18 d after injury	High-energy GSW to trunk and extremities No weight bearing left lower extremity Partial weight bearing right lower extremity Limited left upper extremity movement Open wounds with infection risk	Indicated for early intervention: Knee immobilizer brace limited knee movement, enabled standing and ambulation Partial weight bearing, initially performed in deep water Shoulder Kinesio Tape allowed the performance of buoyancy-assisted exercises with less pain	*Short-term benefits*: Pain reduction, muscle strengthening and improved ROM Early ambulation with improved shoulder movement *Long-term benefits*: Baseline FIM score 101 — wheelchair-bound, assistance needed for activities of daily living Discharge FIM score 112 —independent ambulation with crutches Returned to active military duty on May 1, 2024
#2	Age 44 y Hospitalized at nearby center Initial surgery 2 d after injury Transferred to SMC 9 d after injury eAPT initiation 24 d after injury	Quaternary ballistic trauma Open wound on back with infection risk Left shoulder (brachial plexus injury) Left rib fractures (4-7), with severe left lung contusion and pneumothorax	OpSite dressing for wound protection and infection control; exercises on aqua bike during first session Walking exercises in deep water to improve mobility and increase stamina Resistance exercises for upper extremity muscle strengthening Therapeutic swimming	*Short-term benefits*: Participation in initial sessions achieved without reported complications *Long-term benefits:* Baseline FIM score 115 — limited left upper extremity use Discharge FIM score 120 — independent Returned to active military duty on February 1, 2024
#3	Age 53 y Bullet removal and surgical fixation performed at a nearby large medical center Transferred to SMC for early orthopedic rehabilitation 1 day after injury eAPT initiation 14 d after surgery	High-energy GSW to lower extremity Gustilo type III open fracture with wound on shin: no weight bearing on right lower extremity Wheelchair-bound with fall risk PTSD from previous 2014 injury	Initial treatments were given in a smaller pool with less turbulence and fewer patients OpSite dressing was used for wound coverage On land, the patient walked with the aid of crutches Goggles were worn for swimming and head immersion exercises Daily aquatic exercise and therapeutic swimming was performed with assistance from an instructor	*Short-term benefits:* Initiation of independent transfers, standing, and partial weight bearing walking holding on to parallel bars *Long-term benefits:* Baseline FIM score 75 — wheelchair-bound, assistance needed to perform activities of daily living Discharge FIM score 93 — ambulating with crutches, needed assistance showering and dressing; continued outpatient therapy for independent ambulation; returned to outdoor sports (open-water swimming, long-distance running) and active duty on June 1, 2025

Abbreviations: eAPT, early aquatic physical therapy; GSW, gunshot wound; ORIF, open reduction internal fixation; PTSD, posttraumatic stress disorder; ROM, range of motion; SMC, Sheba Medical Center.

By late November 2023, he walked with crutches without a boot, and pain reduced to VAS 5 of 10. Land-based gait training complemented eAPT. In water (fig 1C), he swam daily and performed shallow water squats to restore ROM and improve balance (fig 9).

FIM score improved from 75 to 93. He continued outpatient rehabilitation, ultimately returning to outdoor sports, including open-water swimming and long-distance running. He resumed active duty on June 1, 2025.

Results summary

eAPT was safe and feasible for all 3 patients, with no adverse events or secondary infections observed. Cases 1 and 2 demonstrated faster functional recovery and earlier return to duty. Case 3 required prolonged rehabilitation but ultimately achieved high-level functional outcomes (table 1).

Discussion

These cases illustrate key distinctions between ballistic/blast trauma and routine orthopedic APT populations. Patients presented with open but noninfected wounds, recent pneumothorax, brachial plexus injury, neuropathic pain, and acute stress reactions. These features necessitated tailored precautions, including waterproof dressings, positional modifications, and trauma-informed practice.

Waterproof dressings (OpSite, Tegaderm) effectively protected wounds, consistent with low infection rates reported during hydrotherapy with advanced dressings.[28] Proximity of pools (fig 1) and staff support facilitated attendance and adherence.

Respiratory compromise was safely managed using aqua bikes and shallow water positioning.[29] Venous thromboembolism risk was mitigated through anticoagulation, with no thromboembolic events observed.[30] Buoyancy enabled early mobilization, hydrostatic pressure supported edema reduction, and water resistance facilitated strengthening and gait retraining.[1,31] Patients reported enhanced confidence, autonomy, and social engagement during eAPT.

Limitations include small sample size and potential confirmation bias. Nonetheless, findings provide early evidence supporting eAPT as an adjunct to land-based rehabilitation after complex combat trauma.

Conclusions

Early APT appears to be a safe and feasible rehabilitation modality after high-energy gunshot and quaternary BIs when delivered under qualified supervision, with strict infection control and individualized adaptations. Larger prospective studies are required to evaluate broader effectiveness across injury types and populations.

Suppliers

a. OpSite; Smith & Nephew.
b. Tegaderm; 3M.
c. Kinesio Tape; Bridges Consumer Healthcare.

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Disclosure

The investigators have no financial or nonfinancial disclosures to make in relation to this project.

Acknowledgments

We extend our gratitude to all the participating patients for their valuable contributions to this study.

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