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Relevance of Medicinal Leeches in Plastic and Reconstructive Surgery – A Literature Review

Joanna Słuchocka

asiaslu@onet.pl

https://orcid.org/0009-0000-8143-2451

University of Warmia and Mazury in Olsztyn

Tymon Lewalski
lewalski.tymon@gmail.com
https://orcid.org/0009-0007-5345-2077
University of Warmia and Mazury in Olsztyn

Martyna Florczyk
martyna.gorlewskag4@gmail.com
https://orcid.org/0009-0000-6385-110X
RCKiK in Olsztyn

Lidia Płuciennik
Lidi_PL@wp.pl
https://orcid.org/0009-0007-5860-9213
Medical University of Lodz

Oskar Lewalski
Oskar.lewalski@o2.pl
https://orcid.org/0009-0000-0914-0219
University of Warmia and Mazury in Olsztyn

Klaudia Jeruć
klaudia.gorlewska.g4@gmail.com
https://orcid.org/0009-0000-8107-7736
Provincial Specialist Children's Hospital in Olsztyn named after Prof. Dr. Stanisław Popowski

Corresponding author: Joanna Słuchocka, asiaslu@onet.pl

ABSTRACT

Background. Medicinal leeches, once emblematic of pre-modern bloodletting practices, have re-emerged as valuable therapeutic tools in contemporary medicine that is now an FDA-approved treatment [1]. Primarily utilized in reconstructive microsurgery, orthopedics, and trauma management, leech therapy (hirudotherapy) provides unique physiological benefits that are difficult to replicate with pharmacological agents alone [2].

Aim. This article reviews the biochemical mechanisms of the components of leech saliva, treatment protocol, safety considerations and administration techniques of the leeches with their current applications in modern healthcare and emphasis on their relevance in plastic and reconstructive surgery

Methods. This paper was based on scientific articles and case reports selected from databases such as PubMed and Google Scholar.

Results. The literature considers medicinal leeches an effective therapeutic tool most famously utilized in plastic and reconstructive surgery [5]. They are currently classified as a medical device that is safe and well tolerated by patients [1,5].

Conclusions. Medical leeches may seem primeval, but a deeper dive into the benefits of their usage in the particular purposes shows that they are still a relevant form of therapy. They may be underestimated but their biochemical actions on hemostasis, inflammation, microcirculation, and pain perception which work synergistically are truly impressive. In many cases leeches are successfully used when conventional medicine is just not enough [2,6].

Keywords: hirudo medicinalis, medicinal leech therapy, hirudotherapy, hirudin, reconstructive surgery, sports medicine

1. Introduction and historical perspective

The therapeutic use of leeches dates back more than 2,500 years. Ancient Egyptian, Greek, and Roman physicians described bloodletting as a method to restore humoral balance [7]. Hippocrates and later Galen advocated for bloodletting to treat inflammatory and systemic conditions [7]. During the 18th and 19th centuries, leeches were widely used across Europe, reaching such a peak in Europe between 1825 and 1850 that their supplies were exhausted. [3]. However, with advances in pathology and pharmacology, bloodletting fell out of favor. Leech therapy experienced a dramatic renaissance in the late 20th century. In 2004, the U.S. Food and Drug Administration (FDA) officially classified medicinal leeches (Hirudo medicinalis) as medical devices [1]. Today, hirudotherapy is firmly grounded in pharmacology and pathophysiology, offering unique solutions where conventional medical interventions sometimes fall short, particularly in cases of compromised microcirculation [2,5].

2. The biochemical mechanism of action

The therapeutic efficacy of medicinal leeches does not solely come from the physical removal of blood which is called phlebotomy, but it is primarily mediated by the molecules secreted in the saliva of Hirudo medicinalis. During feeding, the leech injects a complex mixture of peptides, enzymes, and low–molecular-weight compounds into host tissue. More than 100 bioactive substances have been identified, many of which target key pathways in hemostasis, inflammation, microcirculation, and pain perception. The biochemical actions of medicinal leeches operate synergistically [8].

2.1.Anticoagulant mechanism

The most important action of medicinal leeches is the inhibition of coagulation. The best-known and also most extensively studied salivary protein is hirudin, a potent and highly specific direct thrombin inhibitor. Hirudin binds irreversibly to thrombin (Factor IIa), preventing the conversion of fibrinogen into fibrin and inhibiting clot formation. In contrast with heparin, its activity does not depend on antithrombin III, which confers greater specificity and predictability. Hirudin is known to have dual anticoagulant and antiplatelet effects, by blocking thrombin-mediated platelet activation as well [9].

2.2 Inhibition of Platelet Aggregation

There is also another molecule in leech saliva that interferes with platelets. It is called calin and inhibits platelet adhesion by blocking collagen-mediated binding and interfering with von Willebrand factor–dependent aggregation. [17]. What is more, salivary apyrase degrades adenosine diphosphate (ADP), a key mediator of platelet recruitment and amplification. These effects combined prevent formation of the primary platelet plug and prolong bleeding from the bite site for several hours. Clinically, this sustained oozing is beneficial in the management of venous congestion following microsurgical tissue transfer [10].

2.3. Fibrinolytic Activity

A different important salivary enzyme, destabilase, exhibits fibrinolytic properties. By degrading stabilized fibrin, destabilase facilitates the dissolution of microthrombi within congested tissues. This contributes to restoration of capillary perfusion and reduces the risk of flap necrosis in reconstructive procedures [11].

2.4. Modulation of Microcirculation

Leech saliva also contains histamine-like and acetylcholine-like substances that induce vasodilation. These compounds increase local blood flow and decrease vascular resistance, improving tissue oxygenation. Additionally, hyaluronidase enhances tissue permeability by

degrading components of the extracellular matrix. This enzyme facilitates diffusion of salivary molecules through interstitial spaces and promotes drainage of interstitial fluid, contributing to reduction of edema in congested tissues. Together, vasodilation and enhanced permeability optimize microcirculatory dynamics in compromised tissue [12].

2.5. Anti-Inflammatory and Protease-Inhibitory Effects

Beyond hemostasis, leech saliva exerts anti-inflammatory effects. Several peptides inhibit proteolytic enzymes such as trypsin, chymotrypsin, and elastase when others modulate complement activation and leukocyte migration. These actions may account for observed symptomatic improvements in inflammatory joint disorders, including osteoarthritis, although further controlled studies are required to clarify their clinical significance [13].

2.6. Analgesic Properties

Patients frequently report minimal discomfort during leech attachment. Although the precise molecular basis remains incompletely characterized, salivary secretions appear to contain anesthetic-like substances that attenuate nociceptor activation at the bite site. This local analgesic effect facilitates prolonged feeding without significant patient distress [14].

3. Treatment protocol

The application of medicinal leeches in contemporary medicine follows a structured clinical protocol designed to maximize therapeutic benefit while minimizing complications. Modern hirudotherapy is performed almost exclusively in hospital settings, particularly in plastic, reconstructive, and microsurgical units [15].

Appropriate patient selection is critical. Before initiation, assessment of hemodynamic stability, baseline hemoglobin and hematocrit, coagulation profile, current anticoagulant or antiplatelet therapy and immune status is necessary. There are some contraindications that need to be taken into consideration. They include severe anemia, active systemic infection, hemophilia or coagulopathy, immunosuppression or hypersensitivity reactions [16].

Although medically accepted, leech therapy can provoke psychological discomfort. Informed consent must include explanation of the biological mechanism and expected duration of therapy, risk of infection, anemia or even need for transfusion and possibility of multiple sessions [17].

Medicinal leeches harbor symbiotic Aeromonas hydrophila within their digestive tract. While beneficial to the leech, these bacteria pose a risk of wound infection in humans. Therefore, prophylactic antibiotics are standard. Common regimens include ciprofloxacin, third-generation cephalosporins (in selected cases). Therapy typically continues throughout the

duration of leech application. Leeches used in hospitals are sterile, single-use medical-grade organisms obtained from regulated suppliers [18].

4. Administration techniques

The target area is cleaned with saline (avoid alcohol or antiseptics that repel leeches). A small needle prick may be made to encourage attachment. The leech is applied using forceps or a syringe barrel to localize placement. Depending on defect size, 1–10 leeches may be applied simultaneously. In large flaps, applications may be staggered. Each leech feeds for approximately 20–60 minutes, consumes 5–15 ml of blood and detaches spontaneously once engorged. Forced removal is avoided to prevent regurgitation and infection risk [19].

After detachment, prolonged passive bleeding occurs due to hirudin and other anticoagulants in saliva. Oozing may continue for 6–12 hours. Monitoring includes frequent flap color and capillary refill assessment, measurement of hemoglobin levels (often every 4–12 hours), monitoring of vital signs, quantification of blood loss. In prolonged therapy (3–7 days), transfusion may be required if hemoglobin drops significantly. Leeches are typically applied every 4–6 hours or continuously in rotation. Therapy continues until: neovascularization occurs, venous outflow improves, tissue color normalizes, capillary refill stabilizes. Most courses last 3–5 days, though complex cases may require up to a week [20].

Complications of medicinal leeches include infection, excessive blood loss and allergic reaction which occurs very rarely [21].

After use, leeches are considered biohazard waste, which is disposed of according to hospital infectious waste protocol. They are not reused. This prevents cross-contamination between patients [22].

5. Clinical applications in plastic and reconstructive surgery

In contemporary hospital settings, hirudotherapy is most famously utilized in plastic and reconstructive surgery [23]. Indications include: reattached fingers or toes, compromised skin grafts, hematoma evacuation, venous congestion following trauma [24].

Severed digits, ears, or tissue flaps are reattached, arteries (which have thick walls) are relatively easy to reconnect. However, delicate veins are prone to thrombosis and failure, leading to venous congestion. The tissue becomes engorged with deoxygenated blood and risks necrosis. Leeches act as a temporary, biological venous system, actively draining congested blood while their saliva prevents clotting until new capillaries can form (usually 3 to 5 days) [25].

Leeches can assist in managing postoperative or traumatic hematomas, especially in areas with delicate venous drainage such as ear (auricular hematoma), nasal reconstruction, facial flap surgery. By removing pooled blood and promoting anticoagulation, they reduce tissue pressure and necrosis risk [26].

In the emergency medicine, complex limb injuries and crush trauma may compromise venous return. Although less common than in plastic surgery, leech therapy may be considered in severe soft tissue injuries where vascular compromise threatens recovery [27].

6. Clinical applications in sports medicine

Research explores potential benefits of medicinal leeches in osteoarthritis, tendinopathies, and chronic joint pain [28]. These conditions are often characterized by persistent inflammation, impaired microcirculation, and accumulation of inflammatory mediators within affected tissues. Hirudotherapy, through its combination of anticoagulant, anti-inflammatory, and vasodilatory effects, directly targets these pathological processes at the local level, offering a therapeutic approach distinct from systemic pharmacological interventions.

Numerous clinical trials have demonstrated the efficacy of hirudotherapy in treating osteoarthritis of the knee. The anti-inflammatory and analgesic properties of leech saliva can significantly reduce pain and improve joint mobility, sometimes outperforming topical diclofenac in short-term symptomatic relief [29]. In addition to pain reduction, patients often report improved joint stiffness and functional capacity, which may be attributed to enhanced microcirculation and reduced intra-articular pressure. The prolonged local bleeding induced by leech application may further contribute to decompression of congested periarticular tissues, thereby improving joint biomechanics.

Chronic inflammatory conditions, such as "tennis elbow" (lateral epicondylitis), have shown positive responses to localized leech therapy, likely due to the targeted delivery of anti-inflammatory peptides directly into the compromised tissue [30]. These peptides inhibit proteolytic enzymes and modulate inflammatory cascades, potentially reducing tendon degeneration and promoting tissue repair. Additionally, improved local blood flow may enhance oxygenation and nutrient delivery to poorly vascularized tendon structures, supporting the healing process and reducing recovery time.

There are also case reports of medical leeches being used in diabetic foot and ischemic ulcers treatment, compartment syndrome, reconstructive urology and gynecology, and chronic venous insufficiency [31]. In these conditions, impaired perfusion and microvascular dysfunction play a central role in disease progression. Hirudotherapy may assist by restoring capillary flow,

reducing venous congestion, and promoting removal of necrotic or deoxygenated blood. In chronic wounds, this may translate into improved granulation tissue formation and accelerated healing. However, these applications remain largely supported by case-based evidence, and further controlled studies are required to establish standardized treatment protocols.

Table 1. Sport-Related Applications of Hirudotherapy

Application	**Mechanism of Action**	**Clinical/Practical Relevance in Sports**
Acute soft tissue injury (contusions, hematomas)	Bloodletting + anticoagulant effects (hirudin, calin)	Reduces local venous congestion, decreases pressure in tissues, promotes perfusion and faster recovery
Tendinopathies (e.g., tennis elbow)	Anti-inflammatory peptides + protease inhibition	Reduces localized inflammation and pain, may enhance tendon healing and improve functional recovery
Post-surgical tissue flaps in athletes	Venous decompression, microcirculatory enhancement	Prevents flap necrosis, promotes tissue survival after reconstructive procedures, relevant in sports-related reconstructive surgery
Chronic joint pain / osteoarthritis	Anti-inflammatory + analgesic peptides, improved microcirculation	Decreases pain, improves range of motion, may reduce reliance on systemic NSAIDs in athletes
Compartment syndrome / crush injuries	Temporary venous drainage, fibrinolytic enzymes	Minimizes tissue ischemia, reduces edema, supports tissue viability in severe limb injuries
Chronic venous insufficiency / edema	Vasodilation, hyaluronidase-enhanced tissue permeability	Enhances local circulation, facilitates fluid drainage, potentially aiding recovery in lower limb injuries

Diabetic or ischemic ulcers (athletes with metabolic comorbidities)	Anticoagulant and fibrinolytic effects	Supports wound healing and tissue oxygenation, adjunct therapy for athletes with chronic conditions

7. Discussion

Hirudotherapy presents a unique combination of mechanical and biochemical benefits that are difficult to replicate with conventional pharmacological interventions. In sport medicine contexts, where soft tissue injuries, localized inflammation, and compromised microcirculation are frequent, the mechanisms of medicinal leeches may offer meaningful clinical advantages. Their anticoagulant, anti-inflammatory, vasodilatory, and fibrinolytic properties can facilitate restoration of perfusion in congested tissues, reduce hematoma formation, and alleviate local pain, potentially enhancing recovery after acute musculoskeletal injuries [32].

In athletes, compromised venous return or microvascular congestion, as seen in contusions, tendon injuries, or post-surgical reconstructions, may benefit from localized hirudotherapy. The prolonged oozing induced by leech saliva can act as a temporary biological decompression, promoting tissue survival when conventional approaches such as compression, elevation, and pharmacotherapy are insufficient [2,10,25].

Furthermore, the analgesic and anti-inflammatory peptides delivered directly to the injured tissue may reduce reliance on systemic anti-inflammatory drugs, which is particularly relevant in the athletic population where minimizing side effects and optimizing recovery are critical. Preliminary reports in chronic joint disorders, tendinopathies, and osteoarthritis support this localized effect, although these findings need rigorous validation in sport-specific populations [28–30].

8. Future directions

Despite the well-established role of medicinal leeches in reconstructive and microsurgical practice, several areas require further investigation to fully define and expand their clinical utility. Future research should focus on strengthening the evidence base, optimizing treatment protocols, and exploring innovative applications of hirudotherapy in modern medicine.

One of the most important priorities is the development of high-quality randomized controlled trials. Much of the current evidence - particularly outside reconstructive surgery - is derived from case reports, small cohort studies, or extrapolation from related conditions [28–31]. Large,

well-designed clinical trials are needed to evaluate efficacy, safety, and long-term outcomes in specific indications such as osteoarthritis, tendinopathies, chronic wounds, and sports-related injuries. Standardized outcome measures, including pain scores, functional recovery, tissue perfusion, and return-to-activity timelines, should be incorporated to allow meaningful comparisons across studies.

Another key direction involves the standardization of treatment protocols. Currently, there is variability in the number of leeches used, frequency of application, duration of therapy, and monitoring strategies. Establishing evidence-based guidelines would improve reproducibility, enhance patient safety, and facilitate broader clinical adoption. This includes clearer criteria for patient selection, contraindications, and thresholds for interventions such as transfusion or antibiotic modification.

Advances in molecular and pharmacological research offer promising opportunities. More than 100 bioactive compounds have been identified in leech saliva, yet many remain incompletely characterized [8]. Future studies should aim to isolate, synthesize, and evaluate these molecules individually and in combination. This may lead to the development of novel pharmacological agents that replicate specific effects of hirudotherapy, such as targeted anticoagulation, anti-inflammatory action, or microcirculatory enhancement, without the need for live organisms. However, replicating the full synergistic effect of leech saliva remains a significant challenge.

The role of hirudotherapy in sports medicine represents an emerging field with substantial potential. Future investigations should specifically address athletic populations, focusing on injury recovery, performance outcomes, and return-to-play metrics. Comparative studies evaluating leech therapy alongside standard treatments such as physiotherapy, cryotherapy, and pharmacological interventions would help define its place in evidence-based sports medicine practice.

Another promising area is the integration of hirudotherapy into multimodal and personalized treatment strategies. Combining leech therapy with advanced wound care techniques, regenerative medicine approaches (e.g., platelet-rich plasma), or microsurgical innovations may enhance therapeutic outcomes. Personalized approaches based on patient-specific factors - such as vascular status, inflammatory profile, and comorbidities - could further optimize effectiveness.

Additionally, further research is needed to improve safety and infection control measures. Although prophylactic antibiotics are standard, increasing antimicrobial resistance necessitates ongoing evaluation of optimal regimens and alternative strategies [18]. Development of

standardized protocols for monitoring complications, as well as innovations in sterile breeding and handling of medical-grade leeches, may further reduce infection risk.

Finally, there is a need to address psychological and ethical considerations associated with hirudotherapy. Patient perception and acceptance can significantly influence treatment adherence. Future studies should explore strategies to improve patient education, reduce anxiety, and enhance overall experience, particularly in populations unfamiliar with this form of therapy.

In conclusion, while medicinal leech therapy is already a valuable tool in specific clinical contexts, its full potential remains incompletely realized. Continued interdisciplinary research integrating clinical medicine, pharmacology, and biotechnology will be essential to refine its applications and establish its role in the evolving landscape of modern healthcare.

9. Conclusions

The role of Hirudo medicinalis in modern medicine illustrates how historically rooted therapies can acquire renewed clinical relevance when supported by scientific validation. Far removed from its antiquated association with indiscriminate bloodletting, medicinal leech therapy now occupies a clearly defined niche in reconstructive and microsurgical practice, particularly in the management of venous congestion where conventional techniques may be insufficient. Its value lies not in tradition, but in measurable physiological effects - anticoagulation, microcirculatory enhancement, and temporary venous decompression - that can determine the survival of compromised tissue. When applied within standardized protocols, with appropriate infection control and patient monitoring, leeches are a well-established example of a safe and acceptable therapy with meaningful clinical benefit. In a medical landscape driven by technological innovation, the continued relevance of this biological therapy underscores a central truth: quality in medicine is defined not by novelty, but by outcomes, safety, and benefits.

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