Expert opinion on heat therapy for teenagers' musculoskeletal pain management

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Background: Among children and adolescents, up to 40% will experience musculoskeletal pain (MP), which can significantly impair functional ability, reduce quality of life, cause emotional distress, and lead to sleeping disorders for both patients and their families. The first-line treatment often involves pharmacological interventions, even though there is a lack of evidence supporting the efficacy or the safety of this approach in this specific age group. Recent guidelines recommend the implementation of preventative strategies and physical tools as the first option to minimize the use of medications. We aimed to provide an expert opinion on the use of heat therapy for MP management in young patients.

Methods: This paper is the result of a virtual advisory board held by the authors in order to discuss and provide an expert opinion about the use of heat therapy in MP in children and adolescents.

Results: MP is a significant burden affecting children and adolescents. While non-steroidal anti-inflammatory drugs are currently the first-choice treatment of acute and chronic MP in children and adolescents, avoiding or reducing them in such patients is advisable, to reduce side effects and to prevent the development of chronic pain and medication overuse headaches. Heat therapy can be an additional treatment option due to its ability to promote muscle relaxation, enhance blood circulation, and modulate nociceptors with a good safety profile.

Conclusions: MP in children and adolescents is a common condition that should be approached multidisciplinary, including information, therapeutic exercise and physical therapies like hot or cold therapies. Future studies should be conducted to evaluate the safety, efficacy and indications of each treatment in MP.

Keywords: Delayed-onset muscle soreness (DOMS); heat therapy; musculoskeletal pain (MP); paediatric; teenagers

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Introduction

Musculoskeletal pain (MP) in adolescents

Definition, epidemiology and characteristics

MP is a great burden all over the world, and low back pain is the leading cause affecting up to 20% of the global population (1-3). Among children and adolescents, up to 40% will experience MP (4,5). It has been found that one in every two adolescents develop a MP complaint that lasts for 2 weeks. Between 20% and 40% of these adolescents will continue to experience recurrent pain episodes transitioning from adolescence into adulthood (6-10). Previous research has shown that back and neck pain are the fourth leading cause for years lived with disability in 10–14-year-old worldwide, similarly for older (15–19 years old) adolescents (11). MP can significantly impair functional ability, reduce quality of life, cause emotional distress, and lead to sleeping disorders for both patients and their families (12-15). Studies consistently report that the most affected areas are the knee, back and neck (5,7,10).

MP can be classified into acute or chronic (i.e., lasting for more than 3 months). It can also be classified as focal (localized to a specific area) or diffuse (affecting multiple areas). MP can occur without an identifiable structural cause, known as primary pain, or may be associated to an ostheo-muscular or joint diseases (secondary pain), which in turn are heterogeneously caused by inflammation and/or structural changes due to infection, crystal deposition or auto-inflammatory pathways (16). Additionally, spasticity related to diseases affecting the central nervous system may determine MP, too.

> **Highlight box**
>
> **Key recommendations**
> - Heat therapy can be an additional treatment option for teenagers' musculoskeletal pain due to its ability to promote muscle relaxation, enhance blood circulation, and modulate nociceptors with a good safety profile.
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> **What was recommended and what is new?**
> - Non-steroidal anti-inflammatory drugs are currently the first choice treatment of acute and chronic musculoskeletal pain in children and adolescents.
> - Avoiding or reducing them in children and adolescents is advisable.
>
> **What is the implication, and what should change now?**
> - Future studies should be conducted to evaluate the safety, efficacy and indications of each treatment in musculoskeletal pain in children and adolescents.

Pathophysiology

Skin is highly innervated, as well as periosteum, which is more innervated than any other bone part, including cortical bone and marrow (17). The ligaments and capsules are also innervated by a rich neural network, while the cartilage and menisci are aneural and avascular. Consequently, during joint loading inflammation occurrence is reduced and pain prevented. Ligaments have high-threshold mechanoreceptors, sensible to high intensity mechanical stimuli (18). Different nociceptors (e.g., mechanic, mechano-heat, and polymodal nociceptors) are harbored in skeletal muscle. The majority of them are characterized by a high stimulation threshold, not to be stimulated by physiologic movement or muscle stretch. Some nociceptors are deputed to activate when tonic muscle contractions become ischemic, when the maximum muscle force has been exceeded (19). Finally, also adrenergic and cholinergic sympathetic nerve fibers are present in bone and muscles and can contribute to pain transmission (20).

Normally, receptors in bone are silent, being stimulated only by acute noxious stimuli such as mechanical distortion, local acidosis (by means of acid-sensing ion channels, like TRPV1), or an increase in intramedullary pressure (21-23). Both purinergic and TRPV1 receptors act as pain receptors in skeletal muscle. The first ones are activated by adenosine triphosphate (ATP) released during trauma or other pathologic processes. As a consequence, ATP is indicative of general tissue trauma. On the chronic side, when TRPV1 receptors are persistently activated, they become upregulated and, consequently, cause long-lasting hyperalgesia (i.e., an increased pain response to noxious stimuli) (19). Similarly, hyperalgesia, but also allodynia (i.e., pain in response to innocuous stimuli) are caused by inflammation through the stimulation of sensory afferent fibers. Indeed, inflammation or injury damage cells and release several substances, namely inflammatory mediators (24-26). They directly stimulate peripheral nociceptors, but also act indirectly by promoting inflammation. Following acute inflammation, a significant percentage of fibers, otherwise insensitive to mechanical stimulation in the normal joint, develop responsiveness to mechanical stimulation and exhibit increased activity. Accordingly, these 'silent' nociceptors contribute significantly to bone and joint pain under pathological conditions (27). In addition to these phenomena, aging-related articular microtrauma can also determine the release of damage-associated molecular pattern proteins (DAMPs) (28).

Pattern recognition receptors present on sensory fibers bind DAMPs and trigger an innate immune response by means of chemokines and cytokines (28). At the site of injury inflammatory and stromal cells produce neurotrophic factors (e.g., NGF and vascular endothelial growth factor), which favor nerve sprouting with consequent hyperinnervation of periosteum, bone, and marrow causing pain (29). Generally, after healing, these new fibers involve and bone innervation returns physiological (27). A similar phenomenon has also been found in human intervertebral disc, which are normally aneural and avascular (30).

Primary hyperalgesia occurs at the site of injury as described above, while secondary hypersensitivity appears far from the damage site and is caused by central spinal plasticity (31). The mechanism is a continuous peripheral nociception which can develop long-term spinal potentiation (e.g., long-lasting increase in synaptic transmission). The same mechanism support continuous inflammation both in peripheral and in central nervous system, in a vicious cycle called "complex regional pain syndrome" (CRPS) (24). Consequently, immune and neural system crosstalk and regulate each other, by means of glial, epithelial, and mesenchymal, and mast cells. Recent literature on this topic highlights the role of cannabinoid receptors (CB1 and CB2), which are expressed by glia and neurons at peripheral, spinal, and supraspinal sites (32). They bind different endogenous lipid ligands (i.e., endocannabinoids) and modulate pain, mood, appetite, and emesis. Their antinociceptive activity is exerted through inhibition of presynaptic neurotransmitter release, reduction of neuronal excitability at the postsynaptic level, and activation of descending inhibitory pathways (32).

Diagnosis

Diagnosis of MP relies on understanding body anatomy and common mechanisms of injury. A detailed history and a focused physical examination are the first steps to narrow down possible causes. Key aspects of the patient history include age; location, onset, duration, and quality of pain; mechanical or systemic symptoms; history of swelling; description of any precipitating trauma; and pertinent previous medical or surgical procedures. A systematic approach to examination of the painful area includes inspection, palpation, range of motion and strength evaluation, neurovascular assessment, and special (provocative) tests. Imaging and laboratory studies can play a confirmatory or diagnostic role when appropriate. Radiography and musculoskeletal ultrasonography are commonly used imaging techniques (33). Radiography can reveal bone disease, while ultrasound can detect effusions, tendon and ligament disease, soft tissue involvement and crystal deposits. Computed tomography (CT) and magnetic resonance imaging (MRI) are second-level examinations, reserved for potential surgical indications or specific diagnoses. Laboratory exams could include serology for suspected inflammatory conditions (erythrocyte sedimentation rate or C-reactive protein and complete blood count when infection is suspected), autoimmune conditions (rheumatoid factor or auto-antibodies), or microscopic examination of arthrocentesis fluid for gout crystals or evidence of bacterial infection (34).

Principles of treatment of MP in children and adolescents

The first-line treatment for children and adolescents with acute or chronic MP often involves pharmacological interventions, even though there is a lack of evidence supporting the efficacy or the safety of this approach in this specific age group (35-39). This approach in young patients with MP is primarily due to the widespread drug availability in most countries. This has resulted in limited evidence regarding the efficacy and safety of pharmacological interventions specifically for chronic pain in children. In particular, the use of nonsteroidal anti-inflammatory drugs (NSAIDs) is associated to the development of chronic pain despite an early analgesic efficacy, because transient neutrophil-driven up-regulation of inflammatory responses was demonstrated protective against the transition from acute to chronic pain (40). Moreover, the excessive consumption of pain-relief drugs in childhood is associated with medication overuse headaches (41).

The main principles to reach analgesia by drugs are: the simplest route of administration (e.g., by the mouth), on a regular basis (e.g., by the clock), according to the type and intensity of the pain [e.g., World Health Organization (WHO) analgesic ladder] and patient-managed whenever possible (42). Some integrative drugs can be adopted in each step for reducing or even stopping the use of analgesics for all types of pain. Generally and empirically, if the non-opioids (step 1) and weak opioids (step 2) fail, minimally invasive interventions in step 3 can be recommended before upgrading to strong opioids (step 4) (42).

Recent guidelines recommend the implementation of preventative strategies, psychological therapies and physical tools as the first option to minimize the use of medications. In patients who have had an inadequate response to drugs,

Table 1 Classification of heat therapy (47-50)

Mode of delivery	Energy transmission	Examples
Superficial	Conduction	Wearable heat wraps, heat packs with grain, hot water bottles, hot poultices, hot stones, electric heat pads
	Convection	Hydrotherapy, hot baths, heat lamp, stream/sauna
Deep	Conversion	Ultrasound, diathermy, laser therapy

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the proper use of other alternative techniques is vital for safe and effective management of chronic pain patients (42). In recent years, a growing interest has raised in practicing a biopsychosocial approach for patients with chronic pain (43), that includes psychological therapies like cognitive-behavioral strategies (44) with a majority consensus affirming that this approach should always be present and that future studies should specify the scope of these therapies (45). Additionally, the most recent guidelines of the American College of Rheumatology about the management of osteoarthritis of the hand, hip, and knee consider nonpharmacological treatments as effective complementary options, including heat (HT) and cold therapy (46), to facilitate a return to normal function and activity (47). HT will be discussed in detail below.

Cold application (cryotherapy) is defined as the therapeutic application of any substance to the body that results in decreased tissue temperature (48). Cryotherapy decreases tissue blood flow by causing vasoconstriction, and reduces tissue metabolism, oxygen utilization, inflammation, and muscle spasm (48). Briefly, cryotherapy induces effects both locally (at the site of application, namely neuropraxia) and at the level of the spinal cord via neurologic and vascular mechanisms.

Heat therapy in MP

Mechanism of action

HT is defined as a non-pharmacological therapeutic application of any intervention to the body that increases heat, resulting in elevating tissue temperature. The mode of delivering HT is shown in *Table 1* (47-50).

HT exerts its action on pain and muscle spasms in different modalities. Applying low-level superficial heat, temperature-sensitive nerve endings (thermoreceptors) activate and generate signals blocking nociception in the lumbar dorsal fascia and spinal cord (51).

Moreover, HT conveyed by some devices (e.g., heat wraps) is applied together with a certain level of pressure, which can stimulate the nerve endings deputed to analyze pressure and movement (proprioceptors); also they favour the blockade of pain transmission to the central nervous system.

Thermoception and nociception are partly mediated by TRPV1 receptors, which act as explained above. TRVP1 receptors activation in the brain is probably deputed to control anti-nociceptive pathways, which are involved in reducing muscle tonicity and relaxing muscles, thus lowering spasms and MP and favouring muscle flexibility (47,48,52).

Moreover, HT also lowers the tonus of muscle and fascia (53), probably through a reduction of hyaluronan viscosity, which normalizes the gliding and restores the activity of fascial proprioceptors (54). Also, thoracolumbar fascia increased thickness and hampered shear motion mobility can be responsible of fascial scarring in chronic low back pain (55,56). HT in this context can also have a restoring effect on the thoracolumbar fascia (53). In addition, HT can induce modifications in viscosity and density of connective tissues, thus ameliorating the range of movement and increasing tissue extensibility.

HT elevates tissue temperature, thus enhancing metabolism, vasodilating and favouring the healing process. Every 1 ℃ of tissue temperature increasing determines a 10–15% augmentation of local metabolism. By means of vasodilatation, healing is facilitates by an increased supply of nutrients and oxygen, and a forced removal of pain mediators related to tissue damage.

Some studies highlight that localized, repeated HT may favour angiogenesis and increase muscle strength (47,48,50,57,58).

Safety profile

One notable advantage of superficial HT is the favorable safety profile. A Cochrane review of nine studies found that superficial HT was linked to solely minor adverse events, typically “skin pinkness” rapidly resolving (59). However, it is important to note that there are potential risks associated with the use of superficial HT, typically burns or skin ulceration.

Additionally, in certain conditions, it can lead to complications, progression, or exacerbation of inflammation. Consequently, HT must be cautiously used in case of sensory impairment, such as multiple sclerosis or spinal cord injuries due to neurological concerns, in pain associated to active inflammation, such as autoimmune diseases with joint pain or activated osteoarthritis in order to avoid exacerbation, in poor circulation contexts, and in cancer (60).

Current indications for acute and chronic pain

The published literature deals with only adult patients, so data in children and adolescents can only be argued. Low back pain is a typical indication for HT, after excluding systemic causes (49,61). In the previously mentioned review, regarding 1,117 adult patients, the authors demonstrated that the continuous HT by means of heat wrap applied to the skin provide small, short-term improvements in pain and mobility (59). Consequently, HT represents a favourable and feasible self-treatment approach to acute and sub-acute low back pain, both alone or combined in a multimodal way. In particular, in adults when compared to acetaminophen and ibuprofen, HT provides better short-term pain relief, less muscle stiffness and more lateral trunk flexibility with improved disability scores (Roland-Morris questionnaire) (62). The same can be said for overnight application of HT compared to placebo in adults (63). Interestingly, in two workplace studies in adults, HT by wraps was demonstrated to lower pain level in subjects with acute low back pain, either during treatment and up to two weeks after it (64,65). It also decreased the impact of pain on day life activities, namely ability to lift, work performance, and quality of sleep, and offered sufficient pain relief for the majority of the subjects (64). The prolonged effect in the acute setting implies a better recovery.

HT by wraps has also been studied in the context of a multimodal strategy in acute and chronic scenarios. The combination of HT with exercise in adults determined major short-term pain relief than exercise alone or no treatment/placebo control groups (66). In the chronic setting, heat wrap combined with basic multimodal treatment better improved their parameters (extension and right/left rotation) after 12 weeks in adults (50), as well as short-term improvements in physical and psychological wellbeing (67). Cost-effectiveness studies have demonstrated that HT by wraps to treat low back pain is beneficial to healthcare systems (68) and employers (64). Economic modelling suggests that introducing HT by wraps instead of oral treatments (i.e., acetaminophen or ibuprofen) would save money to the UK National Health Service (62,68). Moreover, a pharmacoeconomic study has confirmed that HT by wraps favours improved workplace productivity, and consequent benefit to employers (64).

Superficial low-level HT-associated muscle relaxant and analgesic properties have also been demonstrated favourable against other types of MP, namely neck pain (69,70), knee pain (including pain from osteoarthritis, where HT was more effective than acetaminophen) (70-73), and wrist pain related to strain or sprain, tendinosis, and carpal tunnel syndrome (74). Localized heating of certain trigger points has also proven effective at relieving neck pain; in this case, the heat is applied on the upper trapezius muscle (69). Studies have also indicated that HT is effective at preventing and treating delayed-onset muscle soreness (DOMS) associated with exercise, with benefits observed in younger and older adults, as well as those with diabetes (a group who reportedly experience greater muscle soreness after exercise) (70,75-77). In addition, the application of HT for 8 hours, namely 4 hours before exercise and 4 hours after it, was found to be significantly more effective than stretching to prevent pain and improve disability and physical function the day after exercise (75). Further to this, studies have also indicated that HT provides greater benefits than cold therapy when applied after exercise (75-78).

Heat wraps as a method of HT for pain relief have shown the key advantage of wearability, which allows for continuous use and the rapid resumption of work/normal daily activities. This feature makes it particularly relevant for other areas of pain management, such as dysmenorrhea, where it has demonstrated pain relief comparable to that achieved with ibuprofen in young female adults (79,80). HT may also be included in a multimodal approach to manage long-term pain due to some surgical procedures (81).

Methods

The following part of the paper is the result of a virtual advisory board held by the authors in order to discuss and provide an expert opinion about the use of HT in MP in children and adolescents.

Expert opinion

Cold therapy vs. heat therapy

According to orthopedics and physical medicine experts, cold therapy is generally recommended in the acute phase of an injury, especially when there is a possibility of structural damage such as bone fractures, ligament tears or muscle injury. Cold therapy can help reduce swelling and provide pain relief during this stage (48). Once structural damage is ruled out and swelling has decreased due to cold therapy, HT becomes a suitable choice for addressing ongoing pain, typically after 3–5 days (47,48,50). There are instances where HT can be used in the acute phase, particularly when a structural damage is quickly excluded, such as in cases involving neuromuscular innervation problems.

In case of muscle contraction, joint pain or sprains, it is advisable to wait 3–5 days before using HT, and to initially use cold therapy (48). The combination of alternating heat and cold therapy can be an option, particularly in muscle stiffness and restricted mobility after ankle and wrist fractures, however, as previously mentioned, explaining this combination to patients may pose some challenges.

Target population and target pathologies for heat therapy

According to orthopedic surgeons and physical/rehabilitation medicine experts, the indications for HT do not generally differ between adolescents and adults with the most common uses being axial pain (e.g., cervical, dorsal or lumbar), joint pain (e.g., knee and shoulder) and muscle spasms or functional muscle disorders (no structural damage visible on imaging) (82).

HT is often used as a complementary treatment to physiotherapy (66). A multimodal approach including manual therapy, therapeutic exercise, physical therapies (such as heat and cold therapy) and proper information and self-management tactics are crucial in the management of these patients. Parents and adolescents are often skeptical of the treatment plans offered by different professionals (physicians, physiotherapists) and in this regard, transmitting the key ideas of the treatment to patients could help: (I) physiotherapy: supervised exercise and manual techniques and (II) complementary treatments: heat or cold therapy.

Nowadays, sedentary lifestyles and incorrect posture in everyday life can lead to postural alterations and MP. With few exceptions, the therapeutic management of these problems mainly involves a therapeutic exercise plan supervised by a physiotherapist (83). Unfortunately, correct compliance with exercise plans is very poor due to several factors: lack of information, pain with exercise execution (especially at the beginning) or lack of motivation or information. HT can play an interesting complementary role in these patients by reducing pain prior to active therapy, helping to provide a more complete treatment and encouraging greater adherence to treatment. In particular, HT can be useful in this context also in reducing the fear of pain and thus favoring the adherence to exercise programs.

Experts suggest that, once a structural injury has been ruled out, the most useful symptom for the application of HT is muscle stiffness associated with pain. It has no influence whether the pain has started after a sport performance (overexertion, microtrauma) or due to a postural cause or disuse.

In the sport setting, the most common therapeutic target treated with HT is the muscle. It can be used for: (I) pre-competition preparation to warm up muscles (with likely effects on performance, due to increased blood circulation and readiness to perform immediately); (II) soften tissues in case of stiffness due to post-traumatic immobilization; (III) reduce pain and warm up a tendon affected by tendinopathy. In this context, HT serves both for pain relief and function improvement. Indeed, exercise combined with HT works on nociceptors and favour the production of endorphins (19,32). When proposing HT in a multimodal approach, it is indicated to let the patient think that there will be an improvement, favouring both pain and functional benefit.

DOMS is a type of ultrastructural muscle injury whose manifestation is caused by eccentric or unfamiliar forms of exercise, which leads to further protein degradation, apoptosis, and local inflammatory response (84). DOMS induces reduced force capacities, painful restriction of movement, stiffness, swelling and dysfunction of adjacent joints (84). The development of clinical symptoms is typically delayed (peak soreness at 48–72 hours post-exercise) as a result of complex sequences of local and systemic physiological responses (85). Although DOMS is considered a mild type of injury, it is one of the most common reasons for compromised sportive performance. HT has been used for this issue, being useful for not only pain relief (i.e., post-exercise), but pain prevention as well (i.e., pre-exercise). HT in this setting is especially useful in young athletes (from 15 to 18 years) (70,75-77).

For conditions such as "growing pains" in children and adolescents, where the cause is unknown, HT or massaging can be empirically tried if the pain persists beyond a few minutes upon waking up in the middle of the night. However, it is important to note that there is currently no evidence from the literature supporting this approach.

Additionally, chronic pain related to tendons and chronic ankle instability may also benefit from HT, potentially reducing the need for pain medication. In general practice, HT is commonly used in combination with analgesics for less younger patients, with healthcare professionals explaining how these strategies work to enhance their benefits, to reduce drug use and to favour adherence.

Contraindications to heat therapy

As suggested above, unknown muscle or skeletal pain or undiagnosed articular or upper/lower limb pain contraindicate the use of HT, almost until a diagnosis is made. Indeed, in the very acute phase or in bone fractures/muscle tears HT is not the choice. In addition, inflammatory processes, actual or suspected bacterial infective or rheumatologic diseases contraindicate HT as well, because the process needs to be calmed down with cold. Burn areas, open or healing wounds or skin injuries are also absolute contraindications. Finally, sensitivity reactions to the patch are an absolute contraindication (59,60).

Relative contraindications include mental disability and cerebral palsy: if HT is not tolerated it should not be applied. Several dermatological conditions (e.g., psoriasis) are relative contraindications depending on their severity. Vascular disease may also constitute a relative contraindication. On the other hand, diabetes mellitus and metabolic disorders should be considered but does not constitute a contraindication.

Patient education recommendations

The lack of evidence and specific guidelines in HT application may be the leading cause that its use is not yet well established. In our opinion, a systematization of the message to patients in the clinical consultation could help to reduce non-compliance. This systematization should include: (I) information on the convenience of its use in the patient's diagnosis; (II) detailed explanation of the application of the therapy; (III) existing precautions and contraindications; and (IV) benefits of its use (e.g., reduction in the use of pain killers).

Actual needs and future perspectives

There is a lack of data on the efficacy of HT in relieving pain in teenagers and adolescents. Its use is almost always empirical the most common anatomic locations being the neck and the low back as well as peripheral muscles. Indeed, a distinction should be made among people 10 *vs.* 20 years old, who typically do not experience long-term pain conditions like tendinopathy, and thus it is preferable to avoid medication use in the second age group to minimize the risk of dependence (36-40). Moreover, HT can potentially reduce the dose of analgesics in this population. Further studies should refute or confirm this point.

It is remarkable how adolescents tend to present less post-traumatic muscle hardening, making HT less useful in these cases (86). In contrast, this population recovers earlier in the context of ankle sprain, acceleration-deceleration injury or muscle tear, so HT could be used earlier. Other potential applications of HT that warrant further study include childhood disabilities, the most common being cerebral palsy, autism spectrum disorders and Down syndrome. Among these patients, heterogeneity is high. This fact complicates the study and subsequent standardization of any treatment. However, it would be valuable to conduct clinical trials in common pathologies associated with disability in adolescents, such as cerebral palsy.

Conclusions

In conclusion, acute and chronic MP is common issues among children and adolescents that should be addressed. According to the experts, MP in this population is mostly related with sedentary lifestyles, incorrect postures and sports practice (87). A correct approach to these patients should include a multidisciplinary view involving: (I) patient information, self-management strategies and cognitive-behavioral therapies in chronic cases; (II) therapeutic exercise; (III) physical therapies as heat and cold therapy; and (IV) rational use of medications is recommended.

In this line, HT would help to avoid or reduce drug administration, promote pain-free rehabilitation programs and favor early recovery in DOMS through their local effects.

The expert panel strongly emphasizes the importance of conducting studies and establishing guidelines to improve the understanding and application of HT in children and adolescents with MP. These efforts will contribute to optimizing treatment outcomes and ensuring the safe and effective use of HT in this population.

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Footnote

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