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REVIEW PAEDIATRIC IR

Pain Management in Pediatrics: What the IR has to Offer

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Abstract Pediatric pain management presents unique challenges due to the intrinsic characteristics of children such as their developmental stages, communication barriers, and varying pain perceptions. Life-limiting conditions affecting children are a growing medical concern, requiring a comprehensive, multidisciplinary approach to improve quality of life or ensure a dignified end of life. Interventional radiology (IR) plays a critical role in this strategy, similar to its role in adult care. Not only life-limiting conditions pose a challenge in pediatric chronic pain management, but also other benign chronic diseases (e.g., cystic fibrosis, muscular dystrophy, neurodegenerative disorders, metabolic disorders). This review focuses on specific IR strategies for pediatric pain management, including ablation, embolization/chemoembolization, and nerve blocks. It emphasizes the importance of tailored approaches for pediatric patients, considering genetic disorders and oncological diseases, which may require a diverse range of IR treatments. The aim is to provide a summary of these interventional techniques and highlight the unique considerations necessary for effective pediatric pain management.

Keywords Child · Children · Interventional radiology · Pain · Ablation

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Introduction

Pain in children has both somatic and neuropathic components. While neuropathic pain in children was considered rare, its prevalence appears to be increasing. Chronic pain in children represents a significant concern, profoundly impacting their overall functioning and quality of life. Numerous studies highlight the challenges faced by children dealing with chronic pain, revealing restrictions in daily living, identifiable triggering factors, a lower pain threshold, and increased behavioral distress compared to children with similar age without chronic pain [1, 2]. The consequences of chronic pain in children extend beyond immediate discomfort, affecting various aspects of their lives, including school performance, and indicating potential long-term implications for their well-being [3]. Pain and discomfort in children are often linked to non-tumoral conditions such as neurological or neuromuscular disorders, with only about one-third of cases related to cancer. Many children with cancer are not referred to interventional radiology (IR) for pain management because severe pain unresponsive to opioid analgesia is relatively uncommon, even in terminal stages, and pediatric clinicians are often less familiar with the pain management options that IR can provide [1–3].

Interventional radiology plays a crucial role in managing complications arising from life-limiting conditions in adults, with pain management being one of the most frequent and challenging issues. Managing chronic pain in children presents unique challenges due to the complexities of assessing pain levels and gauging responses to medications typically designed for adults. The optimal treatment approach for chronic pain in children should consider the potential treatments offered by interventional radiology to

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improve quality of life. Nerve blocks, epidural injections, and joint injections have proven effective in managing chronic musculoskeletal or neuropathic pain in children [4, 5]. Embolization and sclerosis are frequently used to alleviate pain associated with varicocele, aneurysmal bone cysts, or vascular anomalies [6, 7]. However, the use of bland embolization or chemoembolization, commonly utilized in adults for managing painful bone metastases, has only been reported in a limited number of pediatric cases [8, 9].

There is an urgent need to explore the role of percutaneous ablation in managing chronic inflammatory pain with a biomechanical origin or in pediatric benign aggressive or oncological diseases [9–11]. This exploration could provide new ways for effective pain management in children, improving their overall quality of life. This review aims to explore the various interventional radiology treatments available for managing chronic pain in the pediatric population, highlighting their efficacy and potential to improve therapeutic outcomes and enhance the quality of life for affected children.

Nerve blocks, epidural, or joint injections

Undertreated pain in pediatric cancer patients negatively affects patients' emotional, psychological, and social well-being [12]. Interventional pain management techniques are often a leading option to managing pediatric pain as part of multidisciplinary approaches [13]. Numerous interventional techniques (nerve blocks, epidurals, and intrathecal therapies) are widely and early used in adult pain management, whereas are often only considered in pediatric populations when all other treatment options fail [14]. Peripheral nerve blocks are used when systemic analgesia and sedation are rendered ineffective or limited by adverse effects. The technique consists of the delivery of local anesthetics usually with adjuvants, such as corticosteroids, in proximity to a peripheral nerve with ultrasound guidance. This technique can be employed as a single injection, as repeated injections or as a continuous infusion [14]. Several pediatric orthopedic tumors as osteosarcoma, Ewing sarcoma, rhabdomyosarcoma, giant cell tumors, and others improve in their pain scores after nerve blocks [15]. Innovative peripheral nerve blocks allow management of refractory pain in a pediatric patient receiving palliative care as erector spinae plane peripheral nerve block using fluoroscopy-guided catheters placement [16]. Other successful cases of tunneled peripheral nerve catheters for long-term analgesia have been reported in the literature [17]. Cryoneurolysis has shown effectiveness improving pain management in children undergoing thoracotomy for both malignant and benign conditions [18, 19] (Fig. 1).

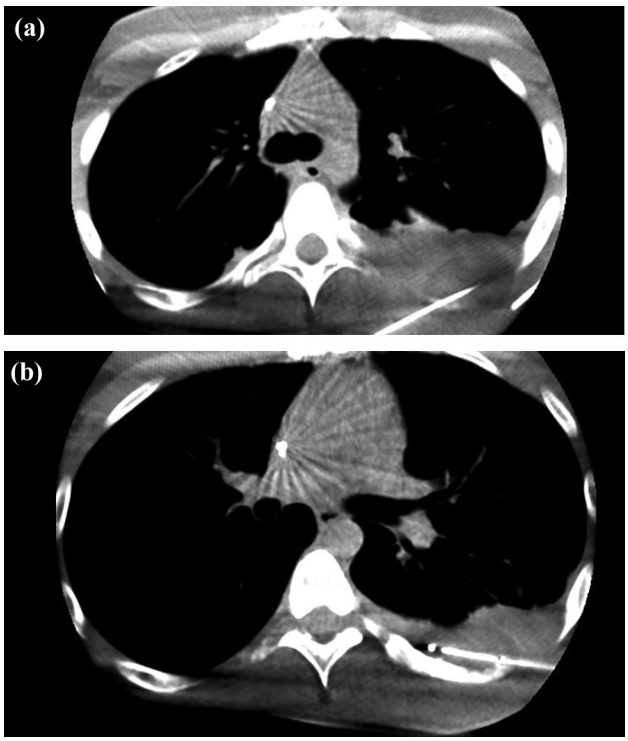
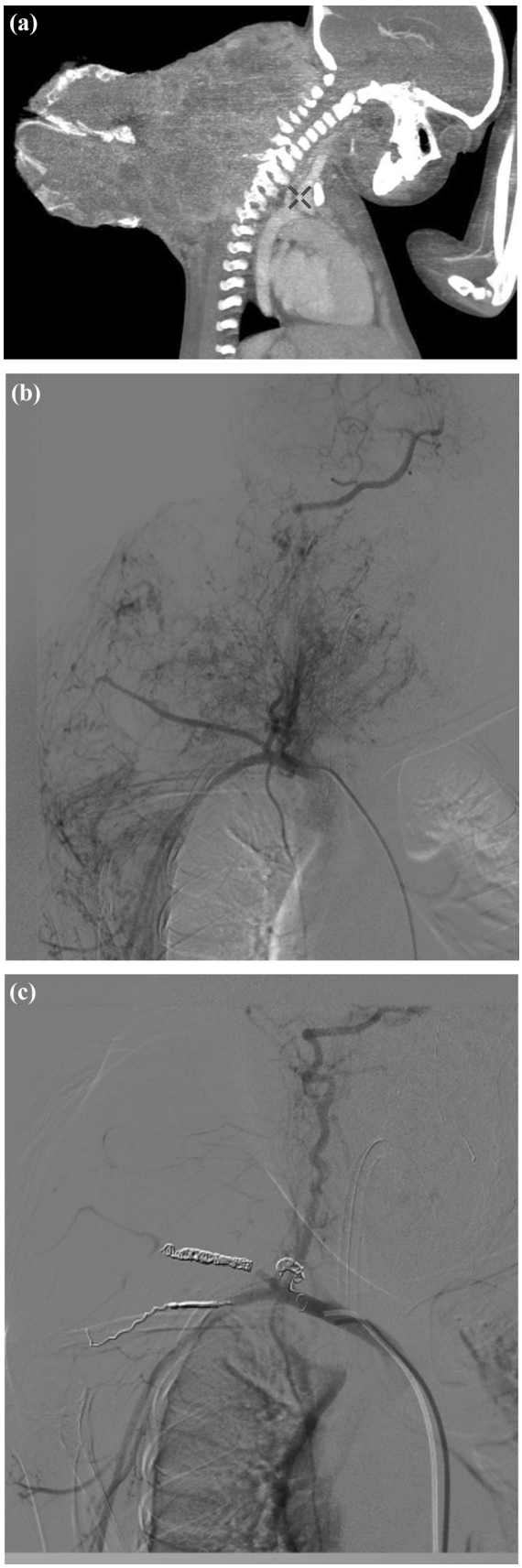


Fig. 1 **a** and **b** Metastatic rib osteosarcoma causing pain treated by means of cryoneurolysis of the intercostal nerves

Compared to other ablation modalities, such as radiofrequency ablation, cryoablation may be better tolerated with decreased need for anesthetics during the procedure [20]. Image guidance using ultrasound, CT, or cone-beam CT has been described and may reduce associated complications (Fig. 2).

Intra-articular injections are widely used in adults for local pain control and can also be performed for localized pain in pediatric patients.

Intra-articular corticosteroid injections (IACIs) are mainly applicable to chronic rheumatoid arthritis and osteoarthritis of temporomandibular joint and knee. IACIs are used alone or as an emergency therapy when nonsteroidal anti-inflammatory drugs are ineffective [21]. To increase the chances of success of IACIs treatment and minimize the risk of local side effects (i.e., subcutaneous atrophy), the needle must be placed correctly in the joint space. Ultrasound-guided injections avoid radiation and allow precise needle location. Depot corticosteroids are most suitable for intra-articular injection therapy. Commonly used drugs include methylprednisolone (MP), triamcinolone acetonide (TA), and triamcinolone hexanoate (TH). TH has a better control effect on joint symptoms than TA [22, 23]. Doses of TH range from 0.25 to 1.5 mg/kg depending on the size of the children and the joints (for example, 0.25–0.5 mg/kg for the wrist; 1–1.5 mg/kg for knees or hips) [24, 25]. According to pharmacokinetic



◀**Fig. 2** **a** Contrast enhanced CT in a 4-year-old boy with a cervical rhabdomyosarcoma causing pain and bleeding. **b** and **c** Digital subtraction angiography before and after bland embolization with beads (500–700 microns) and coils (ranging 3–5 mm in diameter). Observe tumor devascularization showed as reduced contrast enhancement; VAS was not evaluable due to patients condition but opioid consumption was reduced

studies, the biological effect of TA at a double dose is equivalent to that of TH. IACIs treatment can be performed under local anesthesia, conscious sedation, or general anesthesia to ensure accurate injection. Experience and local facilities are important factors in technology selection.

Sympathetic blockade has also a role in the treatment of pediatric cancer pain. Celiac plexus blockade (CPB) is performed in pediatric patients with severe, intractable pain secondary to pancreas cancer but also in liver, neuroblastoma gallbladder, spleen, stomach, and small intestine cancers. The main indication is often limited to terminal oncological patients when profound adverse effects limit the use of opioid therapy [26]. Epidural analgesia is performed either as a single injection or as a continuous epidural infusion through a catheter. In pediatric patients, the catheter is often tunneled subcutaneously for a long-term pain control and to avoid dislodgement and decrease infection risk. Potential complications as accidental dural puncture can be easily avoided using ultrasound or cone-beam CT image guidance [27]. Spinal cordotomy involves lesioning of the spinothalamic and spinoreticular tract after failure of traditional therapies and other invasive procedures. It has been performed as an open procedure but percutaneous CT-guided approach allows an accurate needle placement and permits the use of electrical stimulation to verify the spinothalamic tract needle placement [28].

Embolization and Chemoembolization

The most prevalent symptom in children with advanced cancer is pain, affecting over 80%, and is frequently inadequately managed [29]. Benign aggressive and malignant bone and soft tissue lesions can induce pain due to their size and compression of surrounding structures. The external compression of structures by tumors not only leads to significant discomfort but also poses an acute life-threatening risk [30].

In clinical situations when children suffer severe pain that opioids cannot effectively address due to factors like tolerance, toxicity, or refractory neuropathic pain, radiation therapy typically emerges as the primary option for

managing painful osseous lesions. However, in situations resistant to radiation therapy, endovascular or percutaneous techniques may be employed for localized pain management. Endovascular techniques for the treatment of chronic pain in children can be specially indicated in situations related to cancer pain, but also other benign conditions like aneurysmal bone cysts (ABC) or varicocele [6, 8].

Palliative procedures, such as transcatheter arterial embolization (TAE) and chemoembolization (TACE), have been proven effective, given their minimally invasive nature, repeatability, effectiveness, and rapid action [31]. Common embolics for bland TAE include polyvinyl alcohol (PVA) particles, gelatin sponge (Gelfoam), microspheres, coils, lipiodol, and beads, with the choice depending on the clinical scenario, target vessel size, and desired duration of embolization. The goal is to reduce pain and in certain situations achieve tumor debulking. Palliation in these cases is accomplished by impeding locoregional osteolysis, suppressing cytokine-mediated tumor-associated inflammation, reducing tumor volume to relieve periosteal stretching, and alleviating the mass effect of the tumor on surrounding tissues [32]. Bland embolization is utilized for local control and symptom palliation in bone tumors [33].

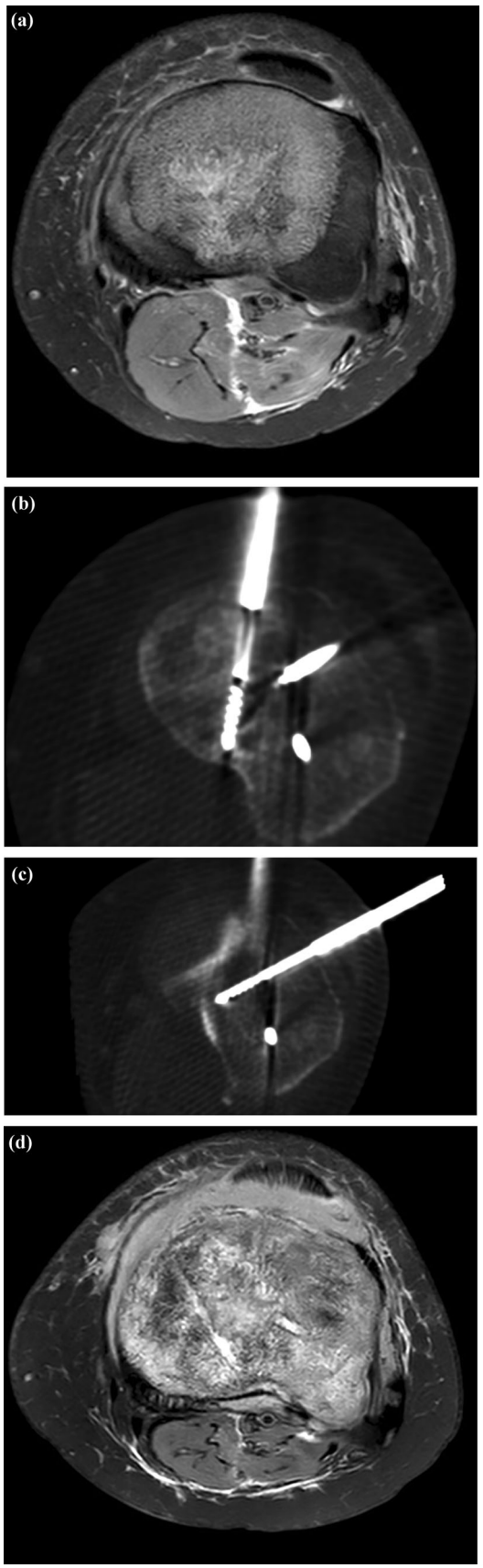
Among benign aggressive diseases, ABC appears as a common benign bone tumor in childhood and early adulthood, presenting as painful expansive osteolytic lesions with the potential for local aggression. Embolization is employed for pain relief and to treat ABC in locations where surgery is challenging and poses a high risk of complications [8]. In cases of malignant osseous and soft tissue sarcomas, although the pain score increases immediately after transcatheter TAE, the score decreases at 2 weeks after embolization [34] (Fig. 1a, b). Chemoembolization with intra-arterial methotrexate has been utilized to treat resistant osteosarcoma [35]. TACE can also be employed in cases of epidural spinal cord compression refractory to radiotherapy [36].

Ablation

Percutaneous ablation is a minimally invasive treatment that allows to improve chronic pain in patients with diseases like vascular anomalies or both malignant and benign tumors.

Ablation helps relieve pain through various mechanisms, including the neurolysis of nociceptive fibers, reducing the compressive effects of tumors on surrounding structures, and decreasing inflammation related to tumor presence. Moreover, it induces a neurolytic effect on nerves or nerve plexuses, targeting the neuropathic component by triggering Wallerian degeneration.

This process blocks pain transmission, amplifies the efficacy of opioid drugs, and consequently lowers the required dosage while mitigating associated side effects [37]. Ablation treatments for pediatric patients should consistently be carried out under general anesthesia to minimize movement, decrease complications, and enhance the patient's positional comfort. These techniques can be used alone or in combination with opioid drugs or external radiotherapy (EBRT). The most frequently used ablative techniques are those using thermal energy such as cryoablation, radiofrequency (RFA), microwave ablation (MW), and chemical ablation with ethanol [38]. Radiofrequency ablation (RFA) is widely used in the pediatric oncological population in the management of osteoid osteoma. In this tumors, pain is a predominant symptom that is often inadequately managed by long-term oral analgesics. Percutaneous RFA allows for destruction of the tumor and total pain relief with no analgesic requirement [39]. In the last years, electrosclerotherapy with bleomycin or electroporation (reversible or irreversible) has also emerged as relatively new options that have an ablative effect [38, 40]. Selection of the specific ablation technique takes into consideration, tumor histology, location, tumor size, and operator experience. One of the advantages of ablation over radiotherapy is its faster effect in pain reduction and the ability to reproduce the technique when the analgesic effect is not effective and the ability to repeat the procedure if the analgesic effect is not sufficient. Moreover, combining percutaneous ablation (RFA, MW, or cryoablation) and EBRT may act synergistically with no increase in the adverse event rate [41]. The musculoskeletal system is affected by primary tumors, metastases, and skeletal-related events (intractable pain, pathologic fractures, or nerve compression), which can significantly reduce a patient's quality of life. (Fig. 3a, c). Percutaneous cryoablation is also an effective ablative treatment option for pain control in bone benign tumors as chondroblastoma and osteoblastoma in the pediatric population. Cryoablation of chondroblastoma and osteoblastoma is effective for pain control in pediatric patients [8]. Vertebral compression fractures related to bone tumors can be a source of intractable pain. Vertebral augmentation using balloon kyphoplasty has been reported as an effective pain treatment tool in this pediatric population [42]. Finally, hemophilic arthropathy, rheumatoid, and idiopathic arthritis are well-known medical conditions that can impair the patient's quality of life seriously. Percutaneous medical joint synovectomy (synoviorthesis) consists of delivering intrarticular radionuclides, 90Y (yttrium-90) (knees) and 186Rh (rhenium-186) (elbows and ankles) to alleviate symptoms (bleeding and pain) with an about 85% success rates. Synovectomy is indicated for patients with joint swelling that have not responded to medical therapy



◀**Fig. 3** **a** Tibial Ewing sarcoma causing invalidating pain in a 10-year-old patient (visual analogue scale = 8). **b** and **c** Cone-beam computed tomography-guided percutaneous cryoablation. d MRI control after treatment showing ablated zone, clinically the pain improved significantly (VAS = 2)

for over six months or for those with ongoing disease progression [43].

Importance of Multidisciplinary Consultation in Psychosocial Support

Pain in children is influenced by physical, emotional, and social factors and is often perceived and expressed differently than in adults. Unlike adults, children may have difficulty verbalizing their pain, making it crucial to consider psychosocial aspects. A multidisciplinary team, including pediatricians, psychologists, social workers, surgeons, diagnostic radiologists, and interventional radiologists, collaborates to assess and manage pain from various perspectives. Pain management strategies, such as opioids, surgery, or interventional techniques, all carry potential side effects. A multidisciplinary consultation service can effectively address complex pain management needs and provide psychosocial support to children and their families. Interventional radiologists play a key role in offering specialized treatment options and communicating the benefits and risks to patients and families. The importance of a multidisciplinary approach is evident in its ability to provide comprehensive psychosocial support, improving pain management outcomes. Psychological interventions are particularly effective in reducing procedural pain and distress in pediatric patients, as supported by systematic reviews and meta-analyses [44, 45]. This collaborative model enhances the quality of care by addressing all dimensions of pediatric pain and ensuring a coordinated approach.

Discussion

Pediatric pain management, usually faces unique challenges including communication barriers, developmental differences, emotional and psychological factors, the need for parent and caregiver involvement, complexities in medication dosage and safety, the long-term impact of chronic pain, and ethical considerations in treatment decisions. For its optimal management, it is imperative to consider the alternatives that interventional radiology can offer. Nerve blocks and sympathetic blockade can be effective in managing cancer pain, while embolization and

chemoembolization offer minimally invasive solutions for conditions like aneurysmal bone cysts and varicocele besides different tumor types. Percutaneous ablation is a highly valuable alternative for a rapid pain alleviation specially in bone (that might include augmentation techniques) but also in soft tissue or abdominal tumors. Other treatments not discussed in this review, like pleural and peritoneal effusion drainages with permanent catheters, can also effectively manage pain in children with advanced diseases. These catheters continuously drain excess fluid, reducing discomfort and respiratory distress. This minimally invasive method improves quality of life by providing pain relief and reducing the need for repeated needle insertions, making it a crucial component of pediatric palliative care [46].

Conclusions

This review stresses the need for a multidisciplinary approach, involving pediatricians, psychologists, and interventional radiologists, to comprehensively address the physical, emotional, and social aspects of pediatric pain. Collaboration ensures a cohesive strategy, minimizing potential conflicts and enhancing the overall quality of care.

Declarations

Conflict of interest The authors explicitly declare that there are no conflicts of interest that could influence the objectivity and integrity of the results presented in this article.

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