Advances in nonpharmacologic interventions for operative puncture pain in children

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Abstract
Venipuncture is an indispensable nursing procedure for intravenous infusion, but it is also an invasive procedure that is highly resisted by hospitalised children due to pain or fear. Non-pharmacological interventions are widely used in clinical practice due to their low cost, low risk and simplicity. This article provides a review with the aim of providing a reference for the selection of optimal analgesic interventions in the future.

Keywords: children; operative pain; nonpharmacological interventions; review
Peripheral venipuncture is a common procedure for children receiving infusions, with more than 90% of hospitalised children having received a venipuncture [1], yet the pain associated with venipuncture is one of the most feared invasive experiences in the treatment of children [2]. Excessive anxiety and pain can affect the child's physical and mental health, resulting in behavioural changes such as screaming, refusal, crying and excessive body writhing, leading to puncture failure and delayed treatment of the disease. Exposing a child to prolonged painful stimuli can have many negative effects on their physical and mental health and growth, including increased pain sensitivity, chronic pain, excessive metabolic and hyperinflammatory changes, psychological disturbances, sleep problems and social learning difficulties [3]. Pain has been ranked as the fifth most important vital sign after respiration, pulse, blood pressure and temperature [4], and it has become a consensus among healthcare professionals to minimise patient pain and discomfort during medical and nursing interventions. Therefore, how to improve nurses' painless venipuncture technique has become an important and urgent issue. This article summarizes domestic and international research on non-pharmacological interventions to reduce venipuncture pain in hospitalised children, aiming to provide an evidence-based basis for nurses in China to implement management practices.

**Behavioural interventions**

**Virtual reality technology**

VR technology has been demonstrated to effectively reduce fear and pain responses in children during venipuncture [5]. However, it is important to note that there may be some adverse effects such as dizziness, nausea, and headache [6]. It is currently not suitable for children aged 3–5 years as suitable sized headphones are not yet available. The dome screen VR experience is a suitable distraction for younger children during intravenous infusion. To set up the experience, a dome screen with a diameter of 1.6m should be placed 0.6m from the floor at the end of the bed. Animations can be projected onto the dome screen using a computer-connected projector. However, it is important to note that the implementation process requires turning off the lights in the ward, which may make it more difficult to perform a puncture. Lee et al conducted a VR intervention experiment on venipuncture in children aged 2–6 years [7]. The results showed that VR could shift the children's attention to things of interest, reduce fear and anxiety, and improve the success rate of venipuncture. The parents of the children were satisfied with the attitude of 88.8%.

The advantage of VR is that it is highly appealing to the child and acts directly or indirectly on pain perception and signaling through attention, emotion, memory, and sensory perception, altering the activity of the pain modulation system and thus pain perception. However, no evidence has been found to suggest that immersive VR is consistently more effective than non-immersive VR in reducing venipuncture pain in children. Therefore, future studies should explore the differences between immersive and non-immersive VR from various perspectives.

**Distraction cards**

Distraction cards are small cards measuring 5 cm × 8 cm that contain hidden pictures and shapes. By carefully observing the patterns and shapes on the distraction cards or kaleidoscope, a child's attention can be diverted from painful stimuli. This is a simple and effective way to reduce pain in children. Karakaya et al conducted an experiment in the blood collection room of a training and research hospital in Turkey on children aged 7–12 years [8]. The intervention group viewed a kaleidoscope and described the patterns they saw. The results showed that the control group had significantly higher facial pain scores than the experimental group. This suggests that kaleidoscopes can be a distraction and may effectively reduce pain levels during venipuncture. Kaleidoscopes are toys that use the principle of mirror reflection and are made of a combination of lenses and coloured paper. In a study conducted by Gündüz et al, the effectiveness of kaleidoscopes in reducing pain perception during venepuncture was assessed in 206 schoolchildren in Turkey [9]. The results showed that the pain scale score in the intervention group (3.14 ± 1.41) was lower than that in the control group (3.80 ± 1.42) with statistical significance.

The advantages of distraction cards are that they are inexpensive and easy to implement, and children are more likely to understand and cooperate with them. However, when using distraction cards and kaleidoscopes, nurses should talk to children face-to-face when they are in a calm state. It is inappropriate to use these tools to distract a crying child in a noisy, understaffed ward. When using distraction cards and kaleidoscopes, nurses should talk to children face-to-face when they are calm. It is inappropriate to use these tools to distract a crying child in a noisy understaffed ward. It is important to maintain a quiet environment for the health of the child.

**Cartoon film**

Wang et al conducted a study on 300 children aged 8–9 years old in the Department of Paediatrics of the Affiliated Municipal Hospital of Qingdao University, China [10]. The study involved watching cartoons and receiving psychological interventions. The study results indicate that the pain scores of the group exposed to cartoons were lower (4.55 ± 2.26 vs. 5.22 ± 2.53, P < 0.05) compared to the control group of children who did not receive any interventions. The study conducted by Dizkaya et al found that watching cartoons can distract children's attention, improve their cooperation, and reduce the pain of puncture in school-age children (4.55 ± 2.26 vs. 5.22 ± 2.53, P < 0.05) [11]. The authors recruited 477 children aged 6–12 years from the paediatric emergency department of a hospital in Turkey and randomly divided them into three groups: watching an animated version of the intravenous injection video, the cartoon group, and the control group. It was determined that there was no statistically significant difference in pain and fear reduction during venipuncture in children between watching an animated film or an animated IV video. Additionally, the pain scores of children in both groups were lower than those in the control group. Therefore, it is recommended to play an animated film or video during venipuncture and IV infusion.

Advantages of watching animated films include time-saving, effort-saving, wide range of interventions, and ease of management. The limitation of this method is that there is currently no evidence that it is suitable for all ages, and further confirmation is needed in future studies with children of different ages at different developmental stages and in different clinical settings.

**Clown care**

The clown care programme was first initiated in 1986 at the Big Apple Circus in New York. Since then, it has become a routine part of many children's hospitals [12]. The clowns wear red-nosed costumes and use brightly coloured medical equipment, guitars, and tambourines as part of their kit. Watching clowns perform magic, dance, children's games and songs can increase children's endorphin secretion and decrease stress hormone secretion, resulting in pain reduction. However, the effectiveness of current clown interventions for children of all ages varies. Kunudirek et al conducted a study on a clown care programme for 78 children in the haematology outpatient clinic of a university health research and application hospital in Turkey [13]. Although there were no statistically significant differences in preoperative pain scores between the clown intervention group and the control group of children, the clown intervention was found to relieve venipuncture pain in children aged 7–12 years (P < 0.05). Kristensen et al used the Facial Expression Scale method (Wong-Banker) combined with the 0-10 numerical grading method to assess post-puncture pain in children aged 4–15 years who received a clown intervention, and the results showed that the clown intervention had a pain-relieving effect only in children aged 7–15 years, and there was no statistically
significant effect on pain scores in children aged 4–6 years, which may be due to the fact that younger children are more susceptible to cognitive, emotional or environmental influences that may lead them to develop a fear of clowns [14].

The advantage of clown care is that its actors are not only volunteers who have received professional clown course training, non-professional entertainers or clown-trained entertainers, but also doctors or nurses, who make use of theatre therapy, performances, jokes, games and other methods, and use humour and "happy therapy" to help children overcome their inner anxiety and fear, and combine clowning techniques with positive psychology knowledge to help reduce the pain and stress caused by illnesses and provide emotional support outside of treatment. The combination of clowning techniques and positive psychology knowledge can help children reduce the pain and stress caused by the disease and provide emotional support beyond treatment. However, most of the current studies show that clown care has a significant effect on venipuncture in children, but due to the limited inclusion of sample sizes, differences in research methodology, and evaluation scales, large-sample, multi-centre randomised controlled trials or evidence-based studies are needed to determine the effect of clown care on venipuncture in children, and to promote the application and development of clown care in the healthcare environment.

**Blowing exercise**

Blowing up a balloon and coughing can increase chest pressure, activate pressure receptors, and elevate heart rate and blood pressure, which can help reduce pain. According to a study on children, blowing up a balloon for at least 20 seconds before a venipuncture and taking deep breaths and coughing before the puncture can effectively relieve pain [15]. In a study of intravenous cannulation, the Valsalva manoeuvre resulted in a significant reduction in the incidence of pain during manipulation [16]. Gupta et al suggested that the balloon blowing manoeuvre in children may contribute to the occurrence of the Valsalva manoeuvre [17]. In a study of children aged 7–12 years old, the intervention group had their children seated on their mother's lap or on the preoperative bed, depending on their age. After identifying the vein in the dorsal part of the non-dominant hand, the child was required to turn their head in the opposite direction and perform balloon inflation for at least 20 seconds. All children in the intervention group experienced mild pain, compared to 64% and 36% of children in the control group who reported mild and moderate pain, respectively. This suggests that the balloon blowing manoeuvre was effective in reducing pain levels in children.

The advantages of blowing training are that it is easy to implement, inexpensive and highly acceptable to children. Disadvantages are that there is no evidence to support an optimal blowing force, the effects of blowing vary considerably between children with different levels of control, and the effects of different blowing forces on pain should be further compared in future studies.

**Medical equipment assistance**

**Buzzy**

Buzzy is a medical device shaped like a bee that combines cold application with vibration. It consists of a body and removable ice wings. The frozen Buzzy can provide sustained cooling at room temperature for up to 10 minutes. To reduce the pain of venipuncture, it is placed 5 cm above the puncture point for 15–60 seconds. According to the down-regulation inhibitory control and ‘gating’ theory, the vibration of the Buzzy device blocked A-δ transmission of acute needlestick pain by causing the C nerve fibres to block the pain signals. Similarly, the ice wings stimulated the C nerve fibres to block A-δ pain transmission signals. According to a French study, pain scores were reduced by an average of 0.62 points in the Buzzy group compared to the control group during venipuncture or vaccination [18]. The Buzzy device's bee-like shape attracts children's attention, while its vibration and the ice packs effectively lower the level of pain perception. This is easily accepted by both children and parents.

Overall, the Buzzy device is a low-cost, versatile device that combines vibration and cold packs in a reusable, rapid, patient-administered intervention. Research on the Buzzy device is still in its infancy and has not yet been used in China, but large, multi-centre trials in children of different ages are needed to validate the effectiveness of the device in relieving pain from venipuncture.

**Skin refrigerant**

Skin refrigerant, also known as Vapocoolant spray, contains a volatile liquid that evaporates quickly upon contact with the skin. This causes a temporary decrease in skin temperature and numbs the area, making it less painful. To use, spray the refrigerant 7.62–20.32 cm above the puncture site and wait 2–10 seconds before performing venipuncture [19]. Currently, several countries, including the United States, the United Kingdom, and Canada, have attempted to use Vapocoolant spray during venipuncture procedures. However, the effectiveness of Vapocoolant spray in relieving venipuncture pain in children remains a topic of debate. Zhu Yun et al conducted a meta-analysis in 2018 on the application of Vapocoolant spray to alleviate venipuncture pain in foreign countries [20]. The study found that the use of Vapocoolant spray in 1,410 patients (adults and children) was able to reduce pain sensation and improve patient satisfaction during intravenous cannulation.

Skin refrigerant avoids the pain of needles during local infiltration anaesthesia, is fast-acting and easy to use, and has a disinfectant effect that reduces the incidence of associated infections. However, due to the fragile nature of children's skin, it cannot be used for prolonged periods.

**Reduced needle type**

Needles with small apertures cause less damage to the vein during skin puncture and produce a less painful experience. In China, infants and young children generally choose 24G cannulated thinner indwelling needles for venipuncture, surgical or older children choose 22G to 24G indwelling needles, and hypovolemic shock or critically ill children choose 20G indwelling needles to puncture the femoral vein and external jugular vein [21]. Currently, the push-button rebound blood collection butterfly wing needle (UT-PBBCS) device reduces the outer diameter of the needle cannula while maintaining the inner bore, and the 5° bevelled-tip design is more capable of reducing the force of needle insertion. Padoan et al compared the application of a 3° bevelled-tip 21G or 23G venous blood collection needle with a 25G model of the UT-PBBCS for venous blood collection in children who had difficulty with venous puncture, and showed that the UT-PBBCS was the best choice for venous blood collection [22]. Blood collection and showed that the UT-PBBCS did not affect the quality of the blood specimen ($P = 0.385$), while producing less pain ($P = 0.0339$) and a 0.42-point lower puncture difficulty, which was the most effective in reducing pain in children aged 3–12 years.

The current study did not demonstrate whether different needle types and sizes are more effective in alleviating puncture pain in children, necessitating further research and testing.

**Ultrasound-guided**

Studies conducted domestically have found that using ultrasound guidance for arterial puncture blood gas specimen collection can reduce patient pain and increase the success rate of the puncture. Ultrasound technology can accurately locate the position of the artery, avoiding peripheral nerves and veins, reducing the risk of mistakenly collecting venous blood and nerve damage, improving the success rate of arterial puncture, and reducing the pain of re-puncture due to the failure of blind puncture [23]. The use of ultrasound-guided dynamic tip positioning can reduce the pain caused by frequent puncture and alleviate children's fear of the procedure [24]. However, it is important to note that ultrasound-guided arterial puncture is still an invasive procedure that may cause vasospasm and muscle contraction at the puncture site, potentially increasing the difficulty of the puncture. Ultrasound-guided subcutaneous injection of phentolamine combined with lidocaine can reduce the pain of arterial puncture in

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children. This is achieved by blocking nerve conduction, decreasing nociceptive sensitivity, inhibiting arterial vasoconstriction triggered by adrenergic neurotransmitters, dilating blood vessels, decreasing the difficulty of puncture, and improving the success rate of puncture [25].

The results of foreign studies addressing the effect of ultrasound-guided arterial puncture techniques on patient pain have been inconsistent. A study by Grandij et al found that patients in the ultrasound-guided group had lower average pain levels associated with arterial puncture, a higher rate of first-time puncture success, and a shorter time spent [26]. However, Bobba et al found that there was no difference in the level of pain associated with arterial puncture between the ultrasound-guided group and the control group, and that patients with ultrasound-guided arterial puncture had a greater number of puncture attempts and took longer [27].

Meta-analysis showed that the technique of ultrasound-guided arterial puncture did not affect arterial puncture-related pain [28]. The role of arterial puncture experience in the outcome of ultrasound-guided puncture remains controversial; puncture-related pain is reduced when experienced medical personnel perform arterial puncture [26]. Due to the limited number of studies related to the ultrasound-guided arterial puncture technique and the high degree of heterogeneity, it is not possible to draw high-quality conclusions regarding the effectiveness of ultrasound-guided arterial puncture in reducing puncture pain, and more studies are needed to investigate the role of ultrasound-guided arterial puncture technique in the management of pain in children.

### Combined multi-method interventions

Most studies on analgesic measures for venipuncture in children have focused on evaluating the effectiveness of a single method. However, few have examined the impact of combining multiple analogical measures. Zhang Yumei et al conducted a meta-analysis of 16 interventions from 45 previously published papers [29]. They concluded that when venipuncture operation can be delayed for 60–90 minutes, it is recommended to use local anaesthetic patches combined with video game analgesia. If rapid analgesia is required, non-pharmacological analgesia using the Buzzy tool combined with distraction cards should be used to achieve optimal pain relief.

### Summaries

Hospitalised children experience frequent and prolonged venipuncture pain, which carries the risk of long-term physical, psychological and behavioural morbidity. This review summarises research on common non-pharmacological interventions to relieve venipuncture pain in children, which may provide a basis for pain management in children. Intervention studies on painless venipuncture in children have been conducted for many years, but the development of relevant intervention studies in China is not ideal due to the influence of the domestic consultation environment and nurse-patient concepts, and some children and their families are wary of the above interventions. Further relevant studies are needed to apply the above interventions in the cultural context of China and to implement appropriate interventions in the hospitals and departments of paediatric venepuncture services to improve and upgrade the process accordingly. In the future, the sample size could be further increased by conducting randomised controlled trials with multi-centre collaboration to improve the level of evidence for the interventions and provide evidence-based evidence with high quality studies. Subsequent studies can include outcome measures such as heart rate, blood pressure, breathing and child and family satisfaction to fully assess the effectiveness of the intervention. In the future, nurses will be able to choose the best interventions for venipuncture according to the clinical setting, age and interest of the children, to reduce the pain of venipuncture and improve the satisfaction of children and their families.

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