International Journal of Contemporary Research In Multidisciplinary

Research Article

From Guesswork to Guidance: Contemporary Advances in Pediatric Difficult Intravenous Access—A Narrative Review

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DOI: https://doi.org/10.5281/zenodo.21536163

Abstract

Peripheral intravenous (IV) cannulation is one of the most frequently performed procedures in pediatric healthcare. Despite its routine nature, obtaining successful vascular access in children remains challenging because of smaller vessel size, poor vein visibility, obesity, edema, dehydration, repeated venous interventions, and limited patient cooperation. Difficult intravenous access (DIVA) frequently results in multiple cannulation attempts, causing pain, anxiety, delayed treatment, increased healthcare costs, and parental distress. Over the last two decades, substantial progress has been made in improving pediatric vascular access through technological innovations and child-centred interventions. Traditional vein assessment techniques have been supplemented by trans illumination devices, near-infrared vein visualization systems, ultrasound-guided cannulation, and dedicated vascular access teams. Simultaneously, increasing recognition of procedural distress has led to the adoption of behavioural interventions such as cartoons, YouTube-based distraction, smartphone applications, virtual reality (VR), and interactive gaming. More recently, artificial intelligence (AI) and augmented reality (AR) technologies have emerged as promising tools for enhancing vascular access success. This narrative review discusses the burden of difficult intravenous access in children, currently available technologies, behavioural interventions, existing evidence, and future directions. Integrating advanced visualization techniques with effective distraction strategies may significantly improve first-attempt success while enhancing the overall procedural experience for children and their families.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 11-06-2026
- **Accepted:** 22-07-2026
- **Published:** 24-07-2026
- **IJCRM:** 5(4); 2026: 431-435

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Arun S, Darshan M M, Sharma S, Sinha S, Shouri S. From Guesswork to Guidance: Contemporary Advances in Pediatric Difficult Intravenous Access—A Narrative Review. Int J Contemp Res Multidiscip. 2026;5(4):431-435.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Difficult intravenous access, DIVA score, paediatric cannulation, ultrasound-guided vascular access, near-infrared imaging, virtual reality, digital distraction, artificial intelligence.

INTRODUCTION

Peripheral intravenous cannulation is an indispensable component of pediatric care. Whether administering fluids, antibiotics, blood products, chemotherapy, parenteral nutrition, or emergency medications, successful vascular access forms the cornerstone of many therapeutic interventions(1). Despite being considered a routine bedside procedure, achieving peripheral venous access in children remains a significant challenge across emergency departments, intensive care units, oncology wards, and neonatal units(2).

Several anatomical and behavioural factors contribute to these difficulties. Compared with adults, children possess smaller, less visible, and more mobile veins. Anxiety, fear, crying, and resistance frequently complicate cannulation attempts. Furthermore, obesity, malnutrition, oedema, dehydration, chronic illnesses, and repeated hospitalisations can significantly reduce vein visibility and palpability(3,4).

Difficult intravenous access (DIVA) has therefore emerged as an important clinical problem. Multiple failed cannulation attempts not only delay treatment but also contribute to pain, emotional trauma, parental dissatisfaction, increased healthcare expenditure, and prolonged procedure times(5,6). Repeated needle punctures may additionally result in vein damage and increase the risk of future vascular access difficulties.

Historically, successful cannulation relied largely upon clinical experience and conventional vein assessment techniques. However, advances in imaging technology, behavioural science, and digital health have transformed the management of pediatric DIVA. Modern approaches now combine technological innovations aimed at improving vein visualization with interventions designed to reduce procedural anxiety and enhance cooperation(7,8).

This review summarizes current concepts in pediatric DIVA and examines how technological and behavioural strategies can be integrated to improve procedural success and patient experience.

UNDERSTANDING DIFFICULT INTRAVENOUS ACCESS

DIVA refers to difficulty obtaining peripheral venous access using conventional techniques, often resulting in multiple insertion attempts or the need for advanced equipment and expertise. The incidence of DIVA varies across studies but is particularly high among infants, critically ill children, oncology patients, and those with chronic diseases requiring repeated venous access. Several factors increase the risk of DIVA(9,10):

Patient-related factors

- Age below three years
- Prematurity
- Obesity
- Malnutrition
- Edema
- Dehydration
- Dark skin pigmentation
- Chronic illnesses
- Previous chemotherapy

Vein-related factors

- Poor visibility
- Poor palpability
- Small calibre veins
- Venous scarring from previous cannulations

Operator-related factors

- Limited experience
- Emergency situations
- Inadequate lighting
- Lack of assistive device

THE DIVA SCORE: PREDICTING DIFFICULT CANNULATION

To facilitate early identification of children at risk of difficult cannulation, Yen and colleagues developed the DIVA score as shown in **table 1**, a validated clinical prediction tool(11).

Predictor Variable	Criteria	Score
Vein visible after tourniquet	Visible	0
	Not visible	2
Vein palpable after tourniquet	Palpable	0
	Not palpable	2
Age category	≥ 3 years	0
	1–2 years	1
	< 1 year	3
History of prematurity	Not premature	0
	Premature	3

Table 1. DIVA (Difficult Intravenous Access) Scoring System

The maximum score is 10.

A DIVA score ≥4 is associated with a substantially increased likelihood of failed first-attempt cannulation and multiple insertion attempts. Routine use of the DIVA score allows early escalation to advanced vascular access techniques such as ultrasound guidance or near-infrared imaging and may reduce procedural delays and patient distress(12).

TECHNOLOGIES FOR VEIN VISUALIZATION

Trans illumination Devices

Trans illumination devices use high-intensity LED light to illuminate tissues beneath the skin. Veins absorb part of the transmitted light and appear as dark structures against a brighter background. These devices are particularly useful in neonates and young infants where superficial veins may be difficult to

identify under normal lighting conditions. Advantages include portability, affordability, ease of use, and suitability for resource-limited settings. However, effectiveness decreases when veins are located deeper within subcutaneous tissues or in obese children(13,14).

Near-Infrared Vein Visualization

Near-infrared technology utilizes wavelengths absorbed by deoxygenated hemoglobin. As a result, veins become visible as dark structures projected onto the skin surface. NIR devices are especially useful in children with obesity, dark skin complexion, chronic illnesses, or poor vein visibility. They improve vein identification and operator confidence, although improvements in first-attempt success rates have been variable across studies. The major limitation remains cost, which restricts widespread adoption in many healthcare settings(15,16).

Ultrasound-Guided Vascular Access

Ultrasound-guided cannulation has transformed pediatric vascular access practice. Unlike trans illumination or NIR systems, ultrasound allows visualization of deeper veins and provides real-time guidance during needle insertion. Clinicians can assess vessel size, depth, patency, and surrounding structures before cannulation. Evidence consistently demonstrates higher first-attempt success rates, fewer insertion attempts, and reduced complications among children with difficult vascular access. For this reason, ultrasound is increasingly regarded as the preferred modality for patients with high DIVA scores or previous failed attempt(17,18).

THE PSYCHOLOGICAL DIMENSION OF CANNULATION

While technological advances improve vein identification, procedural success is influenced equally by the child's emotional state. Fear and anxiety frequently result in movement, crying, and resistance, reducing the likelihood of successful cannulation even when suitable veins have been identified. Pain perception in children is influenced by developmental stage, previous healthcare experiences, parental anxiety, and individual temperament. Consequently, effective management of DIVA requires attention to both technical and psychological factors(19,20).

DIGITAL DISTRACTION STRATEGIES

The widespread availability of smartphones and tablets has introduced simple yet effective approaches to procedural anxiety management. Children can watch cartoons, nursery rhymes, music videos, educational content, or preferred YouTube videos during cannulation. These interventions work by redirecting attention away from painful stimuli and reducing anticipatory anxiety. Several studies have reported lower pain scores, improved cooperation, reduced procedural distress, and greater patient satisfaction when video-based distraction is used during venipuncture and intravenous cannulation. The popularity of these interventions stems from their simplicity, low cost, and ease of implementation. Unlike advanced imaging technologies, digital distraction requires minimal resources and can be readily incorporated into routine clinical practice(21).

VIRTUAL REALITY: A NEW ERA IN PEDIATRIC PROCEDURAL CARE

Virtual reality represents one of the most exciting developments in pediatric pain management. By immersing children within interactive three-dimensional environments, VR creates a powerful cognitive distraction that substantially reduces attention directed toward painful procedures(22,23). Several studies evaluating VR during venipuncture, cannulation, vaccinations, and dressing changes have demonstrated reductions in pain scores, anxiety levels, and procedural distress. Compared with conventional video distraction, VR provides a more immersive experience and may therefore offer greater benefit, particularly in school-aged children and adolescents. Although equipment costs and infection-control considerations remain challenges, increasing affordability is likely to facilitate broader adoption.

DISCUSSION

Management of Pediatric DIVA has evolved from simple visual inspection of veins to a multidisciplinary approach combining advanced imaging technologies and behavioural interventions. Among currently available visualization technologies, ultrasound-guided vascular access possesses the strongest evidence base. Multiple studies have consistently demonstrated superior first-attempt success rates, reduced procedure duration, and fewer complications compared with conventional cannulation techniques. Ultrasound is particularly valuable in children with obesity, edema, chronic illness, or previous failed attempts because it enables visualization of deeper vessels and real-time needle guidance(24).

Near-infrared vein visualization systems have improved vein localization and operator confidence; however, evidence regarding improvements in cannulation success remains mixed. Benefits appear greatest in younger children and those with poor vein visibility. Similarly, trans illumination devices have shown favourable results in neonates and infants but are less effective in older or obese children. Importantly, visualization technologies address only one component of the problem. Successful cannulation also depends upon the child's cooperation and emotional state. Increasing evidence supports the use of digital distraction techniques including cartoons, smartphone applications, and YouTube videos. These interventions reduce procedural anxiety and improve cooperation at minimal cost(25).

Virtual reality appears particularly promising because of its immersive nature. Several studies have demonstrated greater reductions in pain and anxiety compared with standard distraction techniques. Nevertheless, practical barriers such as cost and equipment maintenance currently limit widespread use. Rather than viewing these approaches as competing strategies, they should be considered complementary. A child with a high DIVA score may benefit from ultrasound-guided cannulation combined with topical analgesia and age-appropriate distraction through cartoons, tablet-based games, or virtual reality(26).

The future of Pediatric vascular access will likely involve integration of artificial intelligence, augmented reality, and advanced imaging technologies with behavioural interventions. Such multimodal approaches have the potential to improve first-pass success while minimizing procedural distress(27).

CONCLUSION

Difficult intravenous access remains a common challenge in pediatric healthcare. Advances in trans illumination, near-infrared imaging, and ultrasound guidance have significantly improved vein localization and procedural success. Simultaneously, digital distraction strategies and virtual reality have transformed the patient experience by reducing pain and anxiety. Current evidence suggests that ultrasound-guided cannulation provides the greatest improvement in technical success, while virtual reality and digital distraction offer substantial psychological benefits. The optimal management of pediatric DIVA therefore lies in integrating technological innovation with compassionate, child-centred care. Future developments involving artificial intelligence and augmented reality may further enhance vascular access outcomes and redefine the standard of care for children requiring intravenous therapy.

Declaration by Authors

Ethical Approval: Not Applicable

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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