Clinical review: Vascular access for fluid infusion in children

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Abstract

The current literature on venous access in infants and children for acute intravascular access in the routine situation and in emergency or intensive care settings is reviewed. The various techniques for facilitating venous cannulation, such as application of local warmth, transillumination techniques and epidermal nitroglycerine, are described. Preferred sites for central venous access in infants and children are the external and internal jugular veins, the subclavian and axillary veins, and the femoral vein. The femoral venous cannulation appears to be the most safe and reliable technique in children of all ages, with a high success and low complication rates. Evidence from the reviewed literature strongly supports the use of real-time ultrasound techniques for venous cannulation in infants and children. Additionally, in emergency situations the intraosseous access has almost completly replaced saphenous cutdown procedures in children and has decreased the need for immediate central venous access.

Keywords

- central venous access
- child
- epidermal nitroglycerine
- intraosseous
- transillumination
- venous cutdown

Introduction

Nothing can be more difficult, time consuming and frustrating than obtaining vascular access in the paediatric patient. This was best described by Orlowski in 1984 [1], who stated, 'My kingdom for an intravenous line'. This article reviews the various sites and techniques that may be used to gain acute intravascular access in the routine situation and in emergency or intensive care settings.

Methods

A Medline search (publication dates up to 13 December 2003) was performed using the following MeSH terms: local warmth, epidermal nitroglycerine, GTN, transillumination, peripheral venous access, infant, child, newborn, intraosseous, central venous access, internal jugular vein, subclavian vein, axillary vein, external jugular vein, femoral vein, venous cutdown and complication, and success. Additionally, references from the primary literature were screened and previous reviews, including cross-references and conference and symposia proceedings, were used. Other sources included the Cochrane Central Register of Controlled Trials. From more than 400 references retrieved, the randomized trials and most recent and important articles were used in the present review.

Facilitating techniques for peripheral venipuncture

The application of a tourniquet, tapping or stroking of visible veins, vigorous swabbing, clenching the hand to pump up veins, and hanging the forearm downward help to produce local venous dilatation and increase the visibility and palpability of the veins. To increase the success rate of venipuncture in children, the following other techniques have been used.

Local warming

Local warming dilates the arterioles and decreases α_2-adrenergic vasoconstriction. The hand or lower arm can be warmed by wrapping it in towels moistened with warm/hot water or immersing it in warm water. Only one randomized controlled trial assessed the effect of this procedure in facilitating insertion of venous cannulae. In adult patients, Lenhard and coworkers [2] showed that local warming facilitates the insertion of venous cannulae, and reduces the time and number of attempts required. A controlled study conducted in children is not available.

Transillumination techniques

Finding an accessible vein in infants is frequently difficult when the skin is coloured, the infant is dehydrated, obese or shocked, or when the commonly accessible veins are exhausted. Transillumination techniques have been used for many years to facilitate arterial puncture [3] and venous access [4]. Various devices for transillumination have been described but have not gained popularity. Commonly used are cold-light fibreoptic techniques; complications (burns) are rare but possible [5, 6]. A 40% efficacy of palm transillumination using a common otoscope in an emergency department setting was recently reported [7], and venous access could be established in 39 out of 40 patients with just one venipuncture.

Epidermal nitroglycerine

Ointments containing nitroglycerine (GTN) have been used to produce local dermal vasodilatation. The first successful use of GTN ointment as an aid to venipuncture was reported in 1983 in a randomized placebo-controlled trial [8]. Other investigations showed an increasing diameter of the veins [9, 10], or better success rate for venipuncture [11].

The local application of GTN was efficient in reducing venipuncture failure in children younger than 1 year [12]. However, these results could not be reproduced in another series [13]. Adverse local and systemic side effects were found in neonates and premature babies, and therefore the use of GTN cannot be recommended in this age group [14].

The combination of GTN with local anaesthetics (EMLA – eutectic mixture of local anesthetics) had a beneficial effect in adults by increasing the ease of venipuncture and decreasing the pain and the dose of local anaesthetic required. These results were confirmed in a double-blind randomized controlled trial in 104 children aged between 1 and 11 years [15]. The addition of topical GTN positively affected venous dilatation ($P < 0.01$), choice of cannulation site ($P < 0.001$) and ease of cannulation ($P < 0.001$). Similar findings were achieved when GTN was applied after EMLA removal [16].

Central venous access

The cannulation of a central vein allows administration of large volumes of fluids in short times and at high osmolarities for rehydration, volume replacement, chemotherapy and parenteral nutrition. In addition, it enables haemodynamic monitoring and rapid administration of drugs during cardiopulmonary resuscitation. Percutaneous central venous line insertion has replaced peripheral venous cutdown as the primary mode of short-term venous access in children [17, 18]. The central venous catheter (CVC) can be inserted into the femoral, jugular and subclavian veins or other influent veins, and in most cases catheter insertion is feasible and safe in all age groups [19, 20]. A summary of the features of the different infusion sites is presented in Table 1.

Table 1

Features of the different sites for intravenous access for fluid infusion in children

	IO access	Subclavian vein	Femoral vein	Internal jugular vein	External jugular vein	Axillary vein	Venous cutdown
Emergency access	++++	++	+++	++	+++	+	++
Ease of access for unexperienced clinician	++++	++	+++	++	+++	+	+
Infection	+	++	++	++	+	+	++
Thrombosis	0	+	++	+	+	+	++++
Other complications	+	++	+	+	0	+	0
Long-term use	0	+++	++	++	+	+	0
Short-term use	++++	++	+++	+++	++	+++	++
References	[89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106,	[37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48]	[21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36]	[49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68]	[78, 79, 80, 81, 82, 83]	[69, 70, 71, 72, 73, 74, 75, 76, 77]	[111, 112, 113]

	IO access	Subclavian vein	Femoral vein	Internal jugular vein	External jugular vein	Axillary vein	Venous cutdown
	[107, 108, 109, 110, 116]						

IO, intraosseous; 0, no effect/not suitable/no risk; ++++, excellent effect/very suitable/high risk

Femoral vein

The standard procedure for puncturing the femoral vein has a high success rate and a low rate of arterial puncture in paediatric emergency treatment and in the intensive care unit setting [17, 21], even with unexperienced operators [22]. It was successful in about 92% in critically ill patients [23], in about 89–95% in children, and in about 80% in preterm infants weighing less than 1000 g [24, 25, 26]. A higher success rate can be achieved in obese children using ultrasound techniques [27].

Femoral venous catheterization is a safe method [17, 28] because it does not expose the patient to the potential hazard of intrathoracic complications [29]. Stenzel and colleagues [30] demonstrated a 3.7% complication rate for femoral CVC as compared with 7.3% for nonfemoral CVCs. Goldstein reported a catheter-related sepsis rate of 4.9% and mechanical complications of 3.5% in burned children [31]. The rate of femoral vein thrombosis varies from 4% to 35%, and this is adversely influenced by age, size and underlying condition of the patient [32, 33, 34]. Heparin-bonded material may significantly reduce femoral catheter-related thrombosis and infection [35]. Cannulating the femoral vein is difficult in more than 50% of patients after previous cardiac catheterization, and therefore the contralateral side should be used in the first attempt in such patients [36].

Subclavian vein

Subclavian vein catheterization has proved to be a rapid alternative to surgical cutdown techniques for venous access in children [20, 37, 38, 39, 40]. However, the overall reported complication rate varies significantly from about 3% to 34%, depending on age, indication and side of puncture [19, 29, 40].

Finck and coworkers [41] reported that subclavian access was successful in 78.8% of patients younger than 6 months (average weight 3.1 kg) and in 96% of those older than 6 months (average weight 7.6 kg); there were no complications. Citak and colleagues [42] found similar results in 148 out of 156 central venous attempts (94.9%) in which subclavian vein catheterization was chosen, with a moderate complication rate (arterial injury 12.8% and pneumothorax in two patients; no mortality occurred) and a high success rate 'in experienced hands'.

However, in a large (2290 central venous catheterizations) prospective multicentre study, Iovino and coworkers[43] demonstrated that the overall risk for complications with subclavian puncture was significantly elevated when compared with internal jugular puncture

[42]. The main complications were pneumothorax and arterial puncture, but a low rate of thrombosis was noted.

Various ultrasound techniques and atrial ECG guidance have been used in an attempt to improve success rates [44, 45, 46].

The puncture technique and position of the patient are different in children compared with adults. Positioning without a shoulder roll and placing the head in a neutral position (Fig. 1) optimizes vein diameter [47]. Jung and coworkers [48] showed that tilting the head toward the catheterization side after successful puncture reduced the incidence of catheter malposition.

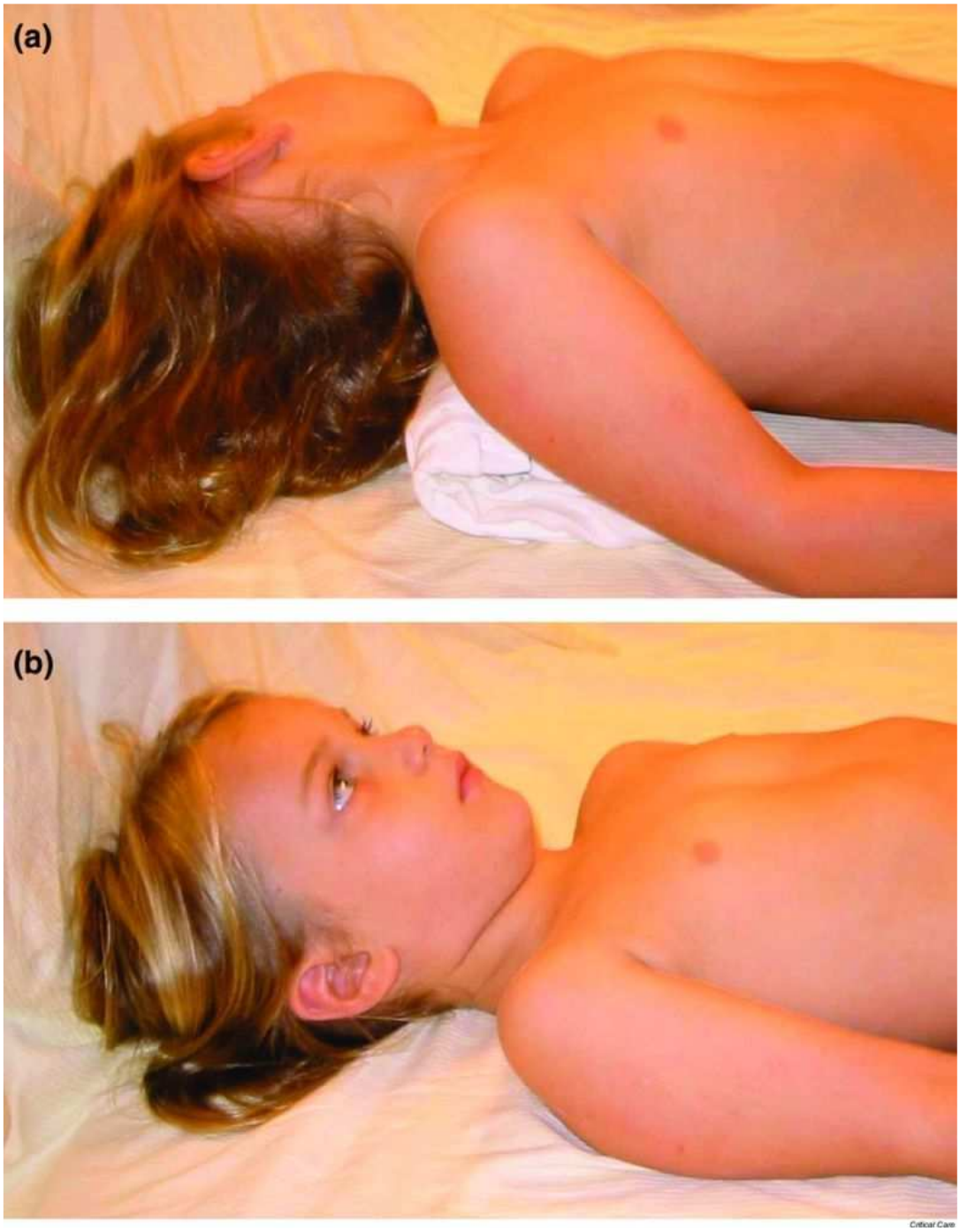

Figure 1

The puncture technique for subclavian catheterization is different in children than in adults. **(a)** The traditional positioning, with a shoulder roll and tilting of the head in the opposite direction. **(b)** Optimal positioning, enhancing the subclavian vein diameter [47].

Internal jugular vein

The internal jugular vein (IJV) provides a useful and reliable site with a low failure rate, and its cannulation is traditionally performed with the aid of both palpation and anatomical landmarks. Various approaches may be used to reach the IJV [49]. Variations between the carotid artery and the IJV, and the depth and size of the IJV may account for failure to locate the vein [50, 51, 52], and these factors were found to be independent of age and size [53]. The IJV was found directly anterior to the carotid artery, at the level between the two heads of the sternocleidomastoid muscle, in about 50% of cases, and anterior or anterolateral at the level of the cricoid cartilage in about 30% of the cases [54, 55].

Doppler ultrasound guided puncture could reduce the time and the number of attempts for successful cannulation [56, 57, 58]. Direct two-dimensional ultrasound identification proved to be more precise and efficient [45, 59], especially in small children, and it is now recommended when difficulties are anticipated, complications have been encountered, or when repeated IJV cannulation is required [60, 61].

Verghese and colleagues [62] reported a 100% success rate using ultrasound guided IJV cannulation in infants, as compared with a 75% success rate using a traditional palpation method, and the incidence of carotid artery punctures was 0% versus 25%. In 2002, these findings were repeated by Asheim and coworkers [63], who found a 100% success rate in 45 consecutive children and a median time to aspirate blood from the IJV of 12 s. Complications include arterial puncture, haematoma formation and catheter malposition, but thrombosis and pneumothorax are rarely reported.

The diameter of the IJV may vary significantly during respiration and after various manoeuvres to increase intravascular filling and pressure [64, 65], and the Valsalva manoeuvre, the Trendelenburg position and manual compression of the liver increased the size of the IVC [66, 67, 68].

Axillary vein

Percutaneous catheterization techniques for the axillary vein have been described since 1967 for adults, children and neonates [69, 70]. Successful and safe use was demonstrated during resuscitation [71], and the risk for catheter-related infections or thrombosis is similar to that with other CVC sites [72, 73].

In neonates, axillary vein cannulation was found to be successful in 217 out of 226 patients, with infection occurring in three and shoulder oedema occurring in eight of the 217. Possible but rare other complications are pleural effusion, haematoma and pneumothorax [74, 75, 76].

In children the axillary approach was found to be an acceptable route for central venous catheterization in about 80%, and the risk of complications was 1.1% per catheter-day [76]. Again, the overall success rate can be improved significantly by ultrasound-guided cannulation [77].

External Jugular vein

Use of the external jugular vein (EJV) for central venous access with a guide-wire technique is associated with a 75–100% success rate in adult patients and a very low complication rate [78].

Applicability in children was first demonstrated by Humphrey and Blitt in 1982 [79]. The overall success rate reported is lower than that in adults, ranging from 54% to about 92%. When the EJV was visible, there were no serious complications reported [80, 81, 82]. A large series of EJV cannulations was reported by Soong and coworkers [83] in 1995. That group used the EJV in 488 out of 1318 central venous accesses in a paediatric/neonatal intensive care unit. The initial success rate was high (>90%); however, the EJV catheters were used for a shorter period of time.

Intraosseous infusions

Over the past two decades, the intraosseous (IO) route into the tibia has become a widely accepted procedure for the resuscitation of critically ill and injured children [84, 85, 86, 87, 88] such as trauma patients [89, 90] and patients suffering from severe burns [91, 92]. Newer devices, such as the 'bone injection gun', may increase the already widespread use of IO access [93, 94].

The IO technique is included in standard protocols and training procedures [95, 96], such as the Advanced Paediatric Life Support textbook, and it is recommended by the American Heart Association, the American Academy of Paediatrics, and the American College of Surgeons [97].

IO lines are not commonly used in newborn infants; however, it is recommended in neonates as an alternative route for medications/volume expansion if umbilical or other direct venous access is not readily available [98, 99, 100]. Neonates were included in some series of IO therapy [101], but only few studies examined this route in neonates and premature infants [99, 102]. Successful use in an 800 g baby has been reported [103]. Additionally, in a model of neonatal emergency vascular access, the IO route was found to be faster and easier than conventional umbilical venous catheterization [104].

Complications from the use of IO access occur rarely and include fractures and osteomyelitis after long-term use of IO access [105, 106] or when hypertonic solutions have been used. Fat embolism is less likely in children than in adults and has minimal clinical consequences [107]. Local extravasation of fluids due to incomplete penetration of the needle into the cortex, IO infusion into a fractured limb, or perforation of the bone may lead to a compartment syndrome [108, 109]. Finally, follow up in neonates ruled out concerns regarding injury to growing bone and the growth plate [110].

Peripheral venous cutdown

The technique of venous cutdown is part of the training programme of Advanced Paediatric Life Support. The most preferred cutdown access site is the saphenous vein above the medial malleolus of the tibia, but antecubital, axillary, cephalic and femoral vessels are also suitable [111] and improved procedures using Seldinger techniques have been reported.

Currently, cutdown procedures are regarded as the methods of last resort. The usual time to achieve access by paediatric surgeons was 6 min in children aged 6–16 years, 8 min in those aged 1 month to 5 years, and 11 min in neonates [112]. This time delay makes its use unrealistic for most clinicians, and IO or percutaneous femoral access can be achieved more rapidly [21, 113].

Conclusion

Application of local warmth proved to be beneficial in increasing the success rate of peripheral venipuncture in children, even in small patients. Transillumination techniques with the use of simple devices such as an otoscope may be a useful adjunct for rapid venous access in all infants in whom placement of an intravenous catheter is considered difficult. Application of epidermal nitroglycerine, especially when combined with topical local anaesthetics, can be recommended in infants and children. Its use in neonates and premature babies, however, appears to be associated with higher rates of side effects.

Percutaneous central venous line insertion has replaced peripheral venous cutdown as the primary mode of short-term venous access in childhood. Venous cutdown is regarded as the method of last resort, but remains useful in emergency situations when other attempts at venous access have failed. The CVC can be inserted into the femoral, jugular and subclavian veins, or other influent veins, and in most cases catheter insertion is feasible. Published data indicate that percutaneous femoral venous cannulation is a safe and reliable technique in children of all ages, and is associated with high success and low complication rates; it should be recommended first. Percutaneous subclavian vein catheterization is commonly used in critically ill children of all ages, and is associated with relatively few serious complications in experienced hands. Cannulation of the internal jugular vein may be difficult because of anatomical variation in the vessel. Ultrasound-guided cannulation of the IJV has exhibited significant advantage over classical landmark and palpation methods, and Trendelenburg and Valsalva manoeuvres increase the diameter of the IJV significantly during cannulation. The EJV is an attractive alternative for central venous access in children and is associated with a very low complication rate. Finally, axillary vein cannulation offers an attractive alternative site for CVC insertion in the critically ill child or neonate.

The IO route provides rapid and reliable access to the systemic venous circulation in the paediatric population. This technique is safe, complications are infrequent and the benefits clearly outweight the risks, especially in the paediatric population. Therefore, the IO technique has almost completely replaced saphenous cutdown procedures in children in emergency situations, while decreasing the need for immediate central line insertion.

Abbreviations

CVC:

central venous catheter

EJV:

external jugular vein

EMLA:

eutectic mixture of local anaesthetics

GTN:

nitroglycerine

IJV:

internal jugular vein

IO:

intraosseous.

Declarations

Authors' original submitted files for images

Below are the links to the authors' original submitted files for images.
13054_2004_2879_MOESM1_ESM.tiff Authors' original file for figure 1

Competing interests

None declared.

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