European Journal of Radiology 83 (2014) 1582–1591

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Ultrasound-guided interventions in children

Matthew P. Lungren, Manish N. Patel*, John M. Racadio, Neil D. Johnson

Cincinnati Children's Hospital Medical Center, United States

ARTICLE INFO

Article history:
Received 11 April 2014
Accepted 21 April 2014

Keywords:
Ultrasound
Pediatric
Interventional
Procedures

ABSTRACT

There are a variety of available imaging modalities used for minimally invasive procedures in children, however, among the most frequently used is ultrasound (US). The advantages of US are vast and include real-time visualization, lack of ionizing radiation, and all-around versatility. US is also inexpensive, portable and widely available. In general US guided procedures in children have applications in nearly every aspect of medical therapy. Properly trained practitioners with US imaging experience and detailed knowledge of the relevant anatomy provide an invaluable service to the care of pediatric patients in many centers. This paper will discuss many of the image guided procedures that are performed in children and offer practical techniques from the collective experience of our practice at a large pediatric tertiary care center.

1. Introduction

Image guided procedures in children can be performed using any available imaging method, including fluoroscopy, computed tomography (CT), and ultrasound (US). Deciding on a particular method is subject to several considerations including location of the lesion, equipment availability, and patient characteristics. In the care of pediatric patients, US is largely preferred as it is often widely available, does not use ionizing radiation, and allows for real-time visualization of the needle position during the procedure, which is critically important in small patients or procedures in and around vital structures. US scanners are also mobile, which makes them ideal for critically ill children in intensive care units or in the operating room. In addition, US is far more cost effective in terms of time and equipment expense than other imaging modalities for image guided procedures, such as CT [1,2]; US guided biopsy has also been described as enjoying higher rates of accuracy in procedures such as liver lesion biopsies than CT guidance [3,4].

Despite the advantages, US has inherent limitations as well. With increasing tissue depth the US signal becomes more attenuated, leading to poorer spatial resolution and less sensitivity in deeper tissues. US signal cannot penetrate bone or air, which limits its use in skeletal or lung interventions. Finally US is a heavily user-dependent modality. Despite these limitations, however, the primary considerations for the use of US in procedures are target visibility and the presence of a visually accessible sonographic window such that the needle can be visualized along its entire path to the target in real time [5,6]. If these considerations are met, any procedure, even in the lung or bony skeleton, can be performed with US guidance.

The frequency of the US probe is a principal factor in image resolution. Higher frequency US provides a vivid image; however, the signals are remarkably attenuated in deep soft tissues. In pediatric interventions, patients can vary in size from less than 1 kg to greater than 200 kg [7]. Therefore to fully realize the benefits of US image guidance in such a wide variation of patient sizes, proper US equipment is essential. Multiple transducers (including endocavitary probes) must be available, ranging from 3 to 10 MHz or greater. In general, the ideal transducers for performing interventions in superficial tissues are linear and high-resolution (8–15 MHz). In deeper lesions, it is often necessary to use 5–3.5 MHz probes [8–10]. The most common procedures performed with US guidance in children include vascular access, aspirations and drainages, biopsies, and percutaneous injections; each of these will be discussed in depth.

2. Image guided vascular access

Pediatric vascular access encompasses a wide variety of procedures, including peripheral and central venous access for pharmacotherapy, central venous access for various interventional procedures, and arterial access for operative and interventional procedures as well as arterial pressure monitoring. Establishment of vascular access in the small vessels of children, particularly

* Corresponding author. Tel.: +1 513 636 6695.
E-mail addresses: matthew.lungren@cchmc.org (M.P. Lungren), manish.patel@cchmc.org (M.N. Patel), john.racadio@cchmc.org (J.M. Racadio), neil.johnson@cchmc.org (N.D. Johnson).

http://dx.doi.org/10.1016/j.ejrad.2014.04.021
0720-048X/

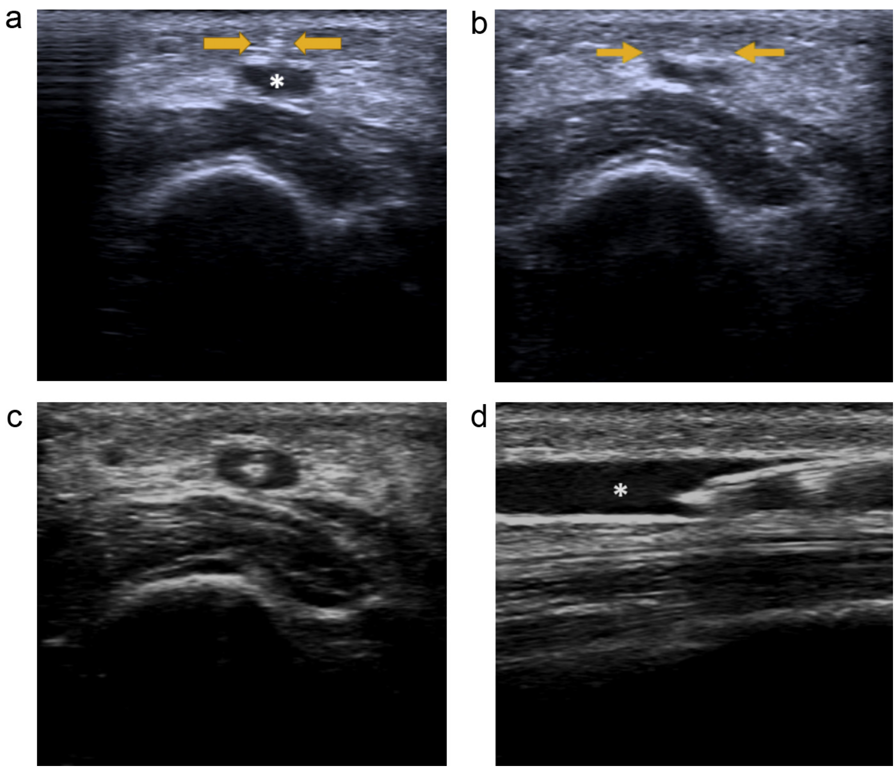

Fig. 1. Sequential transverse ultrasound guided vessel access images from an upper extremity peripheral IV placement. (a) Advancing needle into the subcutaneous tissues superficial to the vessel (arrows), the probe has been moved proximally along the arm to visualize the tip of the needle (arrows) in relationship to the target vessel (*) during advancement; (b) further advancement of needle tip now "tenting" the target vessel (arrows), the ultrasound probe has again been advanced proximally to ensure visualization of the venipuncture; (c) the needle tip is visualized in the target vessel during further advancement to ensure adequate purchase, note the centered needle tip appears as a "bullseye"; longitudinal view (d) during the same access, note that the access needle length as well as the target vessel (*) is visualized in one plane.

critically ill neonates, can be exceedingly challenging; US guidance is often invaluable due to the small vessel size and the inability of the patient to cooperate without deep sedation or general anesthesia [5,11]. A high-frequency linear array US transducer is preferred because the vessels in small children are usually superficial and high spatial resolution is necessary to accurately identify the targeted vessel. Further confirmation can be accomplished using color Doppler and power Doppler imaging.

Two primary techniques exist to access a vessel with US guidance: longitudinal or transverse. The goal of either access under US is single wall puncture; this ensures that damage to the vessel is minimal, and avoids perivascular hematoma formation as might occur in double wall access or multiple punctures. Meticulous vessel access technique is particularly important in coagulopathic patients. The most frequently utilized technique for access into nearly any vessel in our practice is the transverse approach, which can accurately demonstrate the positional relationship and depth of even the smallest target vessels during needle access (Fig. 1). Alternatively, the longitudinal access approach (Fig. 2) is advantageous in that the entire length of the needle can be visualized during vessel access. However, in very small vessels, the spatial resolution of the US can be a limiting factor because although the needle may appear intraluminal in one plane on longitudinal view, adjustment of the plane may also depict the needle lateral or medial to the vessel wall which can be suboptimal in difficult access, such as in small vessels or in proximity to vital structures in the chest or neck [12]. The literature supports a higher success rate using the transverse approach rather than the longitudinal approach (98%, 78% respectively) [5,8].

The most common pediatric vascular access procedure is during placement of a peripherally inserted central catheter (PICC). PICCs have been used for decades in neonatal populations for intermediate- to long-term IV medical and fluid therapy, where they have been associated with a high insertion success and a low risk of catheter-related complications [13–16]. In the pediatric population, particularly in the setting of a non-sedated child or adolescent, the simplest effective PICC placement technique is desired. The use of US has been shown to greatly increase the accuracy and success of PICC placement as well as reduce the risk of complications including hematoma and multiple site insertion attempts [15,17,18].

For arterial access, transverse axis US guided approach is preferred, and ensuring single wall puncture, ideally over an area of the body which allows for vessel compressibility (i.e., femoral head, wrist, medial humeral condyle) is critical to ensure successful hemostasis once access is removed [11]. We typically reserve the 21-gauge micropuncture access for infants and newborns and instead prefer to use an 18-gauge needle for most femoral artery access. A sheathed needle (Angiocath) ranging from 22 to 18 gauge, through which an appropriately sized guidewire can be advanced as needed, can also be used.

Finally, US can be used to access other vessels which are less commonly utilized outside larger tertiary centers. For example, direct percutaneous transhepatic portal vein access (Fig. 2) is often required for portal vein interventions, particularly in children with liver transplants. Access can be obtained either via left or right sided portal vein branches. Puncture of a secondary or tertiary branch of the portal vein can be routinely performed using a longitudinal approach with either a 21-gauge or 22-gauge Chiba needle. An alternative route to the portal vein may also be performed using a trans-splenic approach (Fig. 2). US can be used to properly place and assess the position of the large catheter tip as used for ECMO improving outcome by reducing complication rate [19].