Ultrasound Workshop on Central Vascular Access

Ultrasound for Central Venous Access
The success rate of central venous cannulation is lower and the complication rate is higher in infants and children than in adults (1). The use of an ultrasound-guided technique has been shown to improve the success rate, decrease the necessary time, and reduce the incidence of traumatic complications associated with central venous cannulation in both children and adults (2-7). Additionally, the pre-scan procedure with ultrasound can yield important information about vascular pathologies such as occlusion or thrombosis. This workshop will give the learner the opportunity to practice ultrasound techniques used for central venous access, peripheral arterial and venous access and review the use of ultrasound for the identification of pneumothorax. This syllabus will serve as an overview of the content for this workshop.

Ultrasound-guided vascular access means watching the needle-vessel images in “real time”. With this real time ultrasound-guided vascular access technique, the guide-wire inserted in the objective vessel can also be identified. Ultrasonography represents a three-dimensional object in two-dimensional space. Not only is anatomical knowledge necessary, the operator must also understand the sonographic appearance of the structures being imaged.

Ultrasound-guided vascular access has two main approaches; “long axis” or “in plane approach” and “short axis” or “transverse approach”. The long axis approach visualizes the vessel along the insertion pathway and is commonly used to monitor the entire approach of the needle into the vessel. The short axis approach is easier to show the positional relationship and depth of target vessels but it is much harder to follow the needle tip within the tissues.

According to one report on the ultrasound-guided approach to internal jugular vein, the success rate with the first procedure was much higher with the short axis approach than the long axis approach (short axis approach 98%, long axis approach 78%) (8). For the short axis technique, the probe should be placed vertically to the vessel, not to the skin. The needle should be inserted as near the probe as possible to keep it within the area of the ultrasound beam. This ultrasound-guided technique may cause traumatic complications if the needle is inserted too far from the probe, because the ultrasound gives us no information about the position of the needle until the needle crosses the beam. In short, such a procedure is still a relatively “blind technique” even though ultrasound-guided. After the needle is inserted to skin, movement of the needle gives us the information about the position of the needle tip by wiggling the tissue. When the needle comes in contact with the vessel wall, the anterior wall of the vessel will yield to pressure, and the vessel becomes deformed.

Internal jugular vein access
The most common complication of the internal jugular vein cannulation is carotid artery puncture (9-11). In the pre-scan procedure, the short axis view can confirm the anatomical relationships with the common carotid artery. When the round image of the internal jugular vein is provided, it is necessary to check the positional relationship of the internal jugular vein and the common carotid artery along its length before deciding the puncture point. This is because of the possible variations in anatomical relationships (12,13). Furthermore, the positional relationship is easily changed according to the position of head (14).
In order to identify an optimal insertion site for the internal jugular vein, the combination of “sweep” and “swing” technique is used. For the “sweep technique”; which helps to assess the vessel for size and obstacles along its length, slide the probe along the internal jugular vein and confirm that the internal jugular vein stays in the center of the image. With this procedure, the internal jugular vein is evaluated for its full length. When the puncture point is decided, the “swing technique” can be used to follow the advancement of the needle using the short axis view. For the swing technique, keep the tip of the probe on the puncture point and swing it back and forth. When the arc of the swing is correct, the internal jugular vein stays in the center of the echo image.

When the probe as well as the needle is positioned vertically to the skin at the puncture point, insertion of a guide-wire may be difficult because of striking the back wall. Therefore, the probe should be angled less than 60 degrees to the skin during puncture to visualize the guide wire. In small children, this approach may be difficult due to limited space. When the guide-wire is successfully inserted, confirm with a sweep scan that the guide-wire is in the internal jugular vein.

Alternatively, some chose to identify the internal jugular vein using the transverse plane, sweep along the vessel to identify any obstacles and identify the optimal insertion site. Then rotate the transducer at the optimal insertion site to visualize the in plane (longitudinal) view. Then inserting the needle just below the edge of the transducer, along the wide axis of the probe and observe the needle enter the vessel. It is important to have the arm holding the probe steadied because small movements will cause lose of the in plane vessel center. This technique can be quite difficult in small infants due to limited work space.

**Subclavian vein access**

Ultrasound-guided access to the subclavian vein is more difficult than other central veins, because the clavicle obstructs the beam (15). However, the axillary vein is relatively easily pointed out and accessed with ultrasound-guided technique. Furthermore, the accessible range is much longer than the subclavian vein, and compression is easier in case of accidental artery puncture. The axillary vein is deep in the armpit, but runs gradually shallower towards the subclavian vein. Abduction of the upper limb to approximately 90 degrees makes the axillary vein straight, pushes up the clavicle, and then gives a longer target to access. In the pre-scan procedure, the distance to the vessel, the distance to the lung, positional relationship with artery, and the best puncture point should all be confirmed.

When the probe is positioned almost vertically on the puncture site, the insertion of guide-wire will be difficult. Therefore, the probe should be settled less than 60 degrees to the skin. Then puncture the skin near the probe. When the guide-wire is successfully inserted, the guide-wire in the vessel should be confirmed with a sweep scan. The guide-wire inserted from axillary vein has the possibility of advancing into the internal jugular vein or the brachiocephalic vein accidentally. However, inadvertent brachiocephalic vein cannulation is rare. A guide-wire in the internal jugular vein can easily be identified with ultrasound.

**Femoral vein access**

Considering infection and thrombus formation, the femoral vein is not ideal for long-term use. However, it is easier than other central veins to access, and it has a lower incidence of serious complications. Though the normal anatomy at the femoral region from medial to lateral is “vein, artery, and nerve”, the position and branches of femoral vein and femoral artery have many variations. Therefore, an ultrasound-guided technique may be useful. As above, the probe positioned less than 60 degrees to the skin is ideal for
When the guide-wire is successfully inserted, confirm with the probe that the guide-wire is in the femoral vein.

**Supraventricular approach to the subclavian or innominate vein**

Supraventricular access is a very useful option for central venous catheter management. However, supraventricular access to the central vein is reported to have a greater risk of pneumothorax. This risk should be decreased with ultrasound-guide puncture.

Position the ultrasound probe vertically at the supraventricular fovea along the clavicle. The pulsating subclavian artery can be identified on the first rib. The anterior scalene muscle is between the subclavian artery, and the subclavian vein. In order to prevent complications such as pneumothorax and brachial plexus injury, it is necessary to puncture the subclavian vein while following the needle tip in real time. Therefore, the long axis approach may be better than the short access approach for the supraventricular technique.

Puncture the skin close to the echo probe and advance the needle exactly along the beam, while always confirming the needle tip. When the guide-wire is successfully inserted, the guide-wire in the subclavian vein should be confirmed with a scan.

**Ultrasound for Peripheral Vascular Access**

Arterial catheters for neonates and children are performed routinely for hemodynamic monitoring in both major surgical procedures and in intensive care (16-18). Ultrasound-guided central vein access is becoming standard. However, the application of ultrasound-guided technique to artery puncture has not become widespread. It is reported that the use of real-time ultrasound-guided technique for radial artery catheterization significantly improved the success rate with the first attempt (19). Radial artery is the first choice for invasive arterial blood pressure measurement in anesthesia. Access to the femoral artery is also used frequently, for heart surgery, extracorporeal circulation, cardiac catheter examination, and others.

**Radial artery access**

The radial artery is the most commonly used artery in pediatric and adult patients. Since the radial artery in pediatric patients is very thin and shallow, the depth of the ultrasound probe should be set very shallow. That will increase the frequency of beam and make the image clearer. When the radial artery is identified, scan it to survey the position of the radial artery and the optimal puncture point. The radial artery of pediatric patients is so thin that the very center of it should be punctured. Therefore, the short axis approach may be better than the long axis approach. After the pre-scan procedure, insert the needle very close to the probe. If the position of the needle is inadequate, the needle should not be swung to right and left, the needle should be withdrawn and the puncture point should be changed.

**Brachial artery access**

In neonates and small patients, insertion of the radial arterial catheter may be very difficult because of the small diameter of the artery. When the patients have congenital heart diseases such as hypoplastic left heart syndrome (HLHS), the insertion of an arterial catheter into the radial artery is much more difficult. In such cases, the next choice can be the brachial artery, which is reported not to cause severe complications (20).

The method of the brachial artery puncture is similar to that of the radial artery access. Set the depth of the probe very shallow. When the brachial artery is identified, scan it with the combination of “sweep and swing
scan technique” in order to survey the position of the brachial artery and identify the optimal puncture point. As with the radial artery, the short axis approach may be better than the long axis approach. After the pre-scan procedure, insert the needle very close to the probe. If the position of the needle is inadequate, the puncture point should be changed immediately.

**Femoral artery access**
The method for femoral artery puncture is similar to that for femoral vein access. Confirm the anatomical relationship with the probe. As with ultrasound-guided access to the femoral vein, position the probe less than 60 degrees to skin. The skin should be punctured close to the probe. When the guide-wire is successfully inserted, confirm with a scan that the guide-wire is in the femoral artery.

**Peripheral venous access**
The use of ultrasound for difficult peripheral venous access has become increasingly popular for children and adults (21,22). The obesity epidemic, poor prospective vascular access management and improved resolution of portable ultrasound devices have all likely contributed to this trend. For success with peripheral IV (PIV) cannulation several things must be considered. First, vein depth and available catheter length must be considered together. As one scans to identify a suitable vein, one must have at least 1-1.5 cm of catheter within the lumen to reduce the likelihood of an extravasation injury (22). Standard PIV catheters easily kink once secured to the skin just beyond the hub unless the angle of entry into the skin is less than about 20 degrees. Alternatively one can use more flexible catheters (silastic arterial catheters) to help reduce this issue. Second, particularly with smaller children, one must support the probe arm comfortably to allow a steady, light touch on the vessel to avoid vessel distortion. Third, either a short or long axis approach can be used. If possible, based on vein location, the long axis can give more information regarding needle pathway and allow better planning regarding final catheter position in the vessel. Lastly, one can check the catheter position once inserted to ensure it is fully within the lumen and not protruding into the backwall of the vessel which could result in a post insertion vessel puncture.

**Pitfalls using the ultrasound for vascular access**
Since ultrasonography transforms a three-dimensional object into a two dimensional image, it can create various illusions and frustrate the proceduralist. With the short access view, it is easy to loose site of the needle tip and mistake a portion of the barrel of the needle for the tip. At best this can lead to a missed stick. At the worst it can result in a complication by puncturing the lung, artery or other structure unknowingly. One should either use the “swing ” and “sweep” technique as described above or use the long axis view whenever possible.

Performing the long axis approach can be difficult, especially on small targets (1-2mm vessels). Keeping the needle in full visualization depends on keeping the axis of the probe and needle perfectly aligned while keeping the vessel image on the screen (23). There seems to be a longer learning curve for many to master this technique. Following insertion, the presence of gel on the skin can be a hazard for catheter dislodgement. This is particularly true for short arterial and PIV catheters. Great care must be exercised when cleaning to avoid large movements of the skin which could dislodge the catheter.

**Ultrasound for Identification of Pneumothorax**
The use of ultrasound for the detection of pneumothorax (PTX) was first described in the 1980’s (24). Since that time it has been increasingly recognized to be a more sensitive and specific technique to identify PTX than a chest radiograph. Even though the incidence of PTX with central venous access is low, the ready
availability of ultrasound during access makes it use for post PTX detection practical and efficient. The proceduralist must learn to recognize the classic ultrasound finding to rule in or out PTX.

Ultrasound findings for identification of a PTX include: lung sliding, B-lines, lung pulse and lung point (25). Lung sliding is the easiest sign to recognize and with experience takes only a few seconds per location. It’s presence represent the reflection of ultrasound off the surfaces of the visceral and parietal pleura when they are in contact. The presence of air separates these layers and eliminated this sign. Presence of the lung sliding sign rules out PTX in the area imaged.

B-lines are a vertical artifact created deep to the pleural interface. These are also referred to as the comet sign. This sign seems to be accentuated with increased lung water content. Identification of B-lines rules out the presence of a PTX within the area imaged 100% of the time in one study (26).

Lung point is the only ultrasound finding that rules in a PTX. It is the point where the interface of lung sliding and air from the PTX meet. With respiration the visceral edge of the lung can be seen moving along the parietal pleural but the contact is not complete as with lung sliding providing a moving edge. In some studies this finding confirms the presence of a PTX 100% of the time (27).

Lung pulse is a less frequently used sign and is most useful in areas of the lung that are not ventilated. It reflects the cardiac impulse through consolidated or atelectatic areas of the lung. Like lung sliding it helps to rule out a PTX (25).

It is important to remember that when performing ultrasound assessment for PTX that one assesses the lung in multiple areas. Creating a imaging arc of 4 sample areas from the highest point of the chest to the lateral chest wall around the level of T-4 is one method suggested. This can help to reduce missing air that may be loculated (25).

References