International Journal of Arrhythmia

RESEARCH

Open Access

Feasibility of ultrasound-guided axillary vein access for implantation of cardiac implantable electronic device leads

Seongtaek Oh[1†], Jongmin Hwang[1*†], Hyoung-Seob Park[1], Tae-Wan Chung[1] and Minsu Jung[1]

Abstract

Background The axillary vein is preferred over the subclavian vein, and the cephalic vein for cardiac implantable electronic device (CIED) lead insertion. However, studies on ultrasound-guided axillary vein access (US-AVA) in Asia are scarce. This study aims to evaluate the feasibility of US-AVA for CIED lead implantation in Korean patients.

Methods From September 2021 to September 2023, we employed US-AVA for CIED lead implantation procedures. Patients' demographic and procedural data were collected and analyzed retrospectively.

Results US-AVA was successful in 301 patients (97.7%). There were no occurrences of pneumothorax or severe hematoma due to inadvertent arterial puncture, nor were there any other significant vascular access-related acute complications. During the median 1.7 years of follow-up, no CIED infection or lead-related problems have occurred. Compared to a historical cohort of patients who underwent fluoroscopy-guided axillary vein access (FL-AVA), US-AVA significantly reduced procedure and fluoroscopy time and showed a trend toward reduced radiation doses.

Conclusion US-AVA is a safe and effective technique for CIED lead implantation in Korean patients, with advantages over FL-AVA in terms of procedural efficiency and patient safety.

Keywords Ultrasound, Axillary vein, Cephalic vein, Cardiac implantable electronic device, Pacemaker, Implantable cardioverter-defibrillator, Cardiac resynchronization therapy

Introduction

Cardiac implantable electronic devices (CIEDs) constitute a significant advancement in treating heart rhythm disorders. These devices largely include pacemakers (PMs), cardiac resynchronization therapy devices (CRTs), and implantable cardioverter-defibrillators (ICDs) [1]. The CIEDs are composed of two main components—leads and a generator. A generator is inserted into a subcutaneous pocket in the upper pectoral area, while leads connect the generator and heart, threaded through a central vein to directly reach the heart. Although recent technological advancements have led to the development of leadless PM and subcutaneous ICDs, the majority of CIED procedures are still performed with subcutaneous generators and transvenous leads. Traditionally, the subclavian vein has been used as a venous access point for lead implantation; however, it is increasingly discouraged due to associated risks, such as pneumothorax and long-term lead complications [2–4]. Instead, axillary vein access (AVA) and cephalic vein cutdown are now recommended due to their lower risk profiles [5].

Numerous reports have recently been published on ultrasound-guided axillary venous access (US-AVA) for CIED lead placement, highlighting its advantages over

†Seongtaek Oh and Jongmin Hwang contributed equally to this work.

*Correspondence:
Jongmin Hwang
dsmcep@gmail.com
[1] Division of Cardiology, Department of Internal Medicine, Keimyung University Dongsan Hospital, 1035 Dalgubeol-daero, Dalseo-gu, Daegu 42601, Republic of Korea

fluoroscopy-guided techniques in terms of procedural ease, rapidity, and safety [6–11]. However, there is a paucity of published studies about these subjects in Asia, particularly in Korea.

In this article, we aim to report our experience and research findings on the feasibility of adopting US-AVA to implant CIED leads in Korean patients.

Material and methods

Study patients

We employed US-AVA for all new transvenous CIED lead implantation procedures from September 2021 to September 2023. Patients with previously implanted CIEDs undergoing lead revision, additional lead insertion, or upgrade procedures were excluded. Patients' demographic and procedural data were collected and analyzed retrospectively.

To evaluate the effectiveness and safety of US-AVA, we compared the procedural results of this group with an age- and sex-matched cohort of patients who previously underwent fluoroscopy-guided axillary venous access (FL-AVA) at our institution. The study received approval from the institutional review board of Keimyung University Dongsan Hospital (Approval No. 2021-08-125). All procedures in this study were performed by a single operator (J.H.).

Description of the procedure

Baseline procedure setting

At our center, the baseline positioning for CIED implantation using angiographic equipment is depicted in Supplemental Fig. 1A. The image-guided therapy system, Azurion 7 M20 (Philips, Amsterdam, Netherlands), is used. Traditionally, patients are positioned with their cranial side toward the image intensifier/X-ray tube. However, in our approach, we position the patient's caudal side toward the image intensifier/X-ray tube and then rotate the ceiling-mounted C-arm by 90°. This adjustment means that the C-arm's previous caudal to cranial rotation now corresponds to the conventional right anterior oblique-left anterior oblique (RAO-LAO) view. This positioning strategy allows partial shielding from ionizing radiation emanating from the X-ray tube by using a movable lead skirt. Importantly, with the monitor positioned directly in front of the operator, this setup significantly reduces musculoskeletal pain in the neck region compared to the traditional position.

After the patient was positioned, we performed a timeout, and the patient was draped in the usual sterile fashion, including a surgical drape (Ioban; 3 M, St. Paul, Minn.) over the left infraclavicular area. The implantation procedures were generally performed with moderate conscious sedation using pethidine, fentanyl, and midazolam. Before the procedure, all patients received intravenous antibiotic prophylaxis.

Anatomy

A thorough knowledge of the anatomy around the axillary vein is essential for CIED lead implantation. It is especially important to aim for extrathoracic venous access [12].

The basilic vein is one of the superficial veins of the upper limb and originates from the dorsal venous network of the hand. It ascends along the medial aspect of the upper limb. At the border of the teres major, the vein moves deep into the arm. Here, it combines with the brachial veins from the deep venous system of the upper limb to form the axillary vein. In other words, the axillary vein starts laterally from the confluence of the brachial and basilic veins. The cephalic vein is another superficial vein of the arm. It originates from the radial end of the dorsal venous network of the hand and ascends along the lateral side of the arm. At the medial aspect of the shoulder, the cephalic vein passes between the deltoid and pectoralis major muscles (deltopectoral groove), where it empties into the axillary vein [13]. The axillary vein runs about 2–3 cm medial to the cephalic vein behind the pectoralis muscles and then becomes the subclavian vein after being joined by the cephalic vein distally to the lateral border of the first rib, typically between the anterior first and second ribs (Fig. 1).

The subclavian vein can be divided into 2 parts: the intrathoracic part proximal to the medial border of the first rib before entrance into the costoclavicular space, and the short extrathoracic part over the first rib. The leads placed in the cephalic, the axillary, and the extrathoracic subclavian vein can enter the central veins distal to the medial border of the first rib. Thus, they are intravascular when passing through the costoclavicular space without direct exposure to the surrounding muscle, tendon, ligament, or bones. This is the main mechanism by which extrathoracic venous access can avoid subclavian crush syndrome.

Method of US-AVA

Ultrasound exploration After administering local anesthesia, we attempted to visualize the axillary vein using a linear probe from portable ultrasound devices (Vivid q from GE Healthcare, Milwaukee, WI, or Zonare Z-One Portable Ultrasound from Zonare Medical Systems, Mountain View, California, USA).

Initial ultrasound exploration was performed below the clavicle, focusing on the area where the medial two-thirds and lateral one-third of the clavicle intersect and the medial aspect of the deltopectoral groove. At this location, the axillary artery and axillary vein are readily

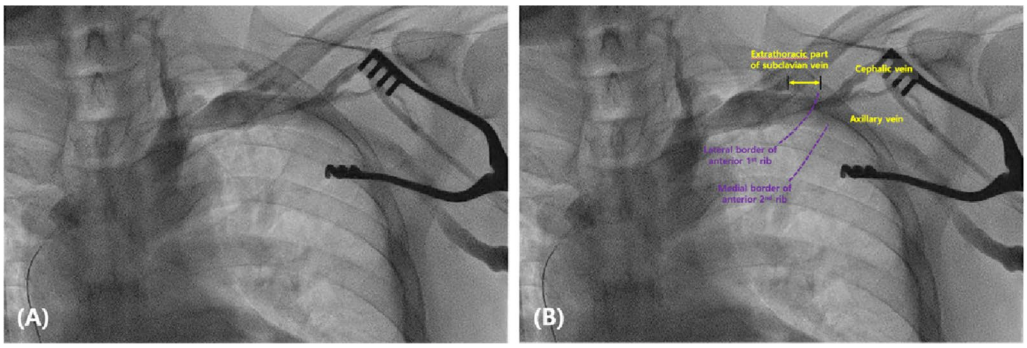

Fig. 1 Fluoroscopy image of the left upper pectoral area during venography and annotated schematic of the venous anatomy. **A** Plain fluoroscopy–venography image showing the axillary vein and surrounding structures. **B** Annotated fluoroscopy–venography image illustrating the anatomy of the axillary vein and adjacent structures. The cephalic vein, axillary vein, and the extrathoracic part of the subclavian vein are highlighted. The borders of the first and second anterior ribs are marked, demonstrating the relationship between these anatomical landmarks and the target veins for access

identifiable through ultrasound examination. Supplemental Fig. 1B depicts the initial setting of a US-AVA procedure performed in our laboratory.

Longitudinal versus cross-sectional ultrasound images for vessels Ultrasound technology can generate both longitudinal and cross-sectional images of vessels. Figure 2 demonstrates the ultrasound probe position and the longitudinal and cross-sectional ultrasound images. Longitudinal images are advantageous for clearly depicting the needle's entry point and the wire's retainment in the vessel (Fig. 2A, B). However, these images can be challenging when distinguishing between the artery and vein and may only show a short segment of the vein if its course is tortuous. Cross-sectional images simplify the differentiation between artery and vein, but capturing a real-time image of the needle entering the vein can be difficult (Fig. 2C, D). Nevertheless, by sufficiently tilting the probe, the needle's entry point into the vein (tenting of the vein) can often be clearly visible. Therefore, while we used both views to scan and evaluate the axillary vein/artery, the cross-sectional image was preferred for the puncture. Confirmation of the axillary vein is typically finalized with compression (the vein is compressible, whereas the artery is not); color Doppler evaluation is rarely needed.

Technical considerations for US-AVA

(a) Ultrasound probe's orientation marker.

In cross-sectional imaging, the ultrasound probe's orientation marker can be directed either caudally or cranially. Positioning the marker caudally demonstrates the pleural space at the bottom left of the screen, with the axillary vein appearing on the left and the axillary artery on the right. This setup maintains an orientation consistent with the clinician's viewpoint, positioning the axillary vein on the left side (patient's caudal side) and the axillary artery on the right (patient's cranial side). This alignment is intuitive and facilitates easier needle management during the procedure. Conversely, setting the marker in the cranial direction produces an image with the exact opposite orientation. Therefore, we recommend positioning the ultrasound probe orientation marker in the caudal direction to enhance procedural intuitiveness and ease (Fig. 2C, D, Supplementary Fig. 2).

(b) Challenges with thick subcutaneous tissue.

In cases where the thickness of subcutaneous tissue is considerable (usually vertical depth of more than 3–4 cm), ultrasound resolution may decrease due to interference from muscle and fat, making vessel delineation difficult. If unsuccessful, an incision can be made to create a pocket, after which the axillary vein can be assessed using ultrasound (Supplementary Fig. 3). The administration of agitated saline into a peripheral vein of the ipsilateral arm can enhance visualization of the axillary vein by saline bubbles (Supplementary video 1). However, even with thick subcutaneous tissue, utilizing ultrasound is more effective than fluoroscopy alone.

(c) Accessing the right axillary vein.

US-AVA can also be applied to access the right axillary vein. Anatomically, the right brachiocephalic vein's course is more acute than the left, leading to a trend of a shorter axillary vein length. When the orientation marker is placed caudally, the axillary artery appears on the left of the screen and the axillary vein on the right (Supplementary video 2).

Statistical analysis

Continuous variables are expressed as the mean value ± standard deviation or interquartile range when the values do not follow a normal distribution.

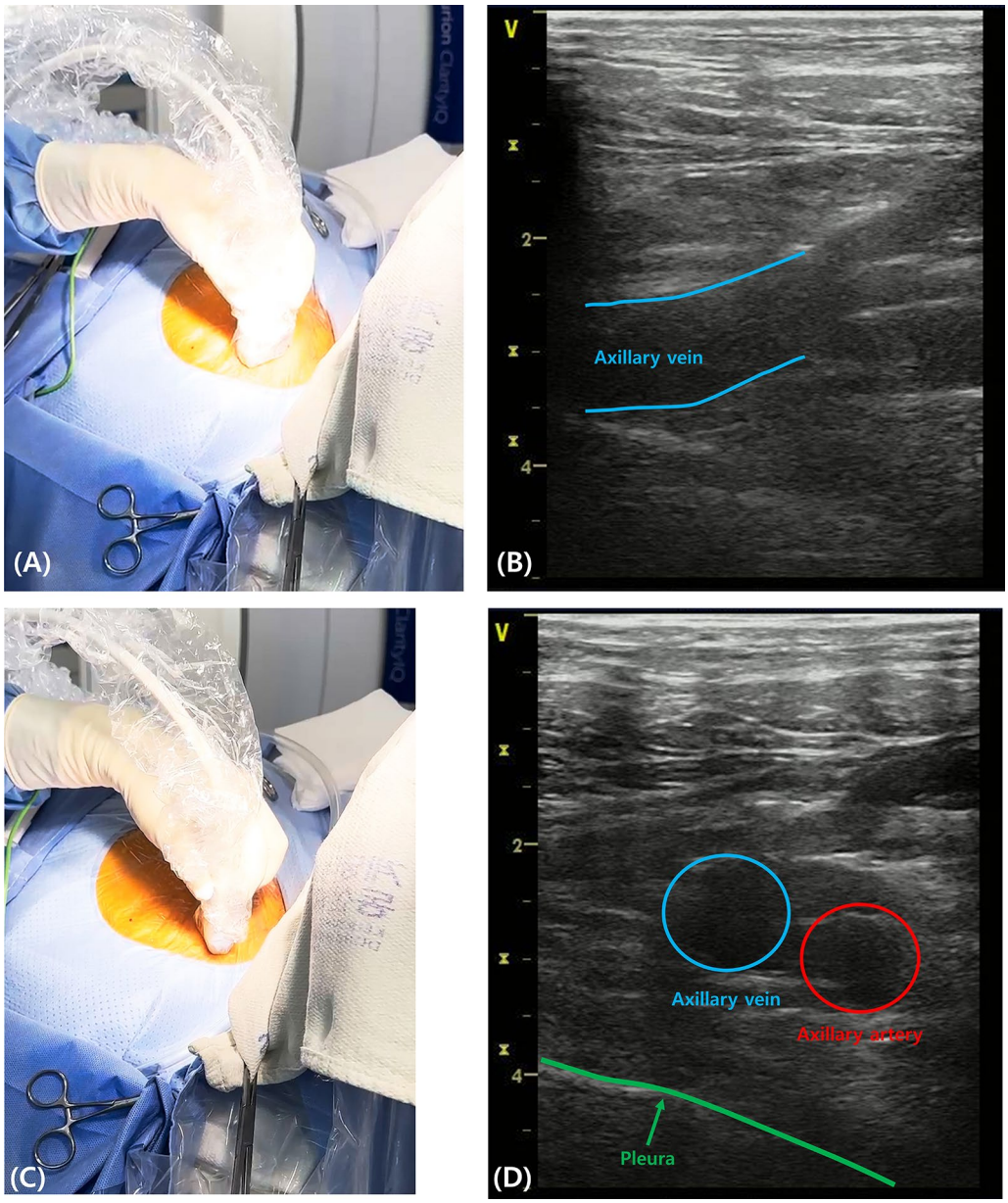

Fig. 2 Ultrasound (US) imaging of the axillary vein and probe positioning. (**A**) Intraoperative photograph showing the US-guidedaxillary vein access procedure. The fluoroscopy inset demonstrates the direction of the ultrasound probe (indicated by the red line). Theprobe was positioned parallel to the vein to obtain a longitudinal US image of the axillary vein. (**B**) Longitudinal US image of theaxillary vein, highlighted with a blue line. (**C**) Another intraoperative photograph shows the probe's positioning to obtain a crosssectionalUS image of the axillary vein. The fluoroscopy inset demonstrates the direction of the ultrasound probe (indicated by the redline). (**D**) Cross-sectional US image of the axillary vein which is indicated by a blue circle, the axillary artery by a red circle, and thepleura by a green line. The area below the green line represents the lung. This image is obtained when the ultrasound's orientationmarker is directed toward the patient's caudal side

Categorical variables are expressed as numbers and percentages. If normality was accepted, the independent sample t test and chi-square test were used for continuous and categorical variables. If the sample did not meet the normality assumption, the following method was used: the Mann–Whitney test was used to compare within-group continuous variables before and after the intervention, and the Wilcoxon signed-rank test was used to analyze the differences and changes in values between the two groups. Statistical analyses were performed using the MedCalc® Statistical Software version 22.016 (MedCalc Software Ltd, Ostend, Belgium; https://www.medca

lc.org; 2023). A P value < 0.05 was considered statistically significant.

Results

Results of US-AVA

Baseline patients' characteristics

From June 2019 to September 2023, US-AVA was attempted on 308 patients. The average age of the patients was 72.2 ± 10.6, and the male patients were 144 (46.8%). The median body mass index was 23.8, and the median body surface area was 1.62, reflecting typical characteristics of an Asian population. A pacemaker was implanted in 203 patients, while 67 and 38 patients received ICD and CRT implantation, respectively. Baseline characteristics are summarized in Table 1.

Procedural outcome

The mean procedure time was 57.1 ± 15.4 min, and the mean fluoroscopy time was 290.3 ± 154.0 s. Radiation doses were as follows: air-kerma 14.3 ± 19.7 mGy and dose-area product 3.2 ± 4.1 Gycm2. The median time from local anesthetic to completion of US-AVA was 6 min (interquartile range [IQR]: 3–11). Procedural outcomes of the US-AVA patients are also summarized in Table 1.

During the study period, we applied US-AVA to all patients undergoing new CIED implantation as an initial approach, and in cases of failure, we accessed the axillary vein using fluoroscopic guidance and real-time venography. The US-AVA was successful in 301 out of 308 patients, with a success rate of 97.7%. Among the seven patients in whom US-AVA failed, 5 had a skin thickness of more than 4 cm. The remaining 2 had a skin thickness of less than 4 cm, but visualization of vessels was poor for unclear reasons. Importantly, in the 301 patients where US-AVA was successful, there were no occurrences of pneumothorax or severe hematoma due to inadvertent arterial puncture, nor were there any other significant vascular access-related complications. In the seven patients where US-AVA failed, two or three puncture attempts were made through US-AVA, but no complications occurred due to these attempts and salvage fluoroscopy–venography-guided axillary vein access was successful.

Comparing the outcomes with FL-AVA

Baseline patients' characteristics

To evaluate the effectiveness of US-AVA, we selected age- and sex-matched patient cohorts who underwent FL-AVA at our institution before the adoption of ultrasound. For a more accurate comparison, only patients who received a dual lead pacemaker or ICD were chosen in both groups. Table 2 shows a comparison of baseline patients' characteristics. Data from 187 FL-AVA patients and 191 US-AVA patients were collected and analyzed for comparison. Demographic and clinical characteristics are not significantly different between the two groups.

Table 1 Baseline characteristics and outcomes of US-AVA attempted patients

Characteristic	US-AVA (N = 308)
Male	144 (46.8)
Age (yr)	72.2 ± 10.6
History of HTN	184 (59.7)
History of DM	107 (34.7)
History of AF	125 (40.6)
Height (cm)	159.2 ± 9.8
Weight (kg)	60.5 (53.2–67.1)
BMI (kg/m^2)	23.8 (21.9–26.0)
BSA (m^2)	1.62 (1.51–1.76)
Type of CIED	
Pacemaker	203 (66.0)
SND	143
AVB	60
ICD	67 (21.7)
CRT	38 (12.3)
Lead number	
Single lead	30 (9.7)
Two or more leads	278 (90.3)
US-AVA time (minutes)	6 (3–11)
Procedure time (minutes)	57.1 ± 15.4
Fluoroscopy time (seconds)	290.3 ± 154.0
Air-kerma (mGy)	14.3 ± 19.7
Dose-area product (Gycm^2)	3.2 ± 4.1

Values are presented as the *n* (%) or mean ± SD. Weight/BMI/BSA are presented as median (interquartile range). USG-AxA: ultrasound-guided axillary vein access, HTN: hypertension, DM: diabetes mellitus, AF: atrial fibrillation, BMI: body mass index, BSA: body surface area, CIED: cardiac implantable electronic device, SND: sinus node dysfunction, AVB: atrioventricular block, ICD: implantable cardioverter-defibrillator, CRT: cardiac resynchronization therapy

Comparison of procedural outcome

The comparison between the US-AVA and FL-AVA groups revealed significant differences in procedure and fluoroscopy times. The mean procedure time for the US-AVA group was 55.5 ± 14.7 min, compared to 59.8 ± 17.0 min for the FL-AVA group, with a statistically significant difference (P = 0.009) (Fig. 3A). Similarly, the mean fluoroscopy time was significantly shorter in the US-AVA group at 289.5 ± 153.5 s, versus 410.6 ± 221.3 s in the FL-AVA group (P < 0.0001) (Fig. 3B). Regarding radiation exposure, although the US-AVA group tended to have lower air-kerma (13.8 ± 15.1 mGy) and dose-area product (3.2 ± 3.6 Gycm^2) compared to the FL-AVA group (16.0 ± 22.1 mGy and 3.8 ± 8.4 Gycm^2, respectively), these differences were not statistically significant

Table 2 Baseline patients' characteristics between the two groups

Characteristic	FL-AVA (*N* = 187)	US-AVA (*N* = 191)	*P* value
Male	96 (51.3)	84 (44.0)	0.153
Age (yr)	69.2 ± 9.2	70.6 ± 9.1	0.126
History of HTN	106 (56.7)	115 (60.2)	0.487
History of DM	55 (29.4)	62 (32.5)	0.522
Height (cm)	160.1 ± 9.8	158.9 ± 9.5	0.247
Weight (kg)	62.2 ± 11.6	61.3 ± 11.4	0.410
BMI (kg/m^2)	24.2 ± 3.4	24.2 ± 3.5	0.961
BSA (m^2)	1.76 ± 1.37	1.64 ± 0.19	0.238
Procedure			0.961
Pacemaker	157 (84.0)	160 (83.8)	
SND	79 (50.3)	98 (61.2)	0.050
AVB	78 (49.7)	62 (38.7)	
ICD	30 (16.0)	31 (16.2)	

Values are presented as the n (%) or mean ± SD. Weight/BMI/BSA are presented as median (interquartile range). FL-AxA: fluoroscopy-guided axillary vein access, USG-AxA: ultrasound-guided axillary vein access, HTN: hypertension, DM: diabetes mellitus, AF: atrial fibrillation, BMI: body mass index, BSA: body surface area, SND: sinus node dysfunction, AVB: atrioventricular block, ICD: implantable cardioverter-defibrillator. Only patients who received a dual-chamber pacemaker or ICD were chosen in both groups

Table 3 Procedural results

Characteristic	FL-AVA (*N* = 187)	US-AVA (*N* = 191)	*P* value
Procedure time (minute)	59.8 ± 17.0	55.5 ± 14.7	0.009
Fluoroscopy time (seconds)	410.6 ± 221.3	289.5 ± 153.5	< 0.0001
Air-Kerma	16.0 ± 22.1	13.8 ± 15.1	0.279
Dose-Area Product	3.8 ± 8.4	3.2 ± 3.6	0.334

($P = 0.279$ for air-kerma and $P = 0.334$ for dose-area product). A comparison of procedural outcomes between the two groups is summarized in Table 3.

The follow-up duration was matched between the two groups. During the median 1.7 years of follow-up, one pneumothorax, one severe hematoma due to superior thoracic artery rupture, and one lead fracture were observed in the FL-AVA group. However, no complications were observed in the US-AVA group.

Discussion

Main findings

The main findings of our research highlight significant benefits of US-AVA, notably in comparison with FL-AVA. Firstly, US-AVA reduced the incidence of acute procedural complications such as pneumothorax or inadvertent arterial puncture. While these complications are not common, they are critical, considering that they can lead to prolonged hospitalization, increased healthcare costs, and adverse patient outcomes. The absence of significant vascular access-related complications in our study is indicative of the enhanced control and visibility that ultrasound guidance offers over traditional fluoroscopic methods. Secondly, US-AVA shortened the duration of both procedure and fluoroscopy times. The mean procedure time was reduced by over four minutes, and fluoroscopy time was reduced by approximately 121 s, representing a substantial decrease in patient exposure to ionizing radiation. This efficiency contributes to enhanced patient safety and potential reductions in healthcare costs. Thirdly, during the median 1.7 years of follow-up, lead safety was effectively maintained with no CIED infection in either group. Notably, there was one case of lead fracture in the FL-AVA group, underscoring potential risks associated with traditional access methods. Lastly, while numerous reports on US-AVA exist in Western literature, studies in Asia regarding US-AVA have been limited. Our findings demonstrate that adopting US-AVA is feasible and effective in Asian populations, who often have lower BMI/BSA, making it a particularly suitable and safe method for axillary vein access in these patients. This study's results can be a promise for widespread implementation, suggesting that US-AVA can significantly enhance the safety and efficacy of CIED implantation procedures.

Axillary vein as a major route for CIED implantation

Initially, the subclavian vein was favored as a venous access point for CIEDs due to its large size, which can accommodate multiple leads [14]. The expeditiousness and high success rate of this approach, in conjunction with the ease of its execution, have established it as the primary choice in many laboratory settings. However, it has been associated with a higher rate of acute procedural complications, such as pneumothorax. Over the long term, the subclavian vein may also present issues such as the "subclavian crush" phenomenon—lead conduction fractures or lead insulation damage due to entrapment of the lead by the costoclavicular ligament and/or the subclavius muscle [2]. Consequently, it is no longer recommended as the first-line venous access point. The cephalic vein offers an alternative route, allowing leads to reach the heart through a pathway that avoids entrapment by the costoclavicular structures. However, its small size and steep, angled entrance into the axillary vein can impede the advancement and handling of leads, especially multiple ones, resulting in lower success rates and longer procedural times than other methods.

A safe and effective extrathoracic venous approach is finally achieved by the axillary vein. The axillary vein combines the advantages of the subclavian and cephalic veins. It has a diameter large enough without concern

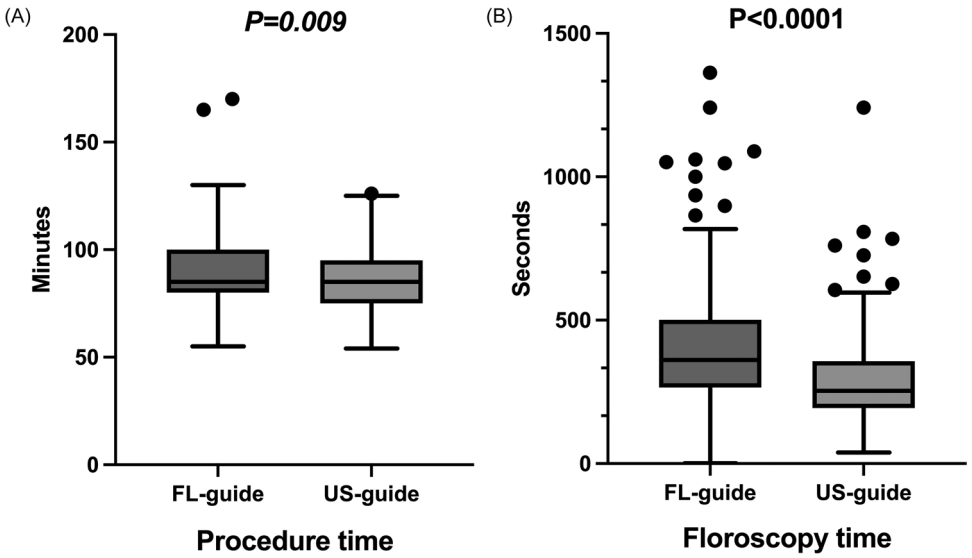

Fig. 3 Comparison of (**A**) procedure time and (**B**) fluoroscopy time between the fluoroscopy-guided group (FL-guide) and ultrasound-guided group (US-guide). Only patients with dual chamber devices were compared. Upper and lower box lines denote 75th and 25th percentiles, and the median is displayed in horizontal lines within boxes. The whiskers denote 5–95% percentiles, while the individual data points (circles) indicate outliers. The US-guided procedure significantly shortened the procedure and fluoroscopy time

for subclavian crush syndrome, making it an ideal vessel for CIED lead insertion. The use of the axillary vein for pacemaker lead insertion has been described since the 1970s, and its use has become more frequent in recent years [3, 15]. Over the past few decades, a considerable body of evidence has accumulated supporting both the axillary and cephalic veins [16, 17]. Usually, axillary vein access was achieved via fluoroscopy guidance, while the surgical cutdown method was used for the cephalic vein. However, fluoroscopy-guided axillary vein access did not eliminate the risk of pneumothorax, and the cephalic vein cutdown requires surgical skills that were unfamiliar to many cardiologists and were subject to significant anatomic variation, making it a persistent challenge in lead implantation for CIED procedures [18].

In response to these challenges, ultrasound-guided axillary/cephalic vein access has been introduced and is being increasingly adopted. Numerous medium-sized feasibility and retrospective studies and meta-analyses have been published [19–24]. These studies consistently report that ultrasound-guided venous access not only reduces the incidence of mechanical complications but also significantly diminishes procedural time and exposure to ionizing radiation.

Recently, two randomized studies have been published. The ACCESS trial was a randomized study comparing intra-pocket ultrasound-guided axillary vein puncture (IPUS-AVP) with cephalic vein cutdown (CVC) for venous access in CIED implantation [25]. The study assigned 101 patients to IPUS-AVP and 99 to CVC. Findings indicated that IPUS-AVP was superior to CVC in terms of success rate, time to venous access, procedure duration, and radiation exposure, with similar complication rates between the two groups. The ZEROFLUOR-OAXI trial randomized 270 patients into two groups: a standard group for fluoroscopy-guided axillary vein puncture (AVP) ($n=134$) and an experimental group for ultrasound-guided AVP ($n=136$) [26]. The composite outcome was lower in the ultrasound group according to intention-to-treat analysis, with significant differences mainly attributed to the lower incidence of inadvertent axillary arterial puncture (17% vs 6%). Additionally, the ultrasound group exhibited lower total procedural x-ray exposure while achieving comparable success rates on the first attempt. These outcomes reinforce the shift toward ultrasound-guided techniques, advocating for their general adoption in clinical practice due to enhanced safety and efficiency. Also, these randomized trials corroborate the trend observed in our research and emphasize the growing consensus on the advantages of ultrasound guidance in CIED lead implantations.

CVC is rarely performed in Korea, and the fluoroscopy-guided axillary vein approach is the typical first approach. Subclavian vein access is not recommended for initial attempts. The absence of significant vascular access-related complications in our study indicates the enhanced control and visibility that ultrasound guidance offers over traditional fluoroscopic methods. Therefore, US-AVA should be considered the first-line approach for axillary vein access during CIED lead implantation.

Learning curve of US-AVA

While numerous studies on the clinical advantages of US-AVA exist, reports specifically addressing the learning curve are relatively scarce. This may be due to the extensive experience many operators already have with transvenous CIED lead implantation, making it challenging to discern significant differences in access times across methods. Additionally, visualizing the vein with ultrasound is generally straightforward, contributing to the perception that the learning curve is not steep.

Studies have shown that the learning curve for US-AVA is relatively short compared to CVC. However, as previously mentioned, many researchers are already proficient in FL-AVA, and the studies show varying results on the learning curve for US-AVA compared to FL-AVA. A recent prospective randomized trial by Courtney et al. suggests that US-AVA may present a significant learning curve for inexperienced operators compared to FL-AVA [10]. In addition, a meta-analysis by D'Arrigo et al., despite indicating a low quality of evidence, also noted a steep learning curve for US-AVA [27]. Moreover, variations in ultrasound equipment and the techniques used for lead insertion post-vein access across different studies highlight the need for further research [27]. Future studies should aim to standardize the methods for extrathoracic venous access, assessing success rates, complication rates, and learning curves for different techniques.

On the other hand, a "steep learning curve" indicates that a skill is initially difficult to learn but becomes easier over time with practice. It suggests that while the US-guided approach to axillary vein access may be challenging to master initially, once it is learned, it can lead to shorter procedure times and greater efficiency, even for those still in training.

Limitations of our research

The major limitation of our study is that this was a single-center retrospective study with a relatively small sample size. Also, a notable limitation of this study is that all procedures were performed by a single operator. While this ensured consistency in technique and minimized variability, it also limits the generalizability of the findings, especially in terms of learning curve. The success rates and complication rates observed in this study may not be directly applicable to other operators with varying levels of experience and skill in ultrasound-guided procedures. Future studies should involve multiple operators to validate the reproducibility of these results across different clinical settings and skill levels. Additionally, the study did not account for the learning curve effect, which could be more pronounced in operators with less prior experience. Lastly, it should also be noted that our method was limited to using a cross-sectional view using a linear probe before skin incision, without attempting various approaches to US-AVA, such as a hockey-stick probe or intra-pocket ultrasound.

Conclusion

This study demonstrated that US-AVA enhances the safety and efficiency of CIED lead implantations in Korean patients. Compared to traditional FL-AVA, US-AVA exhibited lower complication rates, specifically reducing the incidence of pneumothorax and inadvertent arterial puncture. In addition, US-AVA reduces procedural and fluoroscopy times, thereby minimizing patient exposure to ionizing radiation and improving overall procedural outcomes. These results strongly support the adoption of US-AVA as a first-line technique for venous access in CIED procedures. Further large-scale studies are recommended on this technique to evaluate its efficacy and safety widely across diverse patient groups with varied anatomical challenges in real clinical practice.

Abbreviations

US-AVA	Ultrasound-guided axillary vein access
CIED	Cardiac implantable electronic device
FL-AVA	Fluoroscopy-guided axillary vein access
PM	Pacemaker
ICD	Implantable cardioverter-defibrillator
CRT	Cardiac resynchronization therapy
CVC	Cephalic vein cutdown

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42444-024-00125-6.

Supplementary Figure and Video legends.
Supplementary Figure 1.
Supplementary Figure 2.
Supplementary Figure 3.
Supplementary Video 1.
Supplementary Video 2.

Author contributions

All authors read and approved the final manuscript.

Funding

This work was supported by a grant from the Korean Heart Rhythm Society (Grant No. KHRS 2021-1).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Research Ethics Committee of Keimyung University Dongsan Medical Center (DSMC 2021-08-125). All the patients provided written informed consent before enrollment.

Competing interest
Authors have no conflict of interest.

Received: 6 May 2024 Accepted: 19 August 2024
Published online: 17 September 2024

References

1. Al-Khatib SM. Cardiac implantable electronic DEVICES. N Engl J Med. 2024;390:442–54. https://doi.org/10.1056/NEJMra2308353.
2. Magney JE, Flynn DM, Parsons JA, Staplin DH, Chin-Purcell MV, Milstein S, Hunter DW. Anatomical mechanisms explaining damage to pacemaker leads, defibrillator leads, and failure of central venous catheters adjacent to the sternoclavicular joint. Pac Clin Electrophysiol. 1993;16:445–57. https://doi.org/10.1111/j.1540-8159.1993.tb01607.x.
3. Magney JE, Staplin DH, Flynn DM, Hunter DW. A new approach to percutaneous subclavian venipuncture to avoid lead fracture or central venous catheter occlusion. Pacing Clin Electrophysiol. 1993;16:2133–42. https://doi.org/10.1111/j.1540-8159.1993.tb01018.x.
4. Roelke M, O'Nunain SS, Osswald S, Garan H, Harthorne JW, Ruskin JN. Subclavian crush syndrome complicating transvenous cardioverter defibrillator systems. Pacing Clin Electrophysiol. 1995;18:973–9. https://doi.org/10.1111/j.1540-8159.1995.tb04737.x.
5. Atti V, Turagam MK, Garg J, Koerber S, Angirekula A, Gopinathannair R, Natale A, Lakkireddy D. Subclavian and axillary vein access versus cephalic vein cutdown for cardiac implantable electronic device implantation: a meta-analysis. JACC Clin Electrophysiol. 2020;6:661–71. https://doi.org/10.1016/j.jacep.2020.01.006.
6. Deluca G, Massari VFM, Musaico F, Rosa I, Modugno G, Scardigno AD, Valente L, Leo PD, Ceravolo G, Pittiruti M. Ultrasound-guided venipuncture for implantation of cardiac implantable electronic devices: a single-center, retrospective study. Pacing Clin Electrophysiol. 2020;43:713–9. https://doi.org/10.1111/pace.13961.
7. Migliore F, Fais L, Vio R, De Lazzari M, Zorzi A, Bertaglia E, Iliceto S. Axillary vein access for permanent pacemaker and implantable cardioverter defibrillator implantation: fluoroscopy compared to ultrasound. Pacing Clin Electrophysiol. 2020;43:566–72. https://doi.org/10.1111/pace.13940.
8. Chandler JK, Apte N, Ranka S, Mohammed M, Noheria A, Emert M, Pimentel R, Dendi R, Reddy M, Sheldon SH. Ultrasound guided axillary vein access: AN alternative approach to venous access for cardiac device implantation. J Cardiovasc Electrophysiol. 2021;32:458–65. https://doi.org/10.1111/jce.14846.
9. Qin D, Ptaszek LM. A practical guide to ultrasound-guided venous access during implantation of pacemakers and defibrillators. J Innov Card Rhythm Manag. 2022;13:4873–7. https://doi.org/10.19102/icrm.2022.130204.
10. Courtney AM, Chandler JK, Anderson J, Shrestha A, Noheria A, Pimentel R, Dendi R, Ramirez R, Reddy YM, Sheldon SH. UltraSound axillary vein access (USAA): learning curve and randomized comparison to traditional venous access for cardiac device implantation. Pacing Clin Electrophysiol. 2022;45:1364–71. https://doi.org/10.1111/pace.14611.
11. Salcedo J. Ultrasound-guided vascular access for CIED implantation: a step-by-step guide. J Cardiovasc Electrophysiol. 2023;34:1033–6. https://doi.org/10.1111/jce.15860.
12. Su J, Kusumoto FM, Zhou X, Elayi CS. How to perform extrathoracic venous access for cardiac implantable electronic device placement: Detailed description of techniques. Heart Rhythm. 2022;19:1184–91. https://doi.org/10.1016/j.hrthm.2022.02.020.
13. Venous Drainage of the Upper Limb. https://teachmeanatomy.info/upper-limb/vessels/veins/. 2023. Accessed 12, November.
14. Mobin-Uddin K, Smith PE, Lombardo C, Jude J. Percutaneous intracardiac pacing through the subclavian vein. J Thorac Cardiovasc Surg. 1967;54:545–8.
15. Ramza BM, Rosenthal L, Hui R, Nsah E, Savader S, Lawrence JH, Tomaselli G, Berger R, Brinker J, Calkins H. Safety and effectiveness of placement of pacemaker and defibrillator leads in the axillary vein guided by contrast venography. Am J Cardiol. 1997;80:892–6. https://doi.org/10.1016/s0002-9149(97)00542-0.
16. Kim KH, Park KM, Nam GB, Kim DK, Oh M, Choi H, Hong TJ, Park BM, Seo GW, Song PS, et al. Comparison of the axillary venous approach and subclavian venous approach for efficacy of permanent pacemaker implantation: 8-year follow-up results. Circ J. 2014;78:865–71. https://doi.org/10.1253/circj.cj-13-0884.
17. Chan NY, Kwong NP, Cheong AP. Venous access and long-term pacemaker lead failure: comparing contrast-guided axillary vein puncture with subclavian puncture and cephalic cutdown. Europ Eur Pacing Arrhyth Cardiac Electrophysiol J Work Groups Cardiac Pacing Arrhyth Cardiac Cell Electrophysiol Eur Soc Cardiol. 2017;19:1193–7. https://doi.org/10.1093/europace/euw147.
18. Kuck K-H, Kunze K-P, Schlüter M, Duckeck W. Encainide versus flecainide for chronic atrial and junctional ectopic tachycardia. Am J Cardiol. 1988;62:L37–44.
19. Liccardo M, Nocerino P, Gaia S, Ciardiello C. Efficacy of ultrasound-guided axillary/subclavian venous approaches for pacemaker and defibrillator lead implantation: a randomized study. J Interv Card Electrophysiol. 2018;51:153–60. https://doi.org/10.1007/s10840-018-0313-7.
20. Clark BC, Janson CM, Nappo L, Pass RH. Ultrasound-guided axillary venous access for pediatric and adult congenital lead implantation. Pacing Clin Electrophysiol. 2019;42:166–70. https://doi.org/10.1111/pace.13567.
21. Jimenez-Diaz J, Higuera-Sobrino F, Piqueras-Flores J, Perez-Diaz P, Gonzalez-Marin MA. Fluoroscopy-guided axillary vein access vs cephalic vein access in pacemaker and defibrillator implantation: Randomized clinical trial of efficacy and safety. J Cardiovasc Electrophysiol. 2019;30:1588–93. https://doi.org/10.1111/jce.14060.
22. Ahmed AS, Gilge JL, Clark BA, Shah A, Bagga S, Padanilam MS, Prystowsky EN, Joshi SA, Nair GV, Patel PJ. Predictors of successful ultrasound-guided lead implantation. Pacing Clin Electrophysiol. 2020;43:217–22. https://doi.org/10.1111/pace.13855.
23. Tagliari AP, Kochi AN, Mastella B, Saadi RP, di Leoni FA, Saadi EK, Polanczyk CA. Axillary vein puncture guided by ultrasound vs cephalic vein dissection in pacemaker and defibrillator implant: a multicenter randomized clinical trial. Heart Rhythm. 2020;17:1554–60. https://doi.org/10.1016/j.hrthm.2020.04.030.
24. Vetta G, Magnocavallo M, Parlavecchio A, Caminiti R, Polselli M, Sorgente A, Cauti FM, Crea P, Pannone L, Marcon L, et al. Axillary vein puncture versus cephalic vein cutdown for cardiac implantable electronic device implantation: a meta-analysis. Pacing Clin Electrophysiol. 2023;46:942–7. https://doi.org/10.1111/pace.14728.
25. Charles P, Ditac G, Montoy M, Thenard T, Courand PY, Lantelme P, Harbaoui B, Fareh S. Intra-pocket ultrasound-guided axillary vein puncture vs. cephalic vein cutdown for cardiac electronic device implantation: the ACCESS trial. Eur Heart J. 2023;44:4847–58. https://doi.org/10.1093/eurheartj/ehad629.
26. Vitali F, Malagu M, Bianchi N, De Raffele M, Manfrini M, Gibiino F, Boccadoro A, Azzolini G, Balla C, Bertini M. Ultrasound-guided venous axillary access versus standard fluoroscopic technique for cardiac lead implantation: ZEROFLUOROAXI randomized trial. JACC Clin Electrophysiol. 2024;10:554–65. https://doi.org/10.1016/j.jacep.2023.11.020.
27. D'Arrigo S, Perna F, Annetta MG, Pittiruti M. Ultrasound-guided access to the axillary vein for implantation of cardiac implantable electronic devices: A systematic review and meta-analysis. J Vasc Access. 2021;24:854–63. https://doi.org/10.1177/11297298211054621.

Publisher's Note