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Tributaries of the left brachiocephalic vein: problems in central venous catheterization and, potentially, in cardiac implantable electronic device placement

Dopływy lewej żyły ramienno-głowowej — problem kaniulacji żył centralnych/centralnego cewnikowania żylnego i, potencjalny, wszczepialnych urządzeń elektronicznych serca

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Abstract

Introduction. Intravascular procedures, including central venous catheterization and placement of cardiac implantable electronic device (CIED) leads, present an opportunity for radiological assessment of the relevant vessels.

Obtaining vascular access via left clavipectoral triangle veins may lead to an unintentional catheter/lead insertion into a left brachiocephalic vein (BCV) tributary. This article presents the left-BCV tributaries encountered during CIED implantation procedures and discusses the potential impact of vessel topography on the course of such procedures.

Material and methods. Venography records of *de novo* CIED implantation procedures conducted between 2014 and 2018 were analyzed retrospectively. The indication for these venographies had been the need to determine the cause of difficulties in threading a lead through the venous system. As the title suggests, this paper focuses only on the records illustrating the presence and course of left-BCV tributaries.

Results. Out of a total of 315 venographies, we found 12 cases of left-BCV tributaries, including nine left superior intercostal veins (SICVs), two left internal thoracic (mammary) veins (IMVs), and one inferior thyroid vein. Other veins had not been visualized.

Conclusions The left SICV and, less commonly, left IMV were the most commonly visualized left-BCV tributaries in the analyzed imaging records of *de novo* CIED placement procedures. The anatomical variants of those vessels that drain into the left BCV from below, at the outer or convex wall of the bend in the left BCV, increase the risk of unintentional CIED lead or central venous catheter insertion.

Key words: left brachiocephalic vein, left superior intercostal vein, left internal mammary vein, cardiac pacing, central venous catheterization

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Introduction

The growing number of intravenous procedures, including central venous catheter (CVC) insertion or cardiac implantable electronic device (CIED) placement, affords more and more opportunities to detect anatomical variations in the vasculature. In order for CIED implantation to proceed smoothly and the cardiac leads to be easily threaded through the veins of the left clavipectoral triangle, it is crucial that the position and course of the left brachiocephalic vein (BCV), also known as the left innominate vein, and its tributaries be normal [1–4].

Sometimes, however, the junctions of the internal jugular veins (IJVs) with the ipsilateral subclavian veins, which give rise to the left and right BCVs, are shaped in a way that favors an unintentional insertion of a CIED lead or a CVC into a wrong vessel. In most situations when a lead/catheter enters the IJV, this fact can be directly detected under fluoroscopy, without the need to administer intravascular contrast (Figure 1A–D).

In other situations, fluoroscopy alone may prove insufficient in illustrating the cause of difficulty in threading a cardiac lead. In such cases, only an intraprocedural venography can clarify the situation and help make decisions as to the further course of action. Filling vascular lumina with a contrast agent, which illustrates vessel topography and morphometry, helps quickly diagnose potential congenital anomalies in the position and shape of venous tributaries.

The catheter introduced during central venous catheterization may also become unintentionally inserted (or displace spontaneously) into a vessel other than the target vessel (such as a target vessel tributary). Computed tomography (CT) or magnetic resonance imaging (MRI) conducted after the procedure help precisely illustrate the incorrect position of the CVC (Figures 2, 3).

Unintentional CVC insertion into a wrong vessel, particularly as the catheter is being introduced via the left jugular or left subclavian vein, typically involves the left superior intercostal vein (SICV) or the left internal thoracic (mammary) vein (IMV) [5–10].

A similar problem may also occur during a CIED implantation procedure. Any resulting uncertainties as to the precise location of the cardiac lead in the venous system can be resolved directly during the procedure. The relevant veins can be visualized under contrast-enhanced fluoroscopy.

The purpose of this paper was to present radiological images of the types and topographies of left-BCV tributaries, which had been encountered during *de novo* CIED implantation procedures over a 5-year period. The venous segment of the greatest interest to our analysis was a bend in the left BCV where some anatomical variants of left-BCV tributaries, running along the longitudinal axis of the body, drain into the left BCV from below (at the outer or convex wall of the vein's curvature). This venous topography allows the cardiac lead that is being advanced to easily enter a wrong vessel without the operator's intention.

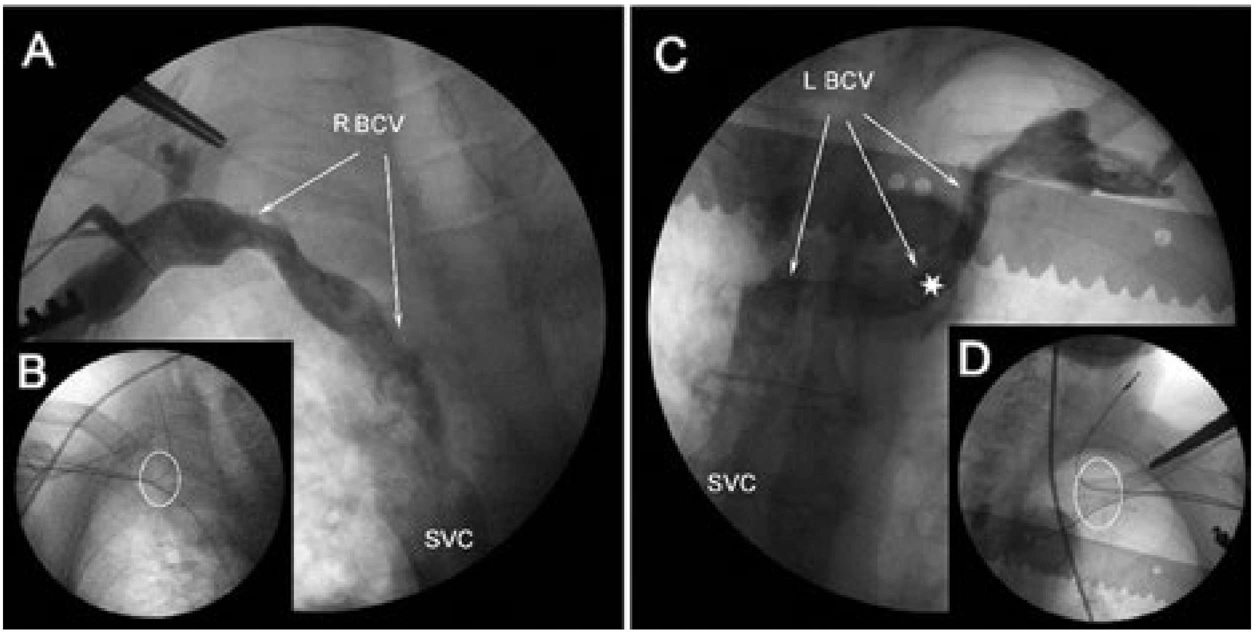

Figure 1A, C. Radiological anteroposterior (AP) views of the typical brachiocephalic vein (BCV) topography observed during cardiac implantable electronic device placement procedures. Right BCV (R BCV) (**A**). Left BCV (BCV); SVC — superior vena cava (**C**). A curve/bend in the L BCV (asterix). Cardiac leads (oval) unintentionally inserted into the right internal jugular vein (IJV) (**B**) and the left IJV (**D**)

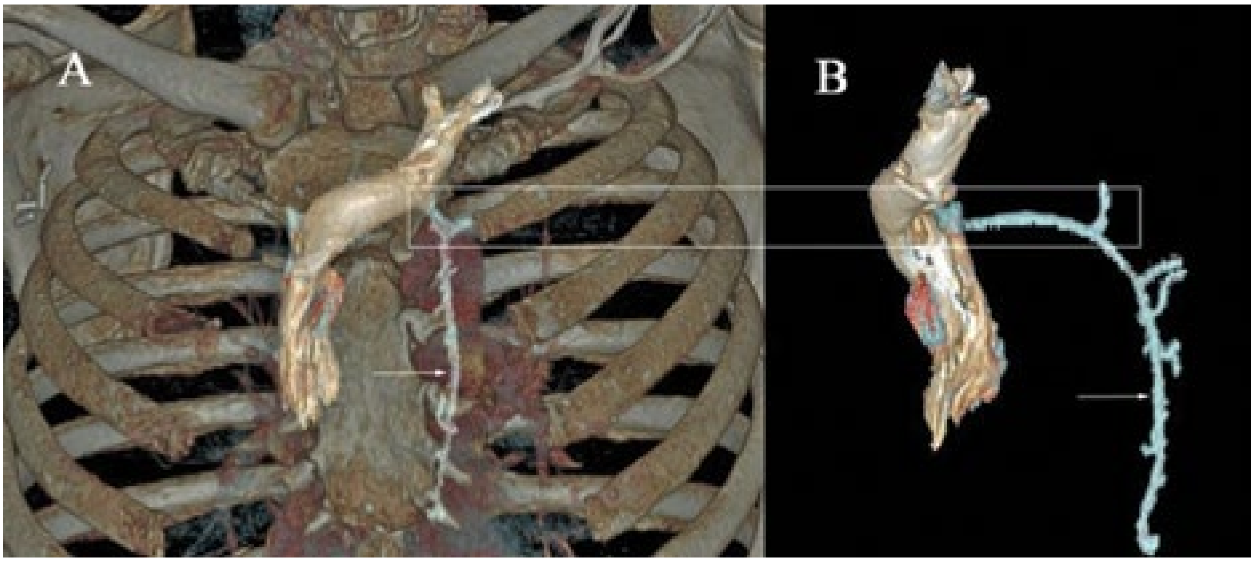

Figure 2. A three-dimensional (3D) computed tomography reconstruction (venous phase) of left superior intercostal vein (SICV) topography (arrow) and the venous junction at the inferior aspect of a curve in the left brachiocephalic vein (rectangular box): **A.** The left SICV: an anteroposterior (AP) view suggesting a straight vertical course of the vessel (a reconstructed image shown in relation to the bony structures of the chest; **B**). The left SICV: a lateral view showing the actual arching of the vessel, which curves around the aorta

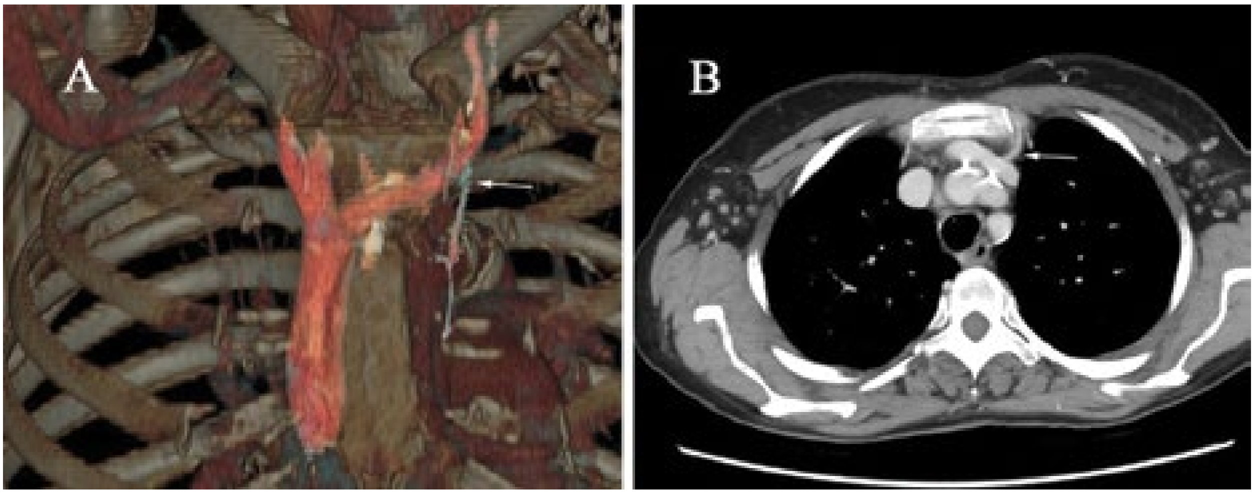

Figure 3. The course of the left internal thoracic (mammary) vein (IMV) (arrow) and the site where it joins the left brachiocephalic vein (BCV) at the inferior aspect of the curve in the left BCV: **A.** An anteroposterior (AP) view; three-dimensional (3D) reconstruction: vessel topography in relation to the bony structures of the chest; **B.** An axial computed tomography (CT) view: the segment of the left IMV (arrow) that joins the left BCV shown in relation to the anterior thoracic wall

Materials and methods

This study involved a retrospective analysis of venography images obtained during *de novo* CIED implantation procedures in the period 2014–2018. The analyzed CIED implantation procedures involved cardiac lead insertion via the veins of the left clavipectoral triangle.

The indication for contrast-enhanced venous imaging was the operator's uncertainty as to the cause of difficulties in advancing the cardiac lead through the venous system. As indicated in the title, for the purpose of this paper we focused only on those medical imaging records that visualized the morphometry and topography of the veins joining the left BCV.

In order to limit the effect of various levels of operator experience and any potential venography protocol variations, we analyzed only the CIED implantation procedures performed by the same team. The intravascular flow of contrast had been recorded in the anteroposterior (AP) view. The analyzed imaging data had been captured at the usual pulse rate of 12 frames per second and included single-frame images.

The venography protocol involved selective contrast administration, directly via the site of approach either via cephalic vein (CV) cutdown or axillary/subclavian vein puncture. Such a selective venography protocol is characterized by a low volume of administered contrast agent, while at the same time ensures an efficient filling of systemic vein lumina within the mediastinum.

The images included in this paper are selected examples of the detected anatomical variants of left-BCV tributaries. Our statistical analysis presented numerical variables in the form of mean values, standard deviations. This study had been approved by the Institutional Review Board.

Results

We analyzed venography records obtained during 315 *de novo* CIED implantation procedures conducted in 133 women (mean age 76.9 ± 12.8 years) and 182 men (mean age 75.1 ± 11.4 years) over a five-year period. Intravenous contrast administration clearly illustrated the presence of the left SICV in nine patients, left IMV in two patients, and inferior thyroid vein (ITV) in one patient.

The ostia of the contrast-enhanced left SICVs were located in the convex inferior wall of the left BCV, at the site where the latter vein curved at an angle. In two cases, the segment of the left SICV that joined the left BCV was found to be horizontal (*i.e.* perpendicular to the long axis of the body) (Figure 4). In the remaining seven cases, the relevant SICV segment coursed vertically (*i.e.* parallel to the longitudinal axis) (Figure 5).

During two *de novo* CIED implantation procedures the left IMV was visualized with its ostium in the convex inferior wall of the left BCV at the site where the latter vein curved at an angle (Figure 6).

Images recorded during one CIED implantation procedure showed one of the left-side ITVs with a well-developed collateral venous drainage via other ITVs, due to distal left-BCV compression.

The evaluated left-BCV venography records conducted during *de novo* CIED implantation procedures did not illustrate the course of thymic, pericardial, or vertebral veins.

Discussion

During a CIED implantation, cardiac leads inserted into the venous system via the veins of the clavipectoral triangle are subsequently advanced via the right or left BCV. The venous approach used preferentially at our facility is via the veins

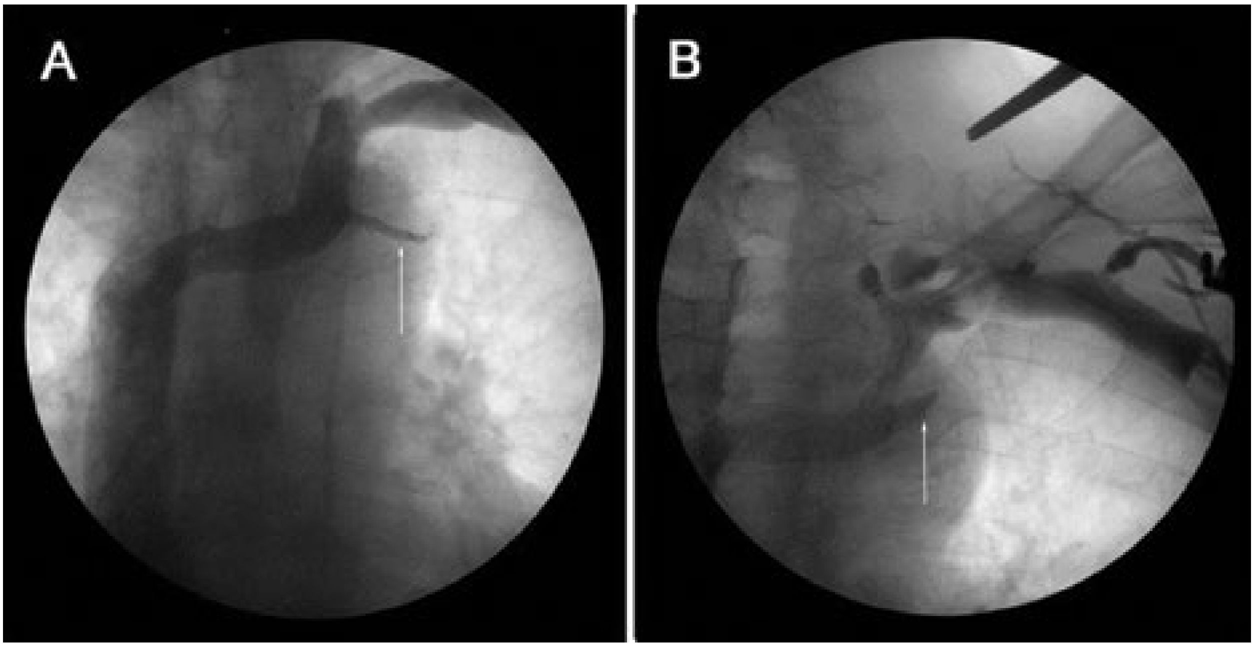

Figure 4. Examples of left superior intercostal veins joining the left brachiocephalic vein in the transverse plane (arrows): **A.** A vessel of typical morphometric parameters in a 92-year-old male; **B.** A vessel with a dilated lumen (due to portal hypertension) in a 71-year-old male

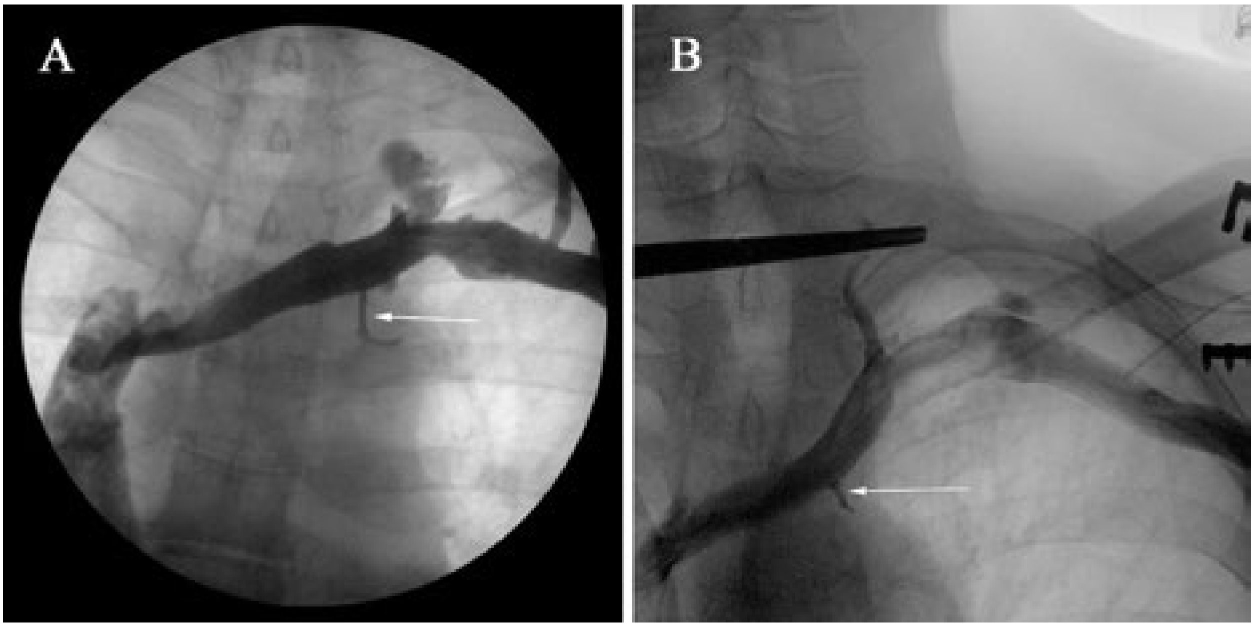

Figure 5. Examples of left superior intercostal veins joining the left brachiocephalic vein vertically (along the longitudinal axis) (arrows) in a 69-year-old female (**A**) and a 66-year-old male (**B**)

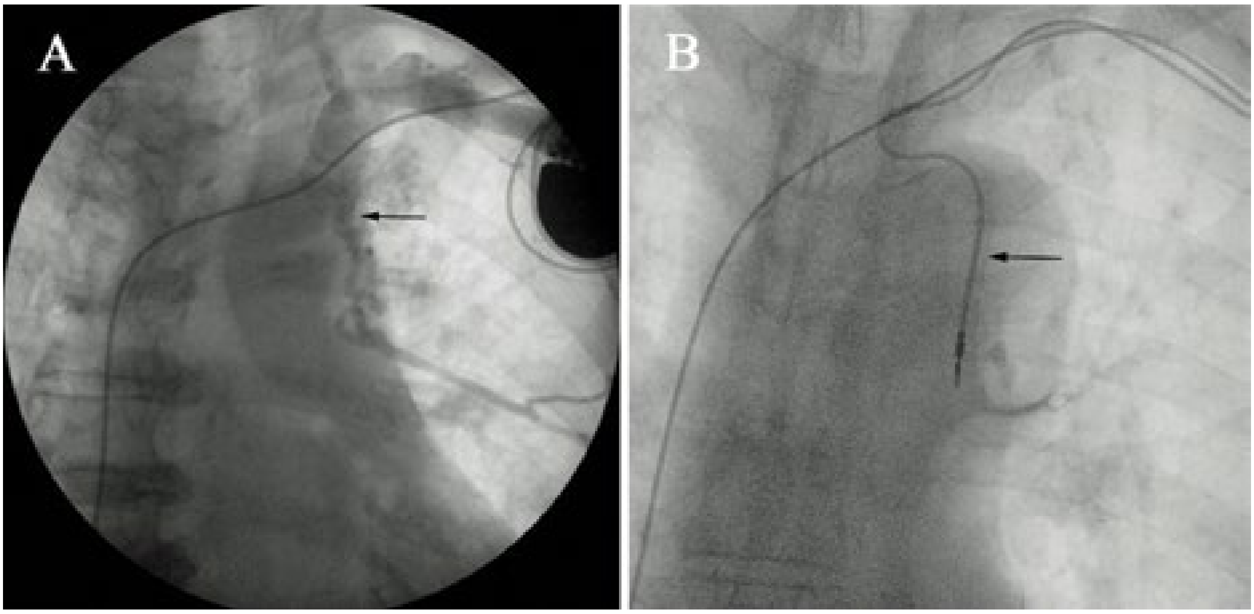

Figure 6. Two instances of visualized left internal thoracic (mammary) veins (IMVs) (arrow): **A.** The left IMV visualized in an 80-year-old female with an implanted VVI pacemaker; the IMV courses along the longitudinal axis and joins the left brachiocephalic vein from below at the convexity formed by the latter vein curving at an angle (arrow) (coronal fluoroscopy image). In this case lead insertion was uneventful; **B.** The left IMV containing a cardiac lead (arrow) unintentionally inserted during a DDD pacemaker implantation in a 74-year-old man

of the left clavipectoral triangle. Hence, the left BCV was involved in cardiac lead advancement during approximately 97% of the analyzed CIED implantation procedures.

The presence of left-BCV tributaries can sometimes cause difficulties during such procedures as central venous catheterization. Similar problems can occur while cardiac leads are being advanced through the venous vasculature during CIED implantation procedures.

During normal embryogenesis, at gestational week 8, both BCVs are formed as a result of an anastomosis between the right and left anterior cardinal veins. Eventually, the left BCV becomes nearly three times longer than the right BCV. This difference in length contributes to a greater morphometric and topographic variation of the two veins and their tributaries (the left SICV, IMV, ITV, thymic veins, vertebral veins, and pericardial veins).

The left SICV has been reported in 1.4–9.5% of non--cardiological patients [6, 7, 11]. We observed the presence of the left SICV in < 2% of the analyzed cases of venography.

As an embryological remnant of the anterior part of the left cardinal vein, the left SICV collects blood from veins draining the region between the first and fourth left intercostal spaces. The left SICV is located at the level of vertebrae T3/T4, anterior and parallel to the lateral aortic wall and drains into the left BCV, typically at the site where the latter vein curves at an angle. The presence of this left-BCV tributary may be suggested by the 'aortic nipple', *i.e.* a chest radiographic finding in the form of a small projection from the lateral contour of the aortic arch [11, 12]. The normal diameter of the left SCIV ranges from 1 to 4 mm, with values exceeding 4.5 mm considered abnormal [9].

Abnormal dilation of the left SCIV may be due to congenital vascular anomalies or an occlusion in the superior vena cava (SVC), inferior vena cava (IVC), or azygos veins [13, 14]. The appearance of a previously absent aortic nipple in chest radiography (AP view), may indicate the development of venous thrombosis in the BCV, SVC, or IVC [5, 15]. A left-SICV ostium that is dilated and/or located along the course of lead advancement (especially if the ostium is located in the inferior wall of the left BCV at the level where the latter vein bends at an angle) may increase the risk of unintentional lead insertion [6].

During central venous catheterization, the catheter may be unintentionally inserted into the left IMV (which is a left-BCV tributary) [16, 17]. This situation is even more likely with a subclavian approach [16]. Accidental catheter insertions into the left IMV happen during approximately 2% of central venous catheterization procedures and are not always asymptomatic [18]. A lateral chest X-ray can help verify the location of the catheter (as the IMV courses along the anterior thoracic wall).

The estimated mean diameter of the left IMV at the level of the third rib is 2.51 mm (1.7–3.2 mm) [2]. The risk of primary placement (or secondary displacement) of the catheter into the IMV lumen increases if the left-IMV ostium is located at a bend in the left BCV, along the convex inferior wall of the latter. The presence of this left-BCV tributary was observed during two CIED implantation procedures. During one of those procedures, the tip of the cardiac lead advanced through the left BCV would repeatedly entered the left-IMV ostium.

One of the analyzed CIED implantation procedures revealed the presence of the ITV. This left-BCV tributary and its anatomical variations can occur in the form of anywhere from one (62%) to five narrow vessels. In its typical location the ITV ostium is in the superior wall of the left BCV, where it poses a very low risk of unintentional catheter//lead insertion [1, 19].

Apart from the examples discussed above, the radiographic records analyzed as part of this study showed no other left-BCV tributaries, such as thymic, pericardial, or vertebral veins.

As mentioned in the introduction, the course of central venous catheterization procedures may be complicated by unintentional insertion (or spontaneous displacement) of a CVC into the left SICV or the left IMV [3, 8, 11, 20]. The venography records from CIED implantations analyzed in this study showed two cases of the left IMVs, one of which resulted in an unintentional lead insertion (as described in the text above). We found no reports of a similar occurrence in the literature on implantable pacemaker treatment. Nonetheless, despite it being so rare, insertion of a cardiac lead into the left IMV or the left SICV should not be disregarded as a potential cause of difficulties in advancing the lead via the left BCV.

Limitations

Our analysis of the prevalence and character of left--BCV tributaries was limited only to the vein variations visualized during *de novo* CIED implantation procedures, which may not reflect their characteristics in other populations. The morphometric and topographic assessment of left-BCV tributaries was limited to AP-view radiographic images.

Conclusions

The most common types of left-BCV tributaries visualized during CIED implantation procedures were the left SICV and, rarely, the left IMV. The orientation of these vessels along the longitudinal axis, with their ostia located at the convex inferior wall of a bend in the left BCV, seems to increase the risk of unintentional lead/catheter insertion.

Conflict of interest

The authors declare no conflict of interest.

Streszczenie

Wstęp. Wykonywanie procedur inwazyjnych, takie jak zakładanie cewników CVC (*central venous catheter*) czy elektrod CIED (*cardiac implantable electronic device*), sprzyja radiologicznym obserwacjom naczyń wykorzystywanych podczas ich realizacji. W przypadku stosowania dostępu żylnego z naczyń lewego trójkąta naramienno-piersiowego może dojść do niezamierzonego wprowadzenia cewnika/elektrody do jednego z dopływów lewej żyły ramienno-głowowej (LBCV). Celem opracowania była prezentacja dopływów LBCV napotkanych podczas CIED i potencjalny wpływ ich topografii na przebieg procedury.

Materiał i metody. Ocenie retrospektywnej poddano wenografie wykonane podczas CIED *de novo* w latach 2014–2018. Wskazaniem do wykonania diagnostyki obrazowej była potrzeba ustalenia przyczyny utrudnionego przeprowadzania elektrody układem żylnym. Z racji tematyki opracowania w powyższej grupie wyodrębniono i poddano analizie jedynie nagrania wizualizujące obecność i charakter dopływów LBCV.

Wyniki. Wśród wykonanych 315 wenografii znaleziono 12 przypadków spływów żylnych do LBCV, w tym: 9 lewej górnej żyły międzyżebrowej (LSICV), 2 lewej żyły piersiowej wewnętrznej (LITV/LIMV) oraz 1 lewej żyły tarczowej dolnej (ITV), innych w ocenianym materiale nie zobrazowano.

Wnioski. W analizowanym materiale procedur CIED *de novo* najczęściej obserwowano obecność LSICV, rzadziej LIMV, zaś ich postacie anatomiczne układające się równolegle do osi ciała i łączące się z dolną ścianą LBCV w obszarze jej kątowego zagięcia mogą sprzyjać niezamierzonemu wprowadzeniu tamże elektrody CIED/cewników CVC.

Słowa kluczowe: lewa żyła ramienno-głowowa, lewa górna żyła międzyżebrowa, lewa żyła piersiowa wewnętrzna, stymulacja serca, kaniulacja naczyń centralnych

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