https://doi.org/10.35336/VA-1327

THE CHANGE IN THE POSITION OF THE ESOPHAGUS DURING RADIOFREQUENCY ABLATION OF THE PULMONARY VEINS IS MINIMAL ACCORDING TO ESOPHAGOGRAPHY WITH WATER-SOLUBLE CONTRAST

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Aim. To study the change in the position of the esophagus during radiofrequency ablation of the pulmonary veins (RFA PV) using esophagography

Methods. The period of the study is from August 2022 to January 2023 inclusive. The study is a single-center observational non-randomized study. The study included 191 patients. RFA PV were performed under conscious sedation with dexmedetomidine and fentanyl. The patients were available for verbal contact throughout the operation. After performing a transeptal puncture, esophagography was performed in the LAO 30° projection using 10 ml of Omnipac water-soluble contrast agent (GE Healthcare Ireland). At the end of the operation, esophagography was performed repeatedly. The position of the esophagus was determined relative to the shadow of the spine. Measurements were carried out at three levels: the upper one at the intersection of the esophagus and the roof of the left atrium, the lower one at the intersection with the ring of the mitral valve; the middle level at the middle of the distance between the upper and lower measurements. The width of the contrasted lumen of the esophagus was measured at the same levels. Lateral displacement of the esophagus was defined as the difference in the values of measurements of the position of the lateral and medial boundaries of the esophageal shadow on esophagograms obtained at the beginning and end of the operation.

Results. The average lateral displacement of the esophagus was 2.0 ±1.9 mm at the upper level, 3.4±1.6 mm at the middle level and 1.4±1.2 mm at the lower level of the left atrium. There was no significant statistically difference in the change in the position of the esophagus at the beginning and end of the operation (p=0.251, p=0.558, p=0.824, respectively, for the upper, middle and lower measurement levels). The most significant displacement of the esophageal shadow was 5.3 mm. The maximum change in the width of the contrasted lumen of the esophagus was 5.5 mm.

Conclusions. According to esophagography with water-soluble contrast, the position of the esophagus during RFA PV does not experience clinically significant changes.

Key words: atrial fibrillation; pulmonary veins; radiofrequency ablation; esophagus; esophagography; complications

Conflict of interest: none.
Funding: none.
Received: 25.01.2024 **Revision received:** 03.06.2024 **Accepted:** 23.07.2024
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For citation: Bazylev VV, Kozlov AV, Durmanov SS. The change in the position of the esophagus during radiofrequency ablation of the pulmonary veins is minimal according to esophagography. *Journal of Arrhythmology.*2024;31(3): 19-24. https://doi.org/10.35336/VA-1327.

Currently, catheter ablation is a routine operation in the treatment of atrial fibrillation [1]. Although the procedure is minimally invasive, it entails certain risks. One of the most serious potential complications is thermal injury to the esophagus, which can lead to the formation of an atrial-esophageal fistula [2]. The use of radiofrequency energy in proximity to the esophagus is an independent predictor of esophageal injury [3, 4]. The anatomical position of the esophagus relative to the left atrium (LA) varies for each patient [5]. Additionally, early studies have indicated that the position of the esophagus relative to the LA can shift significantly within a short period of time, by as much as several centimeters [6, 7]. At the same time, some studies have reported no significant changes in the position of the esophagus during the operation [8, 9]. Thus, it remains unclear whether the esophagus can significantly change its location during radiofrequency ablation (RFA) of pulmonary vein (PV). One method of visualizing the esophagus is esophagography with water-soluble contrast. By performing imaging at the beginning and end of the operation, it is possible to compare the obtained images and assess the extent of esophageal displacement during RFA procedure.

The aim of the study is to investigate the changes in esophageal position during PV RFA using esophagography.

METHODS

The study period spanned from August 2022 to January 2023, inclusive. Single-center observational nonrandomized study. A total of 243 PV RFA were performed during this period, and 191 patients were included in the study.

Inclusion criteria:
- indications for performing PV RFA (from expert agreement [10]),
- patient consent.

Exclusion criteria:
- allergy to iodine,
- need for general anesthesia,
- changes in the patient's body position during surgery according to the nefluoroscopic mapping system,
- need to perform electrical cardioversion during surgery.

Patient characteristics are summarized in Table 1. The surgeries were performed using intravenous sedation with dexmedetomidine and fentanyl. Patients were available for verbal contact throughout the surgery. The coronary sinus was catheterized using multipolar catheters from subclavian or femoral access, depending on operator preference. After performing one or two transseptal punctures under fluoroscopy control, one or two unguided introdjussors were inserted into the LA cavity, respectively. Anticoagulation was accomplished by bolus administration of a loading dose of heparin. Patients taking direct oral anticoagulants received a higher dose compared to patients taking warfarin [11]. Esophagography was performed in the LAO 30° projection using 10 ml of Omnipac water-soluble contrast agent (GE Healthcare Ireland). The use of this drug for oral administration is authorized by the manufacturer [12]. The nurse anesthetist used a syringe to inject a contrast agent into the patient's oral cavity. The operator then gave the command to swallow the contrast and fluorography was performed simultaneously. Passage of the contrast agent through the esophagus took approximately 5-7 seconds. CARTO 3 3D mapping system (Biosense Webster Johnson & Johnson, USA) was used to build an anatomical map of the LA. The position of the esophageal shadow edges was marked on the posterior wall of the LA with dots, using the comparison of esophagography and anatomical mapping data.

PV RFA was performed using the «CLOSE» protocol technique [13] with bidirectional irrigated EZ Steer Nav SmartTouch electrodes (Biosense Webster Johnson & Johnson, USA). Stockert RF energy generator (Biosense Webster Johnson & Johnson, USA) was used in power control mode. A CoolFlow roller pump (Biosense Webster Johnson & Johnson, USA) was used to deliver saline solution, with an irrigation rate of 30 ml/min. For impacts on the anterior wall of the LA, the power of the applied energy was 40 W. During RFA on the posterior wall of the LA in the projection of the esophagus, a power of 30 W was used, with the duration of exposure at any single point limited to no more than 10 seconds.

After isolation of the right and left PVs, esophagography was repeated using the same protocol and in the same projection as at the beginning of the operation (Fig. 1). The time elapsed between esophagographies was recorded in the surgical protocol. If a change in the patient's body position was recorded during the intervention according to the CARTO 3 system, repeated esophagography was not performed, and the patient was excluded from the study.

Fluoroscopic images were stored in an electronic medical record. The DICOM file viewer Vidar Dicom Viewer 3 (Vidar Software LLC) was used for image analysis. The position of the esophagus was determined relative to the shadow of the spine during maximal deviation.

Table 1.

Main characteristics of patients (n=191)

Age (years)	63.9±7.8
Male gender, n (%)	91 (47.6)
Body mass index, kg/m^2	31.3±4.5
Left ventricular ejection fraction, %	64.8±5.6
Left atrial volume, ml	98.2±23.2
Left atrial diameter, mm	42.3±4.6
Arrhythmic history, months	54.0 (22.0;86.0)
Diabetes mellitus, n (%)	21 (11.0)
Arterial hypertension, n (%)	171 (89.5)
Coronary heart disease, n (%)	19 (9.9)

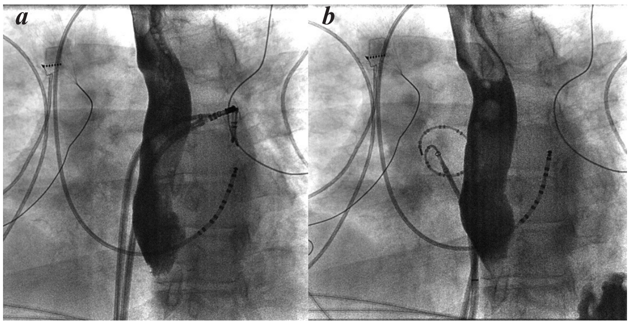

Fig. 1. Esophageal position before (a) and after (b) radiofrequency ablation of pulmonary veins.

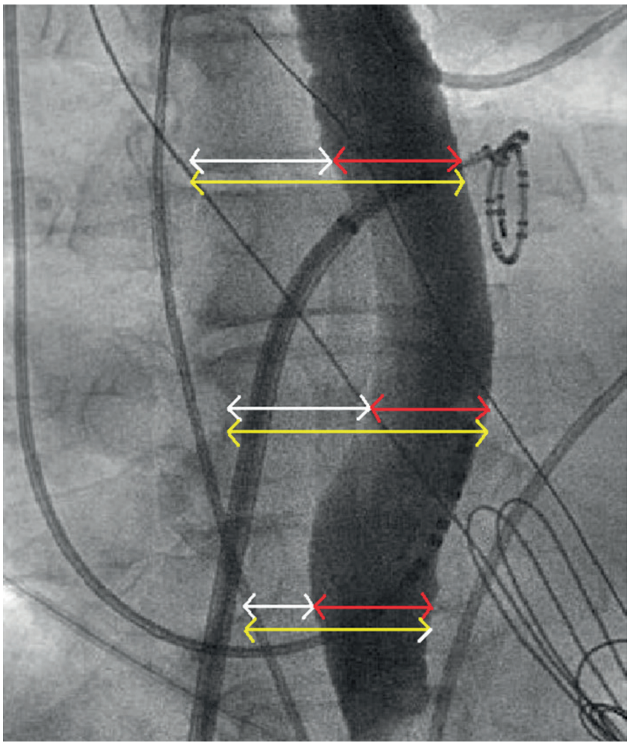

Fig. 2. Measurement of esophageal position relative to the spine shadow, where white arrows indicate the distance between the spine shadow and the medial edge of the esophagus, yellow arrows indicate the distance between the spine shadow and the lateral edge of the esophagus, and red arrows indicate the width of the esophagus.

Measurements were taken from the lateral and medial borders of the esophageal lumen to the vertebral body perpendicularly at three levels: the upper level at the intersection of the esophagus and the roof of the left atrium, with the Lasso catheter in the upper left pulmonary vein as a reference point; the lower level at the intersection with the mitral valve ring, with the catheter position in the coronary sinus as a reference point; and the middle level at the midpoint between the upper and lower measurements (Fig. 2).

The width of the contrasted esophageal lumen was measured at the same levels. The point on the vertebral border from which measurements were taken was selected individually for each case, based on optimal visualization. Repeated measurements were performed similarly, from the same anatomical structures as the primary measurements. Lateral displacement of the esophagus was defined as the difference between measurements of the lateral and medial borders of the esophageal shadow on esophagograms obtained at the beginning and end of the operation. The maximum value of this lateral displacement was recorded and assessed. All measurements were performed after calibration by coronary sinus catheter.

Three variants of esophageal position relative to the spinal shadow were distinguished: central, when the esophagus was aligned with the spinal column; left-sided, when the esophagus was closer to the left border of the spine; and right-sided, when the esophagus was closer to the right border of the spine (Fig. 3).

Statistical analysis

Statistical processing of the study results was carried out using IBM® SPSS® Statistics (Version 20, 2011) system software package. If the distribution was normal, results were expressed as arithmetic mean ± standard deviation (M±SD). In case of asymmetric distribution, results were expressed as median and interquartile range. Frequencies and fractions (in %) were used to describe qualitative data, with 95% CI calculated using Wilson's method. In case of symmetric distribution, paired Student's t test was used to compare the mean values. Wilcoxon's criterion for related samples was used for asymmetric distribution. The critical level of statistical significance for testing statistical hypotheses was taken as 0.05.

RESULTS

The main characteristics of the performed operations are given in Table 2. The most common location was left-sided esophagus found in 112 patients (58.6%), the second most common was central location in 73 patients (38.2%), and the rarest location was right-sided which was found in 6 patients (3.2%).

The mean lateral esophageal displacement was 2.0 ±1.9 mm at the superior level, 3.4 ±1.6 mm at the midline level, and 1.4 ±1.2 mm at the inferior level of the left atrium. There was no statistically significant difference in esophageal position changes between the beginning and end of the surgery ($p = 0.251$, $p = 0.558$, $p = 0.824$ for the upper, middle, and lower measurement levels, respectively). In 79.1% of patients, the maximum lateral displacement of the esophagus did not exceed 3 mm; in 20.9% of patients, the maximum displacement was greater than 3 mm. The most significant displacement of the esophageal shadow was 5.3 mm.

At the beginning of surgery, the width of the contrasted esophageal lumen was 18.2±4.1 mm at the upper level, 19.3±4.5 mm at the middle level, and 16.2±2.1 mm at the lower level. At repeated esophagography, the width of the contrasted esophageal lumen at the upper level was 18.4±4.2 mm, at the middle level 19.5±4.1 mm, at the lower level 16.1±2.3 mm and was not significantly statistically different from the values obtained at the first measurement (Table 3). The maximum change in the width of the contrasted esophageal lumen was 5.5 mm. No cases of vomiting or aspiration have been noted.

DISCUSSION

The data on esophageal location obtained in the study coincide with the literature, which indicates that central and left-sided location is the most frequent [8]. The position of the esophagus relative to the LA may vary [14]. Z.Stárek et al. showed in their study that the esophagus can change its location within significant limits over a long period of time (20-30 days) [15]. Thus, it is not always possible to use data on esophageal position obtained at the outpatient stage during surgery. As noted above, several authors have reported that the esophagus may also experience a significant change in its location during PV RFA (based on the results of esophagography with barium paste as a contrast agent) [6, 7]. Thus, the authors concluded that due to esophageal mobility, esophagography during PV RFA does not provide reliable information about esophageal position throughout the procedure.

The standard barium suspension has good adhesive properties and its progression through the esophagus is ensured by peristalsis. Water-soluble contrast agents in esophagography create a less intense shadow, pass through the esophagus faster, have fewer adhesive properties due to their fluidity. However, there were no differences in the degree of filling of the esophageal lumen compared to barium sulfate; on the contrary, the use of water-soluble contrast agent allowed to reveal anatomical features of the esophageal structure that were not visible when barium sulfate was used [16]. Our results indi-

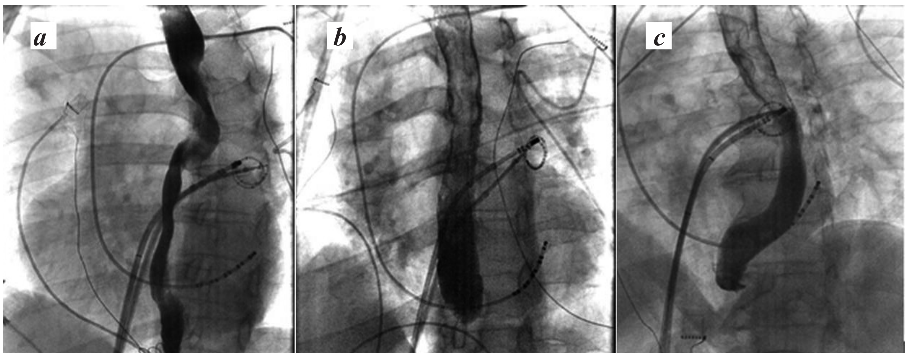

Fig. 3. Variants of esophagus location relative to the spine shadow: a) right-sided, b) central, c) left-sided.

cated that the position of the esophagus remains relatively stable, with patients showing no significant changes in its position during the surgical intervention. The discrepancy with the findings of previous studies may be attributed to the use of barium paste as a contrast agent, which has a thicker consistency compared to the water-soluble contrast agents used in our study. Therefore, barium paste may have caused more active esophageal peristalsis, which contributed to the change in esophageal location.

Thermal injury of the esophagus during PV RFA according to the OPERA study occurs with an incidence of up to 10% [17]. This complication occurs when the zone of tissue heating during RFA on the posterior wall of the LA captures extracardiac structures, including the esophagus, and is a prerequisite for atrial-esophageal fistula [4].

There are several techniques to reduce the risk of thermal injury to the esophagus during PV RFA. Measurement of esophageal lumen temperature during PV RFA is a widely used method to minimize thermal injury [10]. However, there are several studies that question the effectiveness of this technique [18], and moreover, the presence of a foreign body in the esophageal lumen itself may increase the risk of thermal injury [19]. In addition, in most cases, the esophageal transducer requires general anesthesia, but its use under medication sedation is also possible [20]. Changing the position of the esophagus during PV RFA using special devices [21] or a transducer for transesophageal ultrasound [22] can minimize the risks of thermal injury. However, these techniques are invasive and require general anesthesia. There are techniques for cooling the esophagus during ablation [23], but they have the same disadvantages - invasiveness and the need for general anesthesia.

Table 2.

Main characteristics of the performed operations (n=191)

Procedure time, min	98.9±26.4
Time between esophagographies, min	88.9±20.0
Fluoroscopy time, s	131.0±90.7
Radiofrequency ablation time, min	18.0±7.0

Table 3.

Width of the contrasted esophageal lumen at the beginning and end of surgery

Measurement level	Start	End	P
Upper (mm)	18.2±4.1	18.4±4.2	0.162
Medium (mm)	19.3±4.5	19.5±4.1	0.435
Bottom (mm)	16.2±2.1	16.1±2.3	0.766

Esophageal imaging techniques include intracardiac ultrasound, computed tomography combined with nephluoroscopic mapping systems, and esophagography. Intracardiac ultrasound is considered to be one of the useful tools because of the real-time assessment of esophageal location, but it is quite expensive, besides requiring separate vascular access [24]. Computed tomography can accurately determine the position of the esophagus relative to the posterior wall of the LA [25]. Modern nephluoroscopic mapping systems have the capability to integrate the acquired image into the LA map constructed during surgery. However, this method requires additional time and increases the radiation exposure of the patient.

Esophagography using water-soluble contrast agent is a simple way to obtain information about the location of the esophagus, which does not require special material and time costs. As shown in our study, the esophagus does not experience more than a few millimeters of displacement during surgery. This displacement does not result in a change in esophageal location (e.g., from left-sided to right-sided) and, therefore, is not clinically significant. Thus, performing esophagography at the beginning of the operation provides information on the esophageal position, allowing us to avoid aggressive interventions in that area and thereby reduce the risk of thermal damage.

Limitations of the study

The limitations of our study are that during esophagography we only see the esophageal lumen but cannot assess the thickness of the esophageal wall.

CONCLUSION

According to esophagography with water-soluble contrast, the esophagus does not experience clinically significant displacement during PV RFA.

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