Evaluation of Variants and Anomalies of Thoracic Systemic and Coronary Venous System Using Multi-Detector Computed Tomographic Angiography

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ABSTRACT

Background: Multidetector computed tomography (MDCT) coronary angiography is currently considered the ideal tool to three-dimensionally delineate the thoracic venous system, including Superior Vena Cava (SVC), Inferior Vena Cava (IVC), and Coronary Venous System (CVS). Knowledge of systemic venous variants and anomalies prior to surgical or interventional procedures is important to safely perform the procedure.
Aim: To assess the role of MDCT coronary angiography with multi-planar reformation (MPR) and three-dimensional (3D) reconstruction in depicting the variants and anomalies of the thoracic and coronary venous systems before electrophysiological or surgical interventions.
Method: The study was done in the period from June 2019 to February 2020 in Zagazig university hospitals. Sixty patients were enrolled (60% males and 40% females; mean age: 55.87±12.02 years, range: 26–71 years) who had MDCT coronary angiography using a 128-slice MDCT scanner (Ingenuity Phillips health care, best Netherlands).
Results: In our study, Coronary Sinus (CS), Anterior Interventricular Vein (AIV), Middle Cardiac Vein (MCV), and Great Cardiac Vein (GCV) were detected in all cases (100%). Posterior Vein of the Left Ventricle (PVLV) was seen in 96.7% of patients. Thebesian valve was depicted in (73%). Coronary venous system variants represent 20% of cases in the form of (double MCV variants represent 10%, MCV aneurysm represents 3%, and double PVLV variant represents 3.45%). At the same time, thoracic systemic venous abnormalities represent 50% of cases in the form of (interruption of IVC with azygos/hemiazygos continuation about 8.3%, IVC thrombosis about 5.0%, persistent left SVC about 16.7%, SVC thrombosis about 11.7% and SVC attenuation about 8.3%).
Conclusion: This study showed that MDCT coronary angiography is a non-invasive imaging modality in depicting the variants and anomalies of the thoracic systemic and coronary venous system before electrophysiological or surgical interventions.

Keywords: Coronary venous system, MDCT coronary angiography, Thebesian valve,

Superior Vena Cava, Inferior Vena Cava

1. Introduction

Anomalies as well as variants of thoracic systemic venous return are highly diverse congenital abnormalities ranging from completely normal physiology to severe types of right to left shunting requiring surgical correction [1].

Systemic thoracic vein congenital abnormalities are asymptomatic. Imaging modalities ranging from ultrasound (US) to magnetic resonance imaging (MRI) are regularly employed for the positive diagnosis of congenital abnormalities, making it critical to be familiar with their variety of results [2].

Understanding the architecture of the coronary venous drainage system anatomy is critical due to its significance in electrophysiologic procedures as well as cardiac surgery. Numerous procedures, including mapping, left ventricular pacing, arrhythmia ablation, targeted drug delivery, retrograde cardioplegia, and stem cell therapy, utilise the coronary venous system (CVS). As a consequence, it is more critical for clinicians to analyze the findings of coronary computed tomographic (CT) exam in order to determine the anatomy and normal variants of CVS [3].

Investigations of the thoracic and coronary venous system are overshadowed by the numerous studies of the coronary arteries. This is especially true for coronary multidetector computed tomographic (MDCT) venous mapping [4]. Images can be accurately, rapidly, and thoroughly interpreted due to the ability of this technique to capture fine axial images and use multi-planar reconstructions, interactive maximum intensity projection images, and volume rendering techniques [5, 6].

2. Patients and Method

2.1. Patients

This study was carried out at the Radio-diagnosis department, Zagazig University Hospital. A total number of 60 patients were scheduled for elective multidetector CT coronary angiography in the period from June 2019 to February 2020. They were 36 males (60%) and 24 females (40%), their age ranged from 26 to 71 years (mean age= 55.87 years ±12.02). A physician referred the patients for suspicion of having coronary artery disease. We retrospectively evaluated them for the thoracic systemic and coronary venous system. Our patients can be silent or have associated cardiac anomalies resulting in cardiovascular or respiratory problems.

2.1.1. Patient Inclusion Criteria:

Our study included patients who performed chest or coronary CT angiography, patients with suspected coronary heart disease, patients with thoracic venous variants or abnormalities either accidentally discovered or suspected at echocardiography, and patients prepared for cardiac resynchronization therapy; of adult age group and including both sexes.

2.1.2. Patient Exclusion Criteria:

Exclusion criteria of patients were either absolute contraindications (Patients with elevated renal functions (Creatinine level ≥ 2 mg/dl) but not on dialysis, contraindications to contrast media, Pregnancy, morbid obesity) or relative contraindications (renal diseases on dialysis, hemodynamic instability, patients with irregular heart rate, inability to maintain adequate inspiratory breath-hold during the scan).

Full history was taken. Revision of previous laboratory and other cardiac investigations was done prior to MDCT examination. Written informed consent was obtained from all participants; the study was approved by the research ethics committee of the Faculty of Medicine, Zagazig University, and the study was done according to the code of ethics of the world medical association (Declaration of Helsinki) for studies involving humans.

2.1.3. Patient preparation

The patient was asked to fast for 4 hours before the examination. Heart rate was controlled to be kept about 65 beats per minute (Beta-blockers administration one day before examination). Respiration training was done to hold breath for 12 seconds. Then IV route was applied in a right antecubital vein in adults and followed by proper positioning of ECG leads for simultaneous acquisition of both the patient's ECG tracing and the CT data.

2.2. Image acquisition

A retrospective ECG gated CTA technique was achieved during single breath-hold using 128 multidetectors (Ingenuity Phillips health care, best Netherlands) scanner as follows: Scanogram, after that contrast media is given using bolus tracing technique (70-80ml of non-ionic CM injected with a flow rate of 5-6 ml /sec injected via dual-head Medrad stellant power injector pump together with (50ml) saline chaser bolus to washout contrast medium from right side of the heart). Image acquisition started when the contrast threshold reaches 180 with ROI at descending aorta, from carina till 1cm below the diaphragm.

2.3. Postprocedural evaluation of patient

The patient is kept under observation after the procedure for 15 minutes to assess the vital signs (pulse and blood pressure).

2.4. Image reconstruction and interpretation

Cases were evaluated and analyzed on an advanced Philips work station using axial images (as source images), reconstructed images like maximum Intensity Projection (MIP), MPR (curved and oblique), and volume rendering techniques.

2.5. Statistical analysis

Data were collected, coded, entered, and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 23.0) software for analysis. Qualitative data were represented as numbers and percentages, and quantitative data were represented by mean ± SD.

3. Results

3.1. The Percentage of Presence of main coronary veins and Thebesian Valve

The CS is the most persistent part of the coronary venous system and was depicted in all cases. Anterior interventricular Vein (AIV), Middle Cardiac Vein (MCV), and Great Cardiac Vein (GCV) and were detected in all cases. Posterior Vein of the Left Ventricle (PVLV) was seen in 96.7% of patients. 2nd PVLV was noticed in 20 % of patients. Left Marginal Vein (LMV) was detected in 73.3% of patients. Small Cardiac Vein (SCV) was found in 13.3% of patients. Thebesian valve was depicted in 73% of patients (Table 1) (Figure 1).

Table 1. The Percentage of the presence of main coronary veins and Thebesian Valve.

Coronary veins	No of cases	Frequency of presence (%)
Coronary sinus	60	100
Anterior inter-ventricular vein	60	100
Middle cardiac vein	60	100
Great cardiac vein	60	100
Posterior vein of the left ventricle	58	96.7
2nd PVLV	12	20
Left marginal vein	44	73.7
Small cardiac vein	8	13.3
Thebesian Valve	44	73

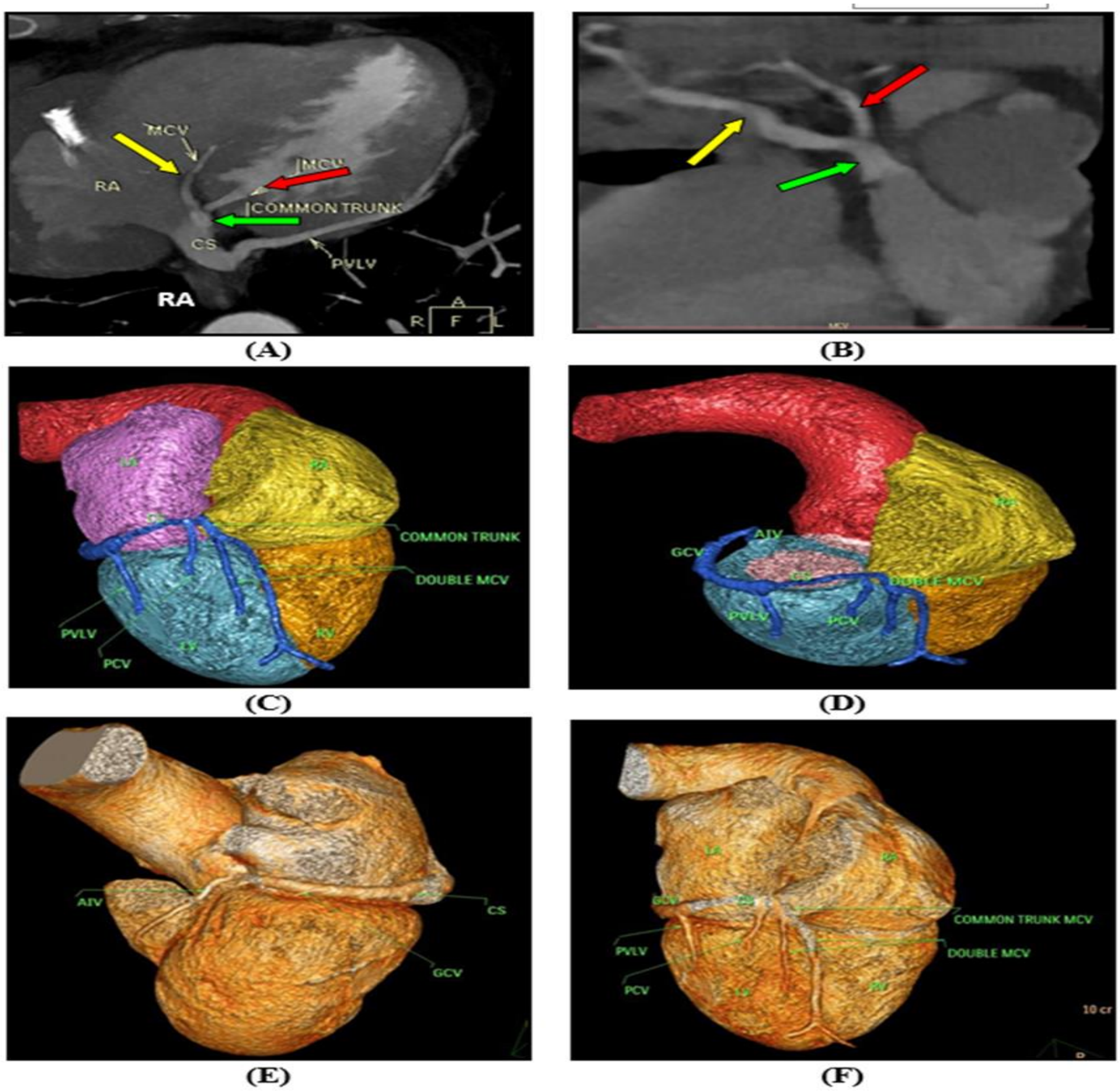

Figure 1. 55-year-old male patient with double MCV variant. **(A)** Curved MPR image and **(B)** Axial MIP image shows double middle cardiac vein (MCV) **(red and yellow arrows)** are parallel, running along the posterior interventricular groove forming a common trunk **(green arrow)** before draining into the CS **(C) and (D)** 3D volume rendering images show Double MCV. **(E) and (F)** 3D volume rendering images show coronary venous drainage system including **(E):** AIV (anterior interventricular vein) then continues as GCV (great cardiac vein) which passes backward to end as CS (coronary sinus), **(F):** showing PVLV (posterior vein of the left ventricle), PCV (posterior cardiac vein) and double MCV.

3.2. Percentage of coronary veins variants

Coronary venous system variants represent (20%) of cases. MCV had six double variants among 60 subjects (10%) and two aneurysms (3%). PVLV had two double variants among 58 subjects (3.45%). No target vein (PVLV) variant in 2 case among 60 subjects (0.33%) (Table 2) (Figure 1).

Table 2. Percentage of coronary veins variants

Coronary vein variant	No. (60)	%
MVC	6 double	10
	2 aneurysms	3
PVLV	2 double	3.45
No PVLV	2	0.33

3.3. Frequency distribution of superior vena cava abnormalities

SVC abnormalities represent (36.7%) of cases. Persistent left SVC is the most common, representing (16.7%) then SVC thrombosis, which was (11.7%) then SVC attenuation with a Percentage of (8.3%) among the studied group (Table 3) (Figure 2).

Table 3. Frequency distribution of superior vena cava abnormalities

Superior vena cava Variants and abnormalities	No. (60)	%
Persistent left superior vena cava	10	16.7
Superior vena cava thrombosis	7	11.7
Superior vena cava attenuation	5	8.3

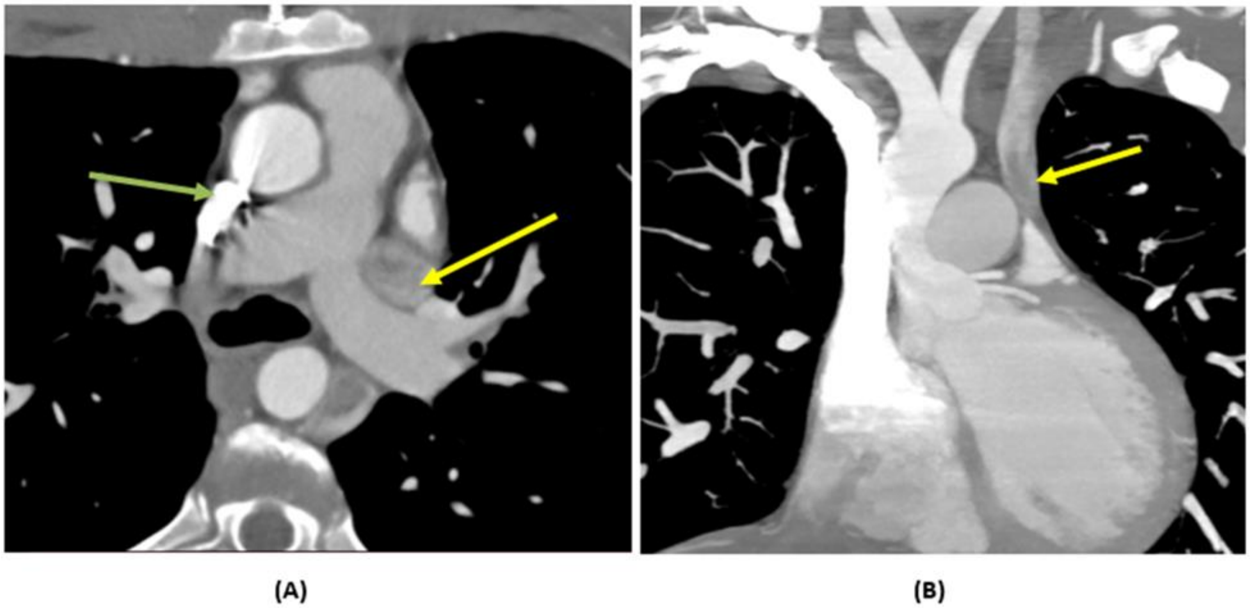

Figure 2. 28 years old male patient with double superior vena cava. **(A)** axial CT image showing right superior vena cava **(green arrow)** and left superior vena cava **(yellow arrow). (B)** coronal CT image showing the left persistent SVC **(yellow arrow)**.

3.4. Frequency distribution of inferior vena cava abnormalities

IVC abnormalities represent (13.3%) of cases. Interruption of IVC with azygos/hemiazygos continuation was the most common IVC venous abnormality (8.3%), followed by IVC thrombosis (5.0%) (Table 4) (Figure 3).

Table 4. Frequency distribution of inferior vena cava abnormalities

Inferior vena cava Variants and abnormalities	No. (60)	%
Inferior vena cava interruption with azygos/hemiazygos continuation	5	8.3
Inferior vena cava thrombosis	3	5.0

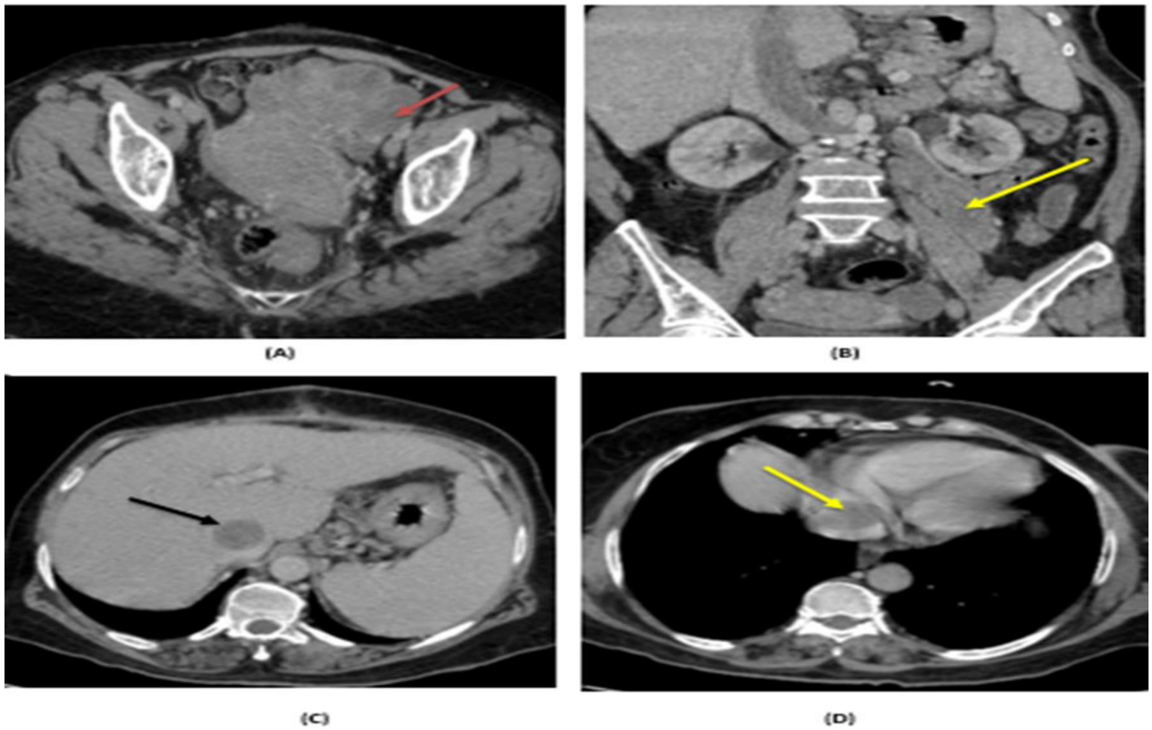

Figure 3. 50 years old female patient with left ovarian malignant mass with left gonadal and IVC thrombosis. **(A)** Axial CT image showing left heterogenous adnexal mass **(Red arrow)** invading uterus. **(B)** Coronal CT image showing left gonadal vein thrombosis **(yellow arrow)**. **(C)** Axial CT image showing thrombosis of hepatic portion IVC (black arrow). (E) Axial CT image showing thrombosis of the thoracic portion of IVC **(yellow arrow)**.

4. Discussion

The congenital abnormalities of the superior and inferior vena cava must be accurately recognised by radiologists, despite the fact that they are generally asymptomatic. When an anomalous venous map is present, this can help to minimise misunderstanding of unexpected imaging results and to ensure proper planning before interventional and surgical procedures [2].

Recently, a major focus has been on the cornary venous system (CVS), that has been overshadowed by multiple coronary arteries research. Comprehensive and detailed information of coronary veins anatomy and variants are required in recent cardiac intervention processes, thereby illustrating the increasing significance of imaging the CVS [7].

The gold standard technique for describing coronary venous anatomy has been retrograde cardiac venography; however it is aggressive, technically complex, and cannot describe the relations between coronary veins and arteries [8].

In Our study, the tributaries of the coronary venous system were identified on axial images, and volume-rendered reconstructions and their presence was evaluated. We found that CS, AIV, MCV, and GCV were noted in all cases (100%).

The PVLV was seen in (96.7%) of cases. 2nd PVLV was visualized in (20%) of cases. The LMV was depicted in (73.7%) of cases. The SCV was found in (13.3%) of cases. Related findings were obtained by the study of Sun et al. [8], who reported that CS, AIV, MCV, and GCV were seen in all cases (100%). The PVLV was noted in (77.5%) of cases. 2nd PVLV was visualized in (12.7%) of cases. The LMV was detected in (66.7%) of cases. The SCV was visualized in (27.5%) of cases. As well as close to Malago et al. [9], who found that CS, AIV, MCV, and GCV were visualized in all cases (100%) The PVLV was visualized in (82%) of cases. The LMV was visualized in (84%) of cases. The SCV was visualized in (18.9%) of cases.

We found it was possible to evaluate at least one main vein with the adequate caliber and regular course running on the postero-lateral wall of the left ventricle in 96.7% of the cases, and two cases had no target veins. In agreement with Sun et al. [8], who found that it was possible to evaluate at least one target vein along the postero-lateral wall of the left ventricle in 96.1% of the cases.

By shedding light on thebesian valve; in our study, it was noticed in (73%) of patients; this is in agreement with previous studies of Genc et al. [10] and Malago et al. [9] and who stated that the Thebesian valve was present in (72.2%) and (77%) of patients respectively.

Illuminating anatomical variants of the cardiac venous system, our study (conducted over 60 patients showed a little bit higher Percentage of cardiac veins anatomic variants) in which 6 cases (10%) had double middle cardiac vein variants with a common trunk which drains into CS on the other hand, **Genc et al. [10]** (Conducted study over 357 patients on 128- MSCT) had found double middle cardiac vein was present in 9 cases (2.6%) of cases. Malago et al. [9] (Conducted study over 301 patients on 64- MSCT) had stated that 6 cases (1.99%) of cases had double-MCV.

Also, we found 2 cases (3%) with middle cardiac vein aneurysm at its proximal part near its drainage into the coronary sinus and this with minor agreement with Genc et al. [10] (Conducted study over 357 patients on 128- MSCT) who found 2 cases (0.58%) with an aneurysm at the proximal part of MCV.

Regarding PVLV, we found 2 cases from 58 cases (3.45%) with double PVLV vein which united together proximally, form a common trunk, and drained into CS A related findings reached by Malago et al. [9] (Conducted study over 301 patients on 64- MSCT) who found 8 cases (2.65%) with double PVLV.

Regarding the systemic venous system, we found that persistent left SVC is the most common , representing 16.7%, then SVC thrombosis with (11.7%) then SVC attenuation, which was (8.3%) among the studied group. We agree with Elfiky et al. [11], who found that persistent left SVC is the most common anomaly of thoracic venous anomalies.

In our study, the prevalence of SVC thrombosis was 11.7 %, which disagreed with Pech-Alonso et al. [12], who stated that Superior vena cava syndrome is a rare disease and that malignant intrathoracic tumors are its common cause. This disagreement is attributed to different sample sizes.

We found that interruption of inferior vena cava with azygos/hemiazygos continuation was the most common inferior vena cava abnormality representing (8.3%) followed by inferior vena cava thrombosis, which was (5.0%). We relatively agree with vijayvergiya et al. [13], who stated that infrahepatic IVC interruption with azygos/hemiazygos continuation is a rare congenital anomaly. On the other side, Elfiky et al. [11] reported that the Percentage of

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azygos/hemiazygos continuation reaches 23.5 % of the studied population. This conflict is because they had a larger sample size.

Regarding inferior vena cava thrombosis, we found that IVC thrombosis represents only 5 % of the studied group. We agree with McAree et al. [14], who reported in their study that despite the neoplastic association with IVC, thrombosis of inferior vena cava remains rare and is found in only 0.07% of hospitalized patients with neoplasms.

5. Limitations

There were some limitations to the study. First, a small sample size thus requires confirmation by involving a larger sample size. Second, use of a sub-optimal protocol for thoracic and coronary veins (retrospective evaluation in patients with suspected CAD).

6. Conclusion and Recommendations

In conclusion, MDCT coronary angiography is an excellent non-invasive modality that can provide a detailed assessment of the thoracic and coronary veins even in non-targeted studies. Also, it provides a preliminary assessment of the thoracic and coronary venous anatomy before catheterization and lead placement.

We recommend using coronary CTA as a routine preliminary investigation for delineation of thoracic and coronary venous anatomy in all patients targeted to undergo surgery or intervention such as radiofrequency ablation of AF and cardiac resynchronization therapy.

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