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The incidence of left atrial diverticula in coronary CT angiography

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PURPOSE
The aim of this study was to characterize the frequency and location of left atrial diverticula by using multidetector computed tomography (MDCT).

MATERIALS AND METHODS
Cardiac imaging was performed for 454 patients using 64-MDCT. Most patients were being examined for coronary artery disease. All images were interpreted by two radiologists on a three-dimensional workstation using multiplanar reformatting, maximum intensity projection, and volume-rendering. Diverticula were characterized by localization and diameter.

RESULTS
A total of 207 atrial diverticula were diagnosed in 186 (41%) of the 454 patients in this study. The diameters of left atrial diverticula ranged from 2 mm to 16 mm, with an average diameter of 5.2 mm. Left atrial diverticula were located anterosuperiorly in 166 patients (36.6%), anteriorly in four patients (0.9%), anteroinferiorly in three patients (0.7%), inferolaterally in one patient (0.2%), inferomedially in two patients (0.4%), laterally in two patients (0.4%), posterosuperiorly in one patient (0.2%), and superiorly in seven patients (1.5%).

CONCLUSION
Left atrial diverticula are frequently detected during routine cardiac computed tomography angiography examinations.

Key words: • *angiocardiography* • *multidetector computed tomography* • *left atrium* • *diverticula*

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Cardiac multidetector computed tomography (MDCT) can produce high-resolution images and depict anatomical structures in detail; thus, it can successfully and rapidly display cardiac anatomy and morphology (1, 2). Recently, MDCT has been used more frequently to evaluate coronary artery disease (3).

Routine evaluation by coronary computed tomography (CT) angiography (CTA) has revealed the existence of sac-like structures in the left atrium. These left atrial diverticula are cyst-shaped protuberances that project outward from the heart cavity and are composed of only a muscle layer (4). Excluding known anatomical variations of the left atrium, atrial diverticula have not been thoroughly examined. Few studies have investigated left atrial diverticula, and these are mainly rare variations identified under pathological conditions (5). Although left atrial diverticula are generally asymptomatic, they may be associated with arrhythmias, thromboembolism, or mitral valve regurgitation (6).

In the present retrospective study, we used images from patients who had previously undergone coronary artery evaluation by cardiac CT. We determined the frequency of diverticula and their location.

Materials and methods

Between August 2008 and April 2011, cardiac imaging using 64-MDCT was performed for 454 patients (322 males [70.9%] and 132 females [29.1%]). The mean age of patients was 56 years (range, 20–86 years). Most of the patients (416/454) were examined for coronary artery disease. Other patients were evaluated for a coronary bypass graft/stent (37 patients) or an ascending aortic stent (one patient).

All CT examinations were performed using 64-section scanners (Brilliance-64, Philips Medical Systems, Eindhoven, Netherlands). A bolus of 80–120 mL of an iodine contrast agent, either iomeprol (Iomeron 400, Bracco, Milano, Italy) or iohexol (Omnipaque 350, GE Healthcare Ireland, Cork, Ireland), was injected into an antecubital vein through an 18–20 gauge catheter, followed by 50 mL of saline solution at a flow rate of 6 mL/s using an automated power injector (Medrad Envision CT, Pittsburg, Pennsylvania, USA). A beta-blocker (5–20 mg, Beloc ampule 5 mg/mL, AstraZeneca, İstanbul, Turkey) was administered intravenously before CTA in patients with a heart rate higher than 70 beats per minute. This retrospective study was approved by the instutitional ethics committee.

Images were reconstructed at 35%–85% of the cardiac cycle in increments of 5%. All images were interpreted by two radiologists on a three-dimensional workstation (EBW, Philips Medical Systems, Eindhoven, Netherlands) using multiplanar reformatting, maximum intensity projection, and volume rendering (Fig. 1).

During evaluation of the left atrium, diverticula were defined as sac-like structures with broad-based ostia that projected outward from

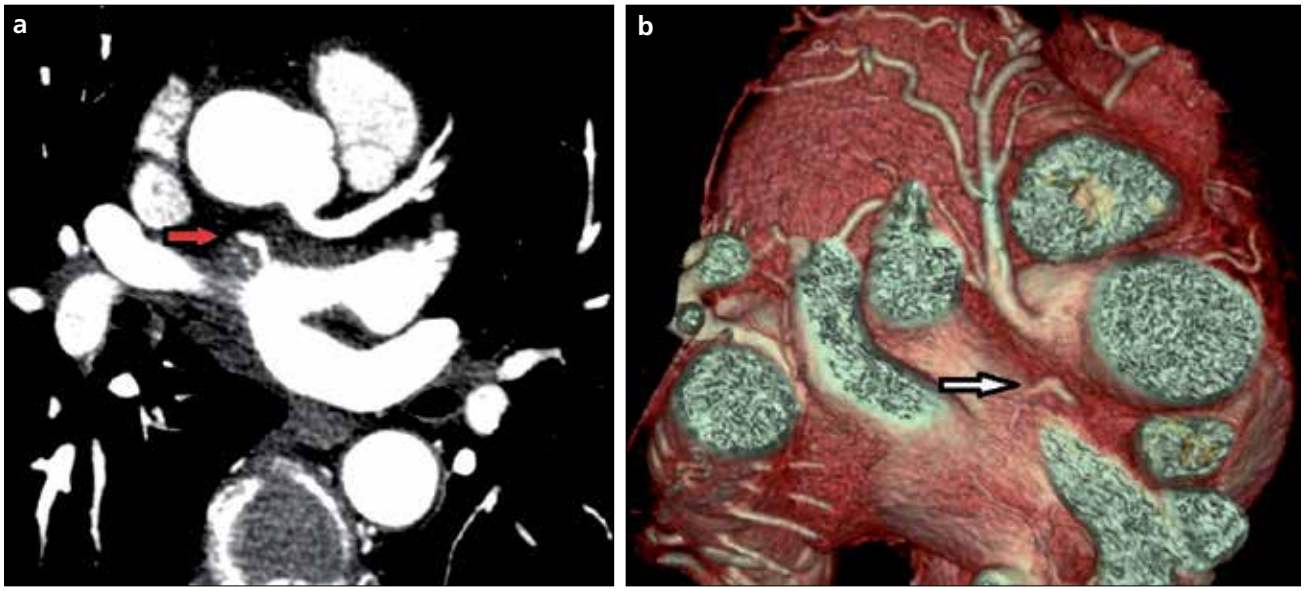

Figure 1. a, b. Axial CT image **(a)** and three-dimensional reconstruction **(b)** demonstrate a lobulated atrial diverticulum (*arrows*).

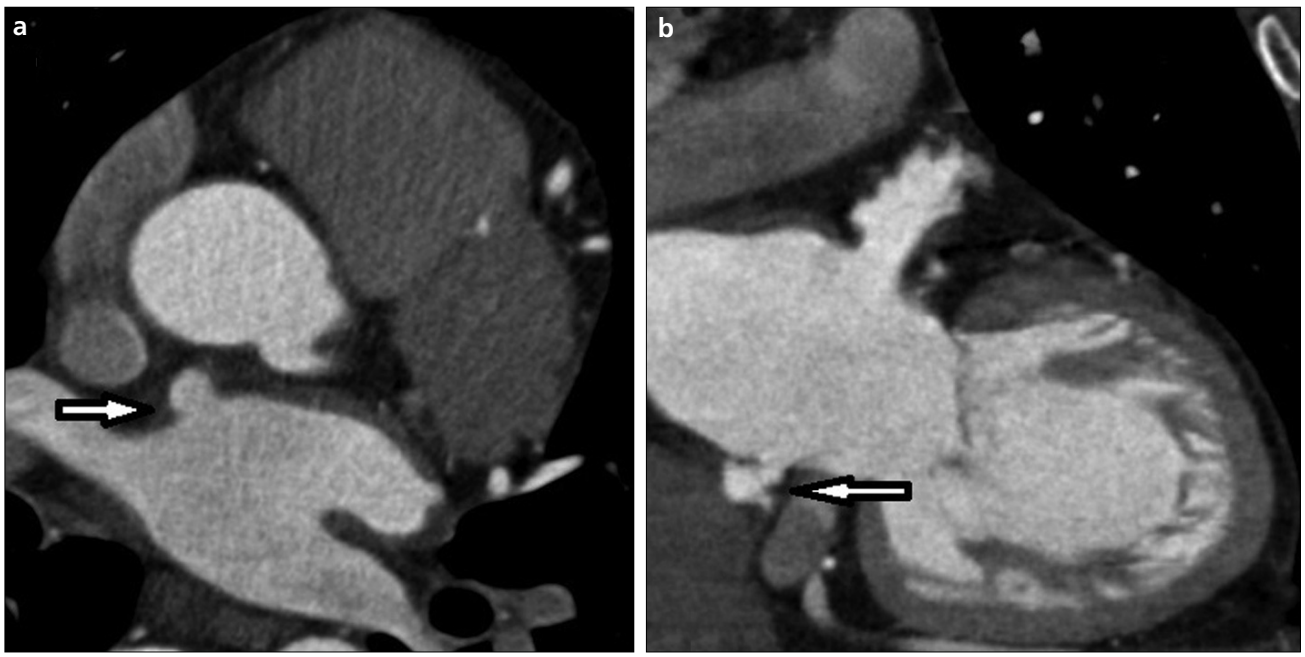

Figure 2. a, b. Typical appearance of atrial diverticula and accessory appendages in different patients. CT image **(a)** shows an atrial diverticulum with a broad base and smooth contour (*arrow*). CT image **(b)** demonstrates an accessory appendage with an irregular contour and a narrow ostium (*arrow*).

the contour of the heart (Fig. 2a). For each diverticulum, the widest diameter parallel to the ostium was measured. Sac-like structures with irregular contours that resembled the pectinate muscle and had narrower ostia were considered to be accessory appendages (5) (Fig. 2b). The locations of atrial diverticula were classified as follows: anterosuperiorly, anteriorly, anteroinferiorly, inferolaterally, inferomedially, laterally, posterosuperiorly, and superiorly.

All statistical analyses were performed using a commercially available software (Statistical Package for Social Sciences, version 15, SPSS Inc., Chicago, Illinois, USA). The relationships between left atrial diverticula and the age and gender of patients were evaluated using Spearman's correlation test. Statistical significance was set at $P < 0.005$.

Results

In 186 (41%) of the 454 patients, 207 left atrial diverticula were identified. In 268 cases (59%), no left atrial diverticula were observed. In 140 of the 322 male patients, 155 diverticula were seen; in 46 of the 132 female patients, 52 left atrial diverticula were observed. No statistically significant relationship was found between gender and the prevalence of left atrial diverticula ($P = 0.009$). Moreover, no statistically significant relationship was observed between age and the prevalence of left atrial diverticula ($P = 0.009$). The diameters of left atrial diverticula ranged

from 2 mm to 16 mm with a mean of 5.2 mm.

Left atrial diverticula were located anterosuperiorly in 166 patients (36.6%), anteriorly in four patients (0.9%), anteroinferiorly in three patients (0.7%), inferolaterally in one patient (0.2%), inferomedially in two patients (0.4%), laterally in two patients (0.4%), posterosuperiorly in one patient (0.2%), and superiorly in seven patients (1.5%) (Table 1).

Left accessory appendages were detected in 14 patients; in six of these cases, a left accessory appendage was observed together with atrial diverticula. Accessory appendages were located inferolaterally in six patients (42.8%), superolaterally in four patients (28.5%), inferomedially in three patients (21.4%), and laterally in one patient (7.1%).

Thrombi were not detected in any of the atrial diverticula or accessory appendages.

Discussion

In the current study, we used MDCT to determine the frequency of left atrial diverticula and their locations. Left atrial diverticula are cyst-like projections that do not usually occur along with other cardiac abnormalities (5). Contrary to previous reports, left atrial diverticula are not uncommon and are frequently observed in routine cardiac imaging performed by MDCT.

In the present study, the frequency of left atrial diverticula was 41%. Accessory atrial appendages, which cause irregularities in the left atrium wall, were not included in this ratio. Abbara et al. (5) reported a frequency of left atrial diverticula of 19% (104/529), with a higher incidence in male patients (19%) than in female patients (7%). In contrast, our study detected no difference in the frequency of left atrial diverticula between male and female patients. Wan et al. (4) reported a left atrial diverticulum frequency of 16% (27 diverticula in 120 patients), and Poh et al. (7) found a frequency of 28% (14 diverticula in 50 patients). Conversely, Troupis et al. (8) observed that the frequency of left atrial diverticula was 40% in cases with atrial fibrillation and 36% in cases with sinus rhythm. The latter data are consistent with the findings of our study (Table 2). Shin et al. (6) reported an 18.3% incidence of left atrial diverticula in a large series.

The locations of the atrial diverticula varied, but they occurred most frequently at the anterosuperior part of the atrium (Fig. 3). Similar results were obtained in previous studies. Although Wan et al. (4) generally detected atrial diverticula anteriorly, they reported multiple and posterior atrial diverticula more frequently in females. In our study, however, we did not identify a significant relationship between the location of diverticula and gender.

Duerinckx et al. (9) reported a 10% frequency of accessory appendages, and Abbara et al. (5) reported a frequency of 8%. Troupis et al. (8) observed accessory appendages in 8.5% of

Table 1. Frequencies of atrial diverticula and accessory appendages with respect to anatomical localization

Localization	Atrial diverticulum n (%)	Atrial accessory appendage n (%)
Anterosuperior	166 (36.6)	-
Anterior	4 (0.9)	-
Anteroinferior	3 (0.7)	-
Inferolateral	1 (0.2)	6 (42.8)
Inferomedial	2 (0.4)	3 (21.4)
Lateral	2 (0.4)	1 (7.1)
Posterosuperior	1 (0.2)	-
Superior	7 (1.5)	-
Superolateral	-	4 (28.5)

Table 2. Review of the literature

Study	Number of patients	Rate of diverticula	Mean diameter of diverticula	Dominant localization of diverticula	Gender distribution	Imaging technique (MDCT)
Poh et al. 2008 (10)	50	14/50 (28%)	Not reported	Anterosuperior aspect of the left atrial roof	Not reported	Sensation 64, Siemens Aquilion 64, Toshiba
Wan et al. 2009 (4)	120	20/120 (16%)	5 mm	Anterior wall of left atrium	No difference	LightSpeed 16, GE
Abbara et al. 2009 (5)	529	104/529 (19%)	6.4 mm	Anterosuperior	More common in males	Sensation 64, Siemens
Shin et al. 2011 (6)	2059	532/2059 (18.3%)	4.7 mm	Right side of the upper left atrial wall	216 males 161 females	Brilliance 64, Philips
Troupis et al. 2011 (7)	47 AF 47 sinus rhythm	19/47 (40%) in AF 17/47 (36%) in sinus rhythm	6.9 mm in AF 12 mm in sinus rhythm	Anterosuperior	No difference	Aquilion 320, Toshiba
Present study	454	186/454 (41%)	5.2 mm	Anterosuperior	No difference	Brilliance 64, Philips

AF, atrial fibrillation; MDCT, multidetector computed tomography.

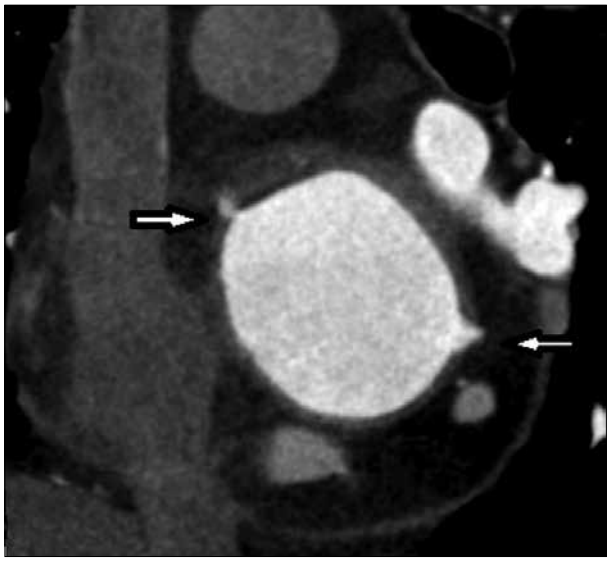

Figure 3. CT image shows two diverticula *(arrows)*, with anterosuperior and lateral localizations, in the same patient.

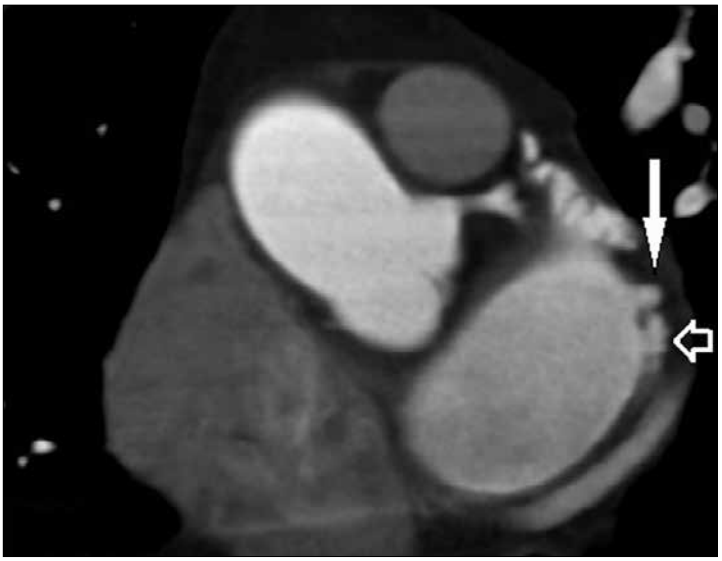

Figure 4. CT image demonstrates atrial diverticula (*long arrow*) and an accessory appendage *(short arrow*) in the same patient.

cases with atrial fibrillation and in 10% of cases with sinus rhythm. In contrast to previous studies, the present study found the frequency of accessory appendage to be 3%. Left diverticula may be difficult to distinguish from accessory appendages because some lesions may have characteristics of both diverticula and accessory appendages (7) (Fig. 4). Left atrial diverticula were most frequently located anterosuperiorly. However, a localization tendency was not identified for accessory appendages.

The physiopathology of atrial diverticula is not sufficiently understood. Wan et al. (4) suggested that atrial diverticula visible by coronary angiography are acquired conditions. Under conditions of other diseases, atrial muscles become weak over time; upon arterial occlusion, the atrial wall projects outward. Poh et al. (7) suggested that endocardial irregularities and vesicles located on the atrial roof result from incomplete development of accessory pulmonary veins, or because they are superiorly located, from incomplete regression of cardinal veins. In one case, a left atrial diverticulum was diagnosed in a 68-year-old female patient with mitral insufficiency; six months after surgical repair of the mitral valve, the atrial diverticulum had disappeared (10). Killeen et al. (11) reported that atrial diverticula are continuous with the myocardial wall and fascia; as such, they may generate electrical activity, causing atrial arrhythmia.

Atrial diverticula are usually asymptomatic structures and are incidentally diagnosed during cardiac MDCT angiography at a considerable frequency (16%–41%). The etiology of left atrial diverticula is unclear. Hemodynamic disorders that create the appropriate environment for development of acquired diverticula do not exist in the majority of patients. Therefore, it is more likely that diverticula have a congenital background.

Although generally asymptomatic, diverticula have been reported to coexist with atrial fibrillation. Smooth and communicating diverticula are suggested to create a potential "loop" to trigger a transmission disorder (8, 9, 11, 12). As coronary CTA is problematic in patients with disordered cardiac rhythms such as atrial fibrillation (13), these patients were excluded from our study, and thus the relationship between atrial fibrillation and the frequency of atrial diverticula could not be evaluated. In a recent study, Troupis et al. (8) examined 47 patients with atrial fibrillation and 47 patients with sinus rhythm using 320 detectors, and demonstrated that the frequency of atrial diverticula did not differ between these two groups of patients. The frequency of diverticula was similar between our study, which excluded cases of atrial fibrillation, and the study by Troupis et al. (8), which included cases of atrial fibrillation (41% and 40%, respectively). This may indicate that diverticula are independent of atrial fibrillation in etiology.

Although the number of previous studies on left atrial diverticula is limited, the ability to perform cardiac imaging has been improved by MDCT (14, 15). In contrast to earlier reports, the present results demonstrate a high frequency of atrial diverticula among the general population. However, the characteristics, coexisting pathologies, and clinical profiles of diverticula are not sufficiently understood. For studies performed *in vivo* by MDCT, it is difficult to determine pathological correlations.

The present study had some limitations. All cases were adult patients. Studies in children and infants may better elucidate the pathogenesis of atrial diverticula. Furthermore, most of the patients in the present study were examined for the coronary artery disease, which disrupts the homogeneity of the patient population. Cases with atrial fibrillation were excluded from the current study; thus, a relationship between atrial fibrillation and atrial diverticula could not be evaluated. Compared with other studies, our study identified a lower rate of left atrial accessory appendages. Importantly, small-diameter atrial accessory structures are difficult to differentiate from atrial diverticula, which might have caused confusion in some cases. Nevertheless, atrial diverticula and accessory appendages were detected in 44% of our patients. This is among the

highest reported frequencies of atrial diverticula. Finally, as mentioned above, as this was an *in vivo* study, it was not possible to determine pathological correlations.

As a conclusion, the field of cardiac imaging has been advanced by MDCT. The present study determined that left atrial diverticula are frequently detected during routine examinations using this technology. Specifically, the present study identified a left atrial diverticulum frequency of 41%. For this reason, we believe that accessory structures should be mentioned in cardiac imaging reports. Although diverticula appear to have negligible clinical importance, obtaining additional information will improve our understanding of their significance.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Turkvatan A, Akdur PO, Olcer T, Cumhur T. Coarctation of the aorta in adults: preoperative evaluation with multidetector CT angiography. Diagn Interv Radiol 2009; 15:269–274.
2. Vural M, Ucar O, Selvi NA, et al. Assessment of global left ventricular systolic function with multidetector CT and 2D echocardiography: a comparison between reconstructions of 1-mm and 2-mm slice thickness at multidetector CT. Diagn Interv Radiol 2010; 16:236–240.
3. Kosar P, Ergun E, Ozturk C, Kosar U. Anatomic variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance. Diagn Interv Radiol 2009; 15:275–283.
4. Wan Y, He Z, Zhang L, et al. The anatomical study of left atrium diverticulum by multi-detector row CT. Surg Radiol Anat 2009; 31:191–198.
5. Abbara S, Mundo-Sagardia JA, Hoffman U, Cury RC. Cardiac CT assessment of left atrial accessory appendages and diverticula. AJR Am J Roentgenol 2009; 193:807–812.
6. Shin SY, Kwon SH, Oh JH. Anatomical analysis of incidental left atrial diverticula in patients with suspected coronary artery disease using 64-channel multidetector CT. Clin Radiol 2011; 66:961–965.
7. Poh AC, Juraszek AL, Ersoy H, et al. Endocardial irregularities of the left atrial roof as seen on coronary CT angiography. Int J Cardiovasc Imaging 2008; 24:729–734.
8. Troupis J, Crossett M, Scneider-Kolsky M, Nandurkar D. Presence of accessory left atrial appendage/diverticula in a population with atrial fibrillation compared with those in sinus rhythm: a retrospective review. Int J Cardiovasc Imaging 2012; 28:375–380.
9. Duerinckx AJ, Vanovermeire O. Accessory appendages of the left atrium as seen during 64-slice coronary CT angiography. Int J Cardiovasc Imaging 2008; 24:215–221.
10. Terada H, Tanaka Y, Kashima K, Sannou K, Arima T. Left atrial diverticulum associated with severe mitral regurgitation. Jpn Circ J 2000; 64:474–476.
11. Killeen RP, Ryan R, MacErlane A, Martos R, Keane D, Dodd JD. Accessory left atrial diverticulae: contractile properties depicted with 64 slice cine cardiac CT. Int J Cardiovas Imaging 2009; 26:241–248.
12. Shah K, Walsh K. Giant right atrial diverticulum: an unusual cause of Wolf-Parkinson-White syndrome. Br Heart J 1992; 68:58–59.
13. Wang Y, Zhang Z, Kong L, et al. Dual-source CT coronary angiography in patients with atrial fibrillation: comparison with single-source CT. Eur J Radiol 2008; 68:434–441.
14. Lee WJ, Chen SJ, Wang TD. Multiple accessory left atrial appendages along a semicircular path. Eur Heart J 2008; 29:2447.
15. Balli O, Aytemir K, Karcaaltincaba M. Multidetector CT of left atrium. Eur J Radiol 2012; 81:e37–46.