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MRI-Based Stepwise Approach to Anterior Mediastinal Cystic Lesions for Diagnosis and Further Management

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As the majority of incidentally detected lesions in the anterior mediastinum is small nodules with soft tissue appearance, the differential diagnosis has typically included thymic neoplasm and prevascular lymph node, with benign cyst. Overestimation or misinterpretation of these lesions can lead to unnecessary surgery for ultimately benign conditions. Diagnosing mediastinal cysts using MRI serves as a problem-solving modality in distinguishing between surgical and nonsurgical anterior mediastinal lesions. The pitfalls of MRI evaluation for anterior mediastinal cystic lesions are as follows: first, we acknowledge the limitation of T2-weighted images for evaluating benign cystic lesions. Due to variable contents within benign cystic lesions, such as hemorrhage, T2 signal intensity may be variable. Second, owing to extensive necrosis and cystic changes, the T2 shine-through effect may be seen on diffusion-weighted images (DWI), and small solid portions might be missed on enhanced images. Therefore, both enhancement and DWI with apparent diffusion coefficient values should be considered. An algorithm will be suggested for the diagnostic evaluation of anterior mediastinal cystic lesions, and finally, a management strategy based on MRI features will be suggested.

Keywords: *Anterior mediastinum; Cystic mass; Thymic cyst; Thymic epithelial tumor; Mediastinal mass*

INTRODUCTION

With chest CT becoming widely popular in routine clinical practice and cancer screening, the detection of asymptomatic anterior mediastinal lesions has increased [1,2]. According to previous studies, the prevalence of incidental anterior mediastinal lesions range from 0.5%–0.9% [1,3,4]. Thymic cysts are the most prevalent benign lesions, and thymic neoplasms are a major concern in malignant lesions. As the majority of incidentally detected lesions in the anterior mediastinum are small nodules with a soft tissue appearance, the differential diagnosis typically includes a thymic neoplasm and prevascular lymph node, with benign thymic cysts sometimes overlooked as a diagnostic possibility because of its solid-like appearance due to relatively high attenuation on CT [5]. Overestimation or misinterpretation of these lesions can lead to unnecessary surgery for ultimately benign conditions. Ackman et al. [6] reported that the non-therapeutic thymectomy rate reached approximately 44% in a quaternary referral hospital due to misinterpretation and concern for thymoma, based on chest CT findings. Moreover, because of their location, small anterior mediastinal lesions are not always readily accessible via percutaneous biopsy, causing patients to occasionally undergo unnecessary thymectomy. Therefore, it is important to identify clinically significant anterior mediastinal cystic lesions and to differentiate nonsurgical benign lesions from malignant tumors. The purpose of this article is to illustrate various real-world cases manifesting as anterior mediastinal cysts through CT and magnetic resonance imaging (MRI) as a problem-solving modality by highlighting its strength in distinguishing surgical from nonsurgical anterior mediastinal lesions. The pitfalls

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Korean Journal of Radiology
KJR

of the interpretation of MRI and pathology of differential diagnoses for anterior mediastinal cystic lesions will be covered. Finally, a diagnostic classification and management strategy based on MRI features will be suggested.

Imaging Modality for the Evaluation of Anterior Mediastinal Cyst

CT

Contrast-enhanced CT has conventionally been the imaging modality of choice for the evaluation and characterization of anterior mediastinal masses. Incidentally detected anterior mediastinal lesions mostly demonstrate small sizes, ranging from 10 to 30 mm, with a median value of 12 to 18 mm [1,3,4,7]. Lesions are typically round or oval in shape, and their attenuation is in the range of 32–43 Hounsfield units (HU) [3,4]. Water attenuation (≤ 20 HU) is a traditionally recognized differential imaging feature between cysts and thymic epithelial tumors [8]; however, recent studies have revealed that approximately three-fourths of thymic cysts show hyper-attenuation to water due to internal hemorrhagic or proteinaceous fluid or milk of calcium [5,9]. Lee et al. [10] demonstrated that compared to the pre-contrast phase for thymic cysts, the mean absolute enhancement of 13 HU mimicked solid lesions with enhancement. This can be explained by pseudoenhancement due to the overlapping beam-hardening effect, which occurs when a cyst is adjacent to dense contrast media that pass through the great vessels in the mediastinum. Pseudoenhancement can lead to the misdiagnosis of cysts as solid lesions, and this phenomenon is well acknowledged in renal cysts [11]. Other ancillary findings that can differentiate thymic epithelial tumors from thymic cysts are post-contrast attenuation of 60 HU or higher, a large difference in HU between post- and pre-enhancement, lobulated contour, and the presence of protrusion from the mediastinal pleura [10,12]. To further complicate this situation, thymomas can frequently show focal cystic degeneration, and these processes can rarely progress further extensively, involving the majority or the entire lesion forming a cystic thymoma, thereby mimicking thymic cysts [13]. In other words, diagnosing asymptomatic anterior mediastinal lesions based on CT findings is often challenging and problematic, as the lesions have limited distinguishing CT features between benign cysts and small thymic epithelial tumors [5].

MRI

While CT is the mainstay for the initial evaluation of mediastinal masses, thoracic MRI offers a noninvasive method to further characterize mediastinal lesions. When a cystic mass is suspected, MRI can be the most useful imaging modality, as it is superior to CT in distinguishing cystic tissue from solid masses (e.g., thymic cysts from thymic epithelial tumors), identifying cystic/necrotic components within solid masses, and discerning thymic hyperplasia from thymic tumors [14]. Although CT is comparable or superior to MRI in the diagnosis of anterior mediastinal tumors, including thymoma, thymic carcinoma, lymphoma, or germ cell tumors, it showed significantly inferior diagnostic performance for diagnosing thymic cysts or nonsurgical cyst-like lesions [9]. The higher soft-tissue contrast of MRI, compared to CT, yields better tissue characterization and offers greater diagnostic specificity. The diagnostic accuracy for differentiating non-neoplastic cysts from malignant tumors using chest MRI has been reported to be 71%–91% [9,15,16]. Quantitative MRI criteria can also be applied using cut-offs for T2, apparent diffusion coefficient (ADC), and relative enhancement ratio [17]. The International Thymic Malignancy Interest Group (ITMIG) suggested the use of MRI for work-up and follow-up of suspected anterior mediastinal cystic lesion [14]. Moreover, recent studies have demonstrated that none of the anterior mediastinal cysts diagnosed based on MRI (a lesion with exclusively fluid content with a thin, smooth wall without septation, mural nodularities, or irregularities based on MRI) turned out to be malignant on follow-up, and did not show any mural nodularity or irregular wall thickening that would raise concern for malignant transformation [18,19]. Moreover, there is evidence that thoracic MRI can improve clinical management, reduce follow-up needs, and reduce surgical intervention rates [20]. For the characterization of mediastinal cystic lesions, basic chest MRI sequences include T2-weighted, diffusion-weighted, and pre- and post-contrast-enhanced, fat-saturated T1-weighted sequences (Table 1). For T2-weighted imaging, breath-hold cardiac-gated double inversion recovery (IR) T2-weighted images provide high-signal and high-resolution images, although they are only suitable for use over a limited area, requiring a ~20 second breath-hold. Pre- and post-contrast imaging was performed using an ultrafast 3D gradient echo (GRE) fat-saturated T1-weighted sequence to provide information regarding any enhancing component within the mass. Subtraction images (post–

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Table 1. Recommended Essential MRI Sequences for the Evaluation of Anterior Mediastinal Cysts

	Sequences	Plane	ST, mm	ECG Gating	Respiration	Fat Suppression	Scan Range	Contrast-Enhancement
T2-weighted*								
	SSFSE or HASTE	Axial and/or coronal	3 (≤ 5)	Yes	Multiple breath-holds	No/yes	Focused range	No
	STIR	Axial and/or coronal	3 (≤ 5)	Yes	Multiple breath-holds	Yes	Focused range	No
	Diffusion weighted (more than three b values; b = 0, 500, 800)	Axial	3 (≤ 5)	No	Free breathing	No	Focused range	No
T1-weighted								
	T1-weighted fast GRE	Axial, coronal and sagittal	≤ 3	Yes	Single breath-hold	Yes	Whole thorax	Pre- and post-† with axial subtraction
	T1-weighted in-/out-of-phase	Axial	≤ 3	Yes	Single breath-hold	No	Whole thorax	No

*Both SSFSE (or HASTE) and STIR can be used complementarily, †Dynamic contrast-enhanced studies can be optionally performed. Post-gadolinium imaging can be also performed at multiple time points after contrast injection (e.g., 20 s [axial], 1 min [axial], 3 min [sagittal], and 5 min [axial]). ECG = electrocardiographic, GRE = gradient echo, HASTE = Half-Fourier acquisition single-shot turbo spin echo imaging, SSFSE = single shot fast spin echo, ST = slice thickness, STIR = short tau inversion recovery

pre-contrast) can also be provided that can help detect true solid enhancement; however, accurate registration of pre- and post-contrast images without significant motion artifacts should be preceded to gain benefit from subtraction images (Fig. 1). Ultrafast in- and opposed-phase chemical shift GRE imaging can also be recommended for T1-weighted imaging, as it provides additional information regarding the presence of microscopic or intravoxel fat. Contrast-enhanced T1-weighted images can be acquired several times after contrast administration. While dynamic contrast-enhanced studies are not always necessary, this method can provide additional information and accurate characterization of a wider range of lesions, including some that may show little enhancement initially, but gradually show contrast enhancement with time.

PET/CT

Although F-fluorodeoxyglucose (FDG) PET/CT is used to stage and monitor response in patients with specific malignant mediastinal lesions, it is not routinely performed to evaluate or characterize an anterior mediastinal cystic mass. Thymic cysts can occasionally exhibit FDG uptake, although this is rare [21]. A previous study demonstrated that the maximum standardized uptake value was significantly higher in thymic epithelial tumors than in cysts (5.3 vs. 1.1; $p < 0.001$) [10].

Pathology of Anterior Mediastinal Cystic Lesions: Differential Diagnoses

Regarding treatment, cystic lesions in the anterior mediastinum may be briefly classified into two categories, depending on the need for immediate interventional approaches (such as tissue confirmation or surgical treatment) (Table 2). For non-neoplastic cystic lesions, surgical treatment is considered only for complications such as infection [22].

Non-Neoplastic Cystic Lesions

Thymic Cyst

Thymic cysts are uncommon and represent only 1% of all mediastinal masses [8]. These can be congenital or acquired [8]. Congenital cysts are typically unilocular, contain clear fluid, and have thin walls. In contrast, acquired thymic cysts result from an inflammatory process [8]. On CT, simple congenital thymic cysts usually appear as

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Korean Journal of Radiology
KJR

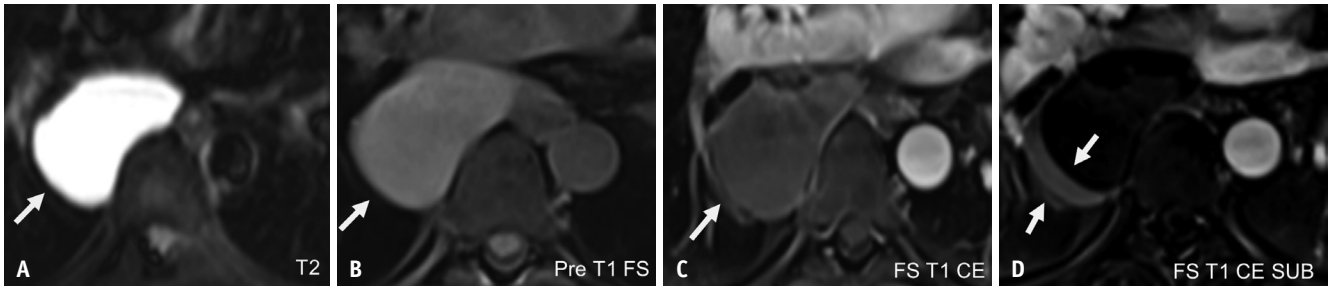

Fig. 1. A representative case of subtraction error caused by inaccurate registration of pre- and post- contrast images.
A-D. T2-weighted image **(A)**, pre- **(B)** and post-contrast FS T1-weighted image **(C)**, and subtraction images between CE and non-contrast T1-weighted image **(D)** of a 30-year-old male revealed 5.4 cm sized mass in the posterior mediastinum. **(A)** On T2-weighted imaging, a purely cystic mass is seen in the posterior mediastinum. There is no evidence of perceptible wall or septation. **(C)** The post-contrast FS T1-weighted image also reveals no definite enhancing portion within the mass. However, **(D)** the subtraction image shows a thick enhancing wall on the right side of the mass (arrows). Considering T2, pre-, and post-contrast T1-weighted images, the enhancement shown in the subtraction image is not the true enhancement within the mass, which is caused by the registration error. To benefit from subtraction images, accurate registration without motion artifacts is necessary in order to avoid registration errors. A mediastinal mass excision was performed, and a bronchogenic cyst was confirmed on pathological examination. CE = contrast-enhanced, FS = fat-suppressed

well-defined water-attenuation masses with imperceptible walls [23]. However, some thymic cysts may have increased CT attenuation if hemorrhage or infection occurs as a complication and may be misdiagnosed as solid masses [23]. On MRI, the contents of thymic cysts demonstrate the typical characteristics of fluid (i.e., low signal intensity on T1-weighted images and uniform high signal intensity on T2-weighted images) [8]. Histologically, the wall of the thymic cyst is lined by squamous, transitional, or simple cuboidal or columnar epithelia. Thymic tissue can be identified focally in the cyst wall and is necessary for diagnosis [23].

Bronchogenic Cyst

Bronchogenic cysts result from abnormal ventral budding or branching of the tracheobronchial tree during embryological development [8]. They are lined with pseudostratified columnar respiratory epithelium and their walls usually contain cartilage, smooth muscle, and mucous gland tissue. They may be filled with clear, serous fluid or a thick mucoid material [8]. They may occur in any part of the mediastinum, but most occur near the tracheal carina in the middle or posterior mediastinum [8]. The anterior mediastinum is a rare but possible location of bronchogenic cysts [23]. They may undergo an abrupt increase in size as a result of hemorrhage or infection [8]. On CT, a bronchogenic cyst appears as a single, smooth, round, or elliptical mass with an imperceptible wall and uniform attenuation. On T2-weighted MRI, cysts have high signal intensity regardless of the nature of the cyst contents, whereas variable patterns of signal intensity are seen on T1-weighted MR because of variable cyst contents and the presence of protein, hemorrhage, or mucoid material [8].

Pericardial Cyst

Pericardial cysts result from aberrations in the formation of the coelomic cavities. Persistence of the ventral recess of the pericardial coelom forms the diverticulum, constriction of the proximal part of the persistent recess accounts for either a diverticulum with a narrow neck or results in the origin of a pericardial cyst in communication with the pericardial cavity, and complete closure of the proximal recess forms the pericardial cyst [24]. However, visible communication between the cysts and pericardium is found in only a few surgical cases [23]. The cyst walls are composed of connective tissue and a single layer of mesothelial cells. Pericardial cysts usually contain a clear fluid. Most pericardial cysts arise in the anterior cardiophrenic angle, more frequently on the right side, but can be seen as high as the superior pericardial recesses [23]. On conventional radiography, these cysts appear as well-defined, round, or oval masses at the cardiophrenic angle [8]. The CT and MR features are similar to those of other congenital mediastinal cysts [8]. They show fluid signal intensity on MRI, and occasionally, they are observed as high as the pericardial recess [25].

Lymphangioma

Lymphangiomas are rare, benign congenital malformations consisting of the focal proliferation of well-differentiated lymphatic tissues [23]. Lymphangiomas usually have homogeneous low attenuation similar to that of water but

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Table 2. Differential Diagnosis of Anterior Mediastinal Cystic Masses

Type	Incidence (% of Anterior Mediastinal Mass)	Location and Characteristic Imaging Findings	Clinical Considerations
Thymic cyst	< 5%* [14] < 5%† [14]	Well-circumscribed, round/oval/saccular, homogeneous mass located near thymic bed [14] If purely cystic (no soft tissue nodules and no internal septations) → Unilocular thymic cysts [14] If cystic but with soft tissue components → Multilocular thymic cyst or cystic thymoma [14]	
Bronchogenic cyst	Majority presented in the first few decades; age > 50 years (unusual) [14]	Anterior mediastinum (3%) - rare location [31] Single, smooth, round or elliptic mass with an imperceptible wall and uniform attenuation [14]	
Pericardial cyst	4%–7% of all mediastinal masses [37]	Well-circumscribed lesion measuring water fluid density with thin or imperceptible walls in the cardiophrenic angle [8]	
Lymphangioma‡	Majority discovered during the first 2 years of life [8] 0.7%–4.5% of all mediastinal tumors [8]	1% of all lymphangiomas confined to the chest [8] Heterogeneous signal intensity on T1WI High signal intensity with or without serpentine, vessel-like septa on T2WI [8]	Complete surgical resection may be difficult Follow-up needed to exclude recurrence [8]
Thymoma‡	15%–25%, age 20–39 –50%, age > 40 [14]	Lobular homogeneous or slightly heterogeneous mass [14] Nearly entirely cystic are very rare [29]	Strongly considered in men and women, age > 40 years with cystic anterior mediastinal lesion and symptoms related to myasthenia gravis or paraneoplastic syndromes [14]
Germ cell tumor‡			
Mature teratoma	Most commonly between 2nd and 4th decades [14] 75% of primary germ cell tumor in young patients [38]	Anterior mediastinum (most common),only 3% arise within posterior mediastinum [14] Only 15% of teratomas consist only of cystic lesions contain neither fat nor calcification) [8] Most common imaging appearance: heterogeneous mediastinal mass with variable mixture of fat, fluid, soft tissue, and calcification [14]	
Seminoma	25%–40% of primary malignant mediastinal germ cell tumor [14] Male 3rd, 4th decades 5%–10% of male, age < 40 0%–2% of female, age < 40	Large masses with sharply demarcated borders and homogeneous attenuation, but areas of low attenuation may be identified [38]	
NSGCT	10%–25% of male, age < 40 < 5% of male, age > 40 2%–5% of female, age < 40 [14]	Large, bulky masses with inhomogeneous low attenuation due to cystic or necrotic components [14] Lung metastases [14]	Markedly elevated serum α-FP or β-HCG levels are present in 90% of patients [14]
Thymic carcinoma‡	< 2%, age 20-39 –5%, age > 40 [14]	Large heterogeneous mass, local invasion, lymphadenopathy, with/without distant metastases [14]	
Lymphoma‡	20%–50% of female, age < 40 [14] 20%–25% of male, age < 40 < 10% of male and female, age > 40	Necrotic, cystic-appearing mediastinal lymph nodes, common finding in newly diagnosed Hodgkin disease (21%) [30] Multiple markedly enlarged lymph nodes/masses, encasing but respecting vessels [14]	"B" symptoms* Elevated LDH [14]

"B" symptoms indicates fever, sweats, and weight loss. *Unilocular thymic cysts, †Multilocular thymic cysts or cystic thymoma, ‡Tumors which requires require immediate interventional approach such as tissue confirmation or operation. αFP = alpha-fetoprotein, HCG = human chorionic gonadotropin, LDH = lactose dehydrogenase, NSGCT = nonseminomatous germ cell tumor, T1WI = T1-weighted images, T2WI = T2-weighted images

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Korean Journal of Radiology
KJR

can have higher attenuation or consist of a combination of fluid, solid tissue, and fat [8]. Lymphangiomas may be unilocular or multilocular [8]. Thin septations within a mass can be observed occasionally [23]. On MRI, lesions have heterogeneous signal intensity on T1-weighted images [8]. They usually have high signal intensity on T2-weighted images, which reflects their fluid content [8]. It is sometimes easier to recognize serpentine and vessel-like septa on MR imaging [8].

Cystic Neoplasms with Solid Component

Many neoplastic tumors can undergo cystic degeneration and demonstrate mixed solid and cystic elements on CT or MRI. If degeneration is extensive, the gross appearance of the lesion is indistinguishable from that of a congenital cyst [8]. Malignancy has been reported in 2.4% of all cases, with cystic findings detected by mediastinal CT [26]. This category includes thymoma, thymic carcinoma, lymphoma, and germ cell tumors, including mature cystic teratomas.

Thymoma

Thymomas are the most common primary tumors of the anterior mediastinum [23]. Pathologically, thymoma has been classified as encapsulated (intact fibrous capsule), invasive (benign cytologic appearance with infiltrative growth), or metastasizing (benign cytologic appearance with pleural and pulmonary parenchymal seeding, but no extrathoracic spread) [23]. On CT, thymoma is usually well-defined, round or lobulated, homogenous, and enhanced after contrast injection [27]. Nevertheless, at times, it can be cystic because of areas of hemorrhage and necrosis [27]. On MRI, thymomas usually show low signal intensity on T1-weighted images and high signal intensity on T2-weighted images [25]. They can show intralesional foci of low signal intensity on T2-weighted images due to hemorrhage, flow voids, or calcifications [25]. Approximately one-third of these lesions exhibit necrosis, hemorrhage, or cystic components, and one-third of cases show local regional tumor spread infiltrating the capsule and surrounding anatomical structures [28]. Thus, cystic thymoma is a rare variant of thymic neoplasm. Although cystic regions are present in up to 40% of thymomas, those that are nearly entirely cystic are very rare [29]. While thymomas with cystic changes may resemble other congenital cysts on CT or MRI, the presence of a solid portion, mural nodules, or septa within a cystic lesion in the prevascular mediastinum should prompt another diagnosis, such as cystic thymoma [25].

Germ Cell Tumor

Mediastinal germ cell tumors include mature cystic teratomas, immature teratomas, seminomas, and non-seminomatous malignant germ cell tumors [8]. Mature cystic teratomas are the most common germ cell neoplasm [23]. They occur more frequently in young adults [23]. Mature cystic teratomas are cystic tumors composed of well-differentiated derivations from at least two of the three germ cell layers (ectoderm, mesoderm, and endoderm) [23]. Cyst formation is typical, and cysts are usually lined by tall mucus-secreting epithelial cells [8]. In 15% of cases, teratomas consist only of cystic lesions that contain neither fat nor calcifications [8]. Most cystic teratomas are multilocular, but unilocular cystic lesions also occur [8]. The calcifications may be focal or rim-like [23]. On CT, these tumors are heterogeneous, well-defined masses with walls of variable thickness that may be enhanced [23]. They may contain all four tissue types, including soft tissue, fluid, fat, and calcium, but fluid-containing cystic components are usually prominent [8]. The most common MRI appearance is that of a heterogeneous mediastinal mass containing a variable admixture of fat, fluid, soft tissue, and calcification [8].

Other Cystic Neoplasms

Anterior mediastinal tumors, such as thymic carcinomas or lymphomas, can appear as cystic tumors due to cystic or necrotic changes. Necrotic, cystic-appearing mediastinal lymph nodes are a common finding in newly diagnosed Hodgkin's disease, occurring in 21% of cases [30]. These necrotic areas range from minute foci of fibrinoid necrosis to large areas of disrupted granular tissue containing necrotic cells. Necrosis is most commonly seen in the nodular sclerosing and mixed cellularity subtypes of Hodgkin lymphoma and is not seen in the lymphocyte-predominant type [30].

Pitfalls and Special Consideration on MR Evaluation for the Anterior Mediastinal Cystic Lesion

T2 Signal Intensity Is the First Step, but It Is not Enough

McAdams et al. [31] suggested the usefulness of T2-weighted MR images in characterizing the cystic nature of mediastinal masses by showing markedly increased signal intensity in true cysts. Therefore, the first step for differentiating cystic masses should be evaluating T2-

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weighted MR images to determine whether the tumor shows homogenous high signal intensity. However, solid masses may also show high signal intensity on T2-weighted MR images, and it may be difficult to differentiate between solid and cystic masses using only conventional T2-weighted MR images. Internal components such as proteinous mucus might increase the signal intensity of cysts more than that of CSF, and cysts with subacute or chronic hemorrhage might show low signal intensity on T2-weighted MR images [16]. Therefore, a comprehensive approach using diverse MR sequences is required.

Both Enhancement and ADC Must Be Considered Together

Conventionally, it is well known that enhanced MR can differentiate between cystic and solid lesions. However, solid masses can be seen as high-signal-intensity lesions on T2-weighted images and as non-enhancing lesions when extensive cystic degeneration or necrosis is observed on pathological correlation [16]. To overcome the limitations of enhancement analysis, the ADC is considered as a quantitative tool. It can provide cut-off values not only for differentiation between solid and cystic internal characteristics but also for differentiation between malignant and benign mediastinal lesions [15]. Shin et al. [16] demonstrated that with a cut-off ADC value of 2.5 x 10^{-3} mm^2/s, the ADC value enables characterization of the internal component of mediastinal lesions with a higher confidence level than using CT or conventional MRI.

However, the hemorrhagic component in the anterior mediastinal mass may show variable signal intensity on DWI, ADC values, and short tau inversion recovery (STIR) images (Fig. 2). The DWI signal intensity of the

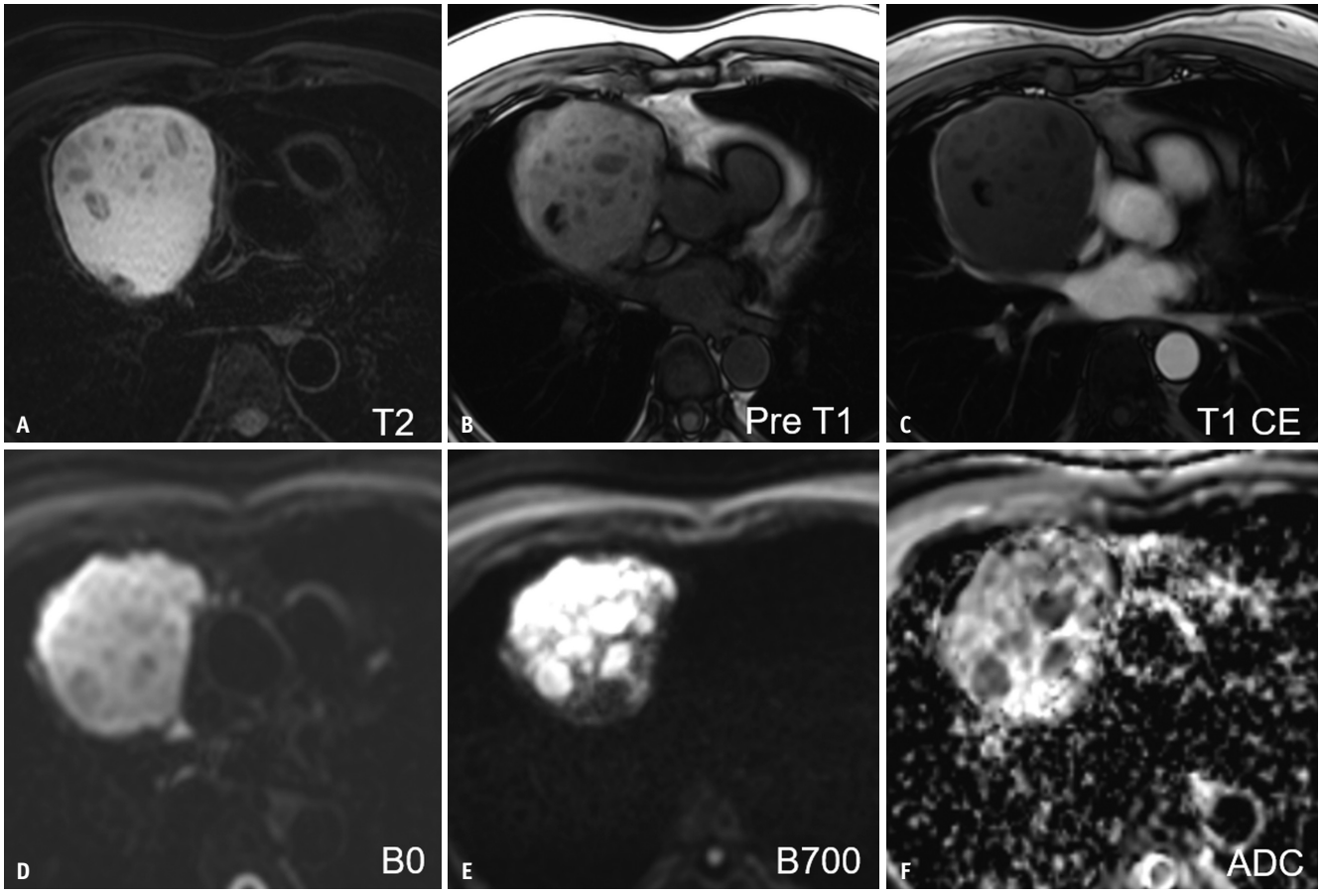

Fig. 2. A representative case of hemorrhagic component within cystic mass.
A-F. T2-weighted image **(A)**, pre- **(B)** and post-contrast T1-weighted images **(C)**, DWI b0 **(D)**, b700 **(E)**, and ADC map **(F)** of a 57-year-old male revealed a 12.5 cm sized anterior mediastinal mass. On T2-weighted imaging, multiple low-signal intensity lesions are seen within a high-signal intensity mass. Low signal intensity lesions on T2-weighted images show no contrast enhancement and demonstrate an unusual combination of signal intensity on DWI with low and high b values and ADC maps. It shows low signal intensity on low b value, high signal intensity on high b value of DWI, and decreased ADC values, suggesting a hemorrhagic component rather than a solid component. A mediastinal mass excision was performed, and a mature cystic teratoma with an old hemorrhage was confirmed on pathology. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed

https://doi.org/10.3348/kjr.2022.0606

Korean Journal of Radiology
KJR

hemorrhagic component may be related to both its ADC value and magnetic susceptibility effect [32]. Moreover, fat suppression is not tissue-specific but depends on the T1 relaxation time on STIR images [33]. Hemorrhagic content may have a short T1 relaxation time similar to that of fat and show a signal decrease in STIR [33]. Moreover, sometimes ADC alone is not sufficient to differentiate non-neoplastic cystic lesions from indeterminate tumors. Possibly because of the cystic component leading to the T2 shine-through effect in DWI, small solid lesions might be missed. Moreover, evaluation of diffusion restriction is difficult for a very small portion of the solid component or septum (Fig. 3). Even though there has been emphasis on ADC values when differentiating malignant and benign cystic masses, in order to overcome the limitations of ADC values as mentioned above, enhanced MR should also be considered at the same time.

Hence, both the enhanced MR and ADC values will play a complementary role when evaluating cystic lesions in the anterior mediastinum. To detect solid lesions within the cystic mass, the ADC value is capable of detecting not only the solid portion but also differentiating between malignant and benign mediastinal lesions by overcoming the limitations of enhancement analysis. On the other hand, enhancement MR should also be considered as a complementary role to overcome the T2 shine-through effect, which makes it difficult to evaluate diffusion restriction of cystic masses. Therefore, we focused on the role of both enhanced MR and ADC values when suggesting an algorithm for the diagnostic evaluation of anterior mediastinal cystic masses.

Suggested Algorithm for the Diagnostic Evaluation of the Anterior Mediastinal Cystic Lesions

The first step in differentiating cystic masses in the anterior mediastinum is to evaluate the homogeneity of the mass using T2 or T2 STIR images. Any suspicious T2 low signal intensity would be considered as a heterogeneous component, except for the thin wall or septum within the mass. If the mass shows a T2 low signal intensity portion, the next step should be focused on T2 low signal intensity, and the ADC value of the T2 low signal intensity lesion

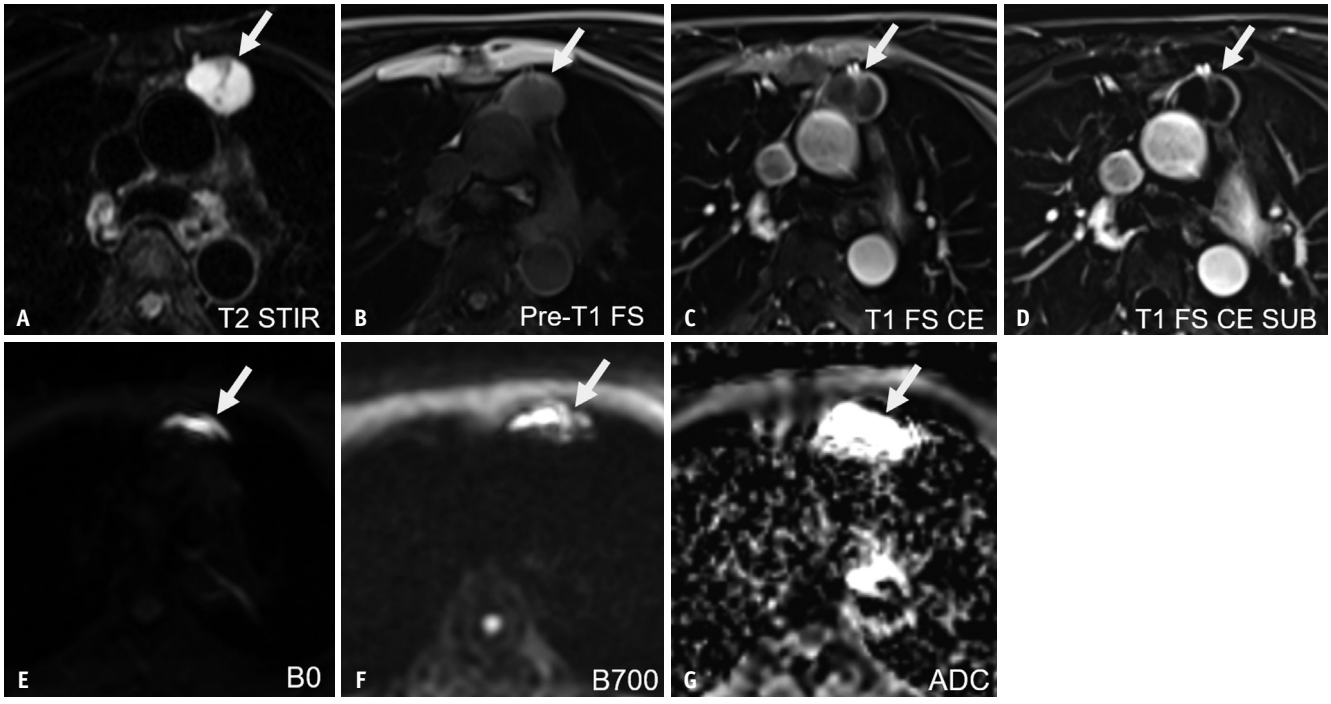

Fig. 3. A representative case of anterior mediastinal mass showing thick septal enhancement, but no diffusion restriction.
A-G. T2 STIR **(A)**, pre- **(B)** and post-contrast FS T1-weighted images **(C)**, subtraction images between CE and non-contrast T1-weighted images **(D)**, DWI b0 **(E)**, b700 **(F)**, and ADC map **(G)** of a 55-year-old female revealed a 3 cm sized anterior mediastinal mass. On T2 STIR images, thick low-signal intensity septation is seen within a high-signal intensity mass. On CE FS T1-weighted imaging, thick septation shows enhancement, but no diffusion restriction is seen regarding thick septation. A mediastinal mass excision was performed, and a thymoma with cystic change was confirmed on pathological examination. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, STIR = short tau inversion recovery

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should be evaluated. Even though T2 low signal intensity show low ADC values, further evaluation with enhanced MR should be performed. Cystic lesions with various stages of hemorrhage may contain a T2 low signal intensity portion and low ADC value, but they do not show enhancement of the T2 low signal intensity portion. For confirmation, DWI images with low and high b values may be used. Although the hemorrhagic component may show a low ADC value, it may not show high signal intensity on both high- and low-b value images. Several examples of representative cases are demonstrated following the flow chart (Figs. 4, 5).

Management of Anterior Mediastinal Cystic Lesions

According to the recommendation of ITMIG in 2014, chest MRI is recommended for incidental and asymptomatic anterior mediastinal lesions. According to recommendations from the American College of Radiology in 2018, chest MRI or PET/CT is recommended in cases where the lesion is not purely cystic or shows high attenuation on CT; the modality of choice depends on the suspected etiology or malignancy potential, and MRI is recommended for its superiority in distinguishing cystic and solid lesions [14,34]. After further characterization with chest MRI, the next step for management should be stratification based on the probabilities of cysts or tumors.

Based on the MRI classification, no follow-up or resection would be needed for definite or probable cysts defined on MRI with a high diagnostic confidence level, unless it is too large to cause symptoms. According to recent studies, although cysts defined on MRI demonstrated changes in size (decrease, increase, or fluctuation), CT attenuation, and MRI signal over long-term follow-up, there were no events of malignant transformation in those cases with a high probability of cysts on MRI [18,19]. When diagnosing an anterior mediastinal cystic lesion, accurate evaluation of its characteristics on the initial MRI, whether it is purely cystic or not, has paramount importance over evaluating a radiological size change on follow-up examinations. There are still different degrees of concern among physicians regarding the reliability of chest MRI for diagnosing anterior mediastinal cystic lesions. However, considering that non-complicated or simple cystic lesions of other organs,

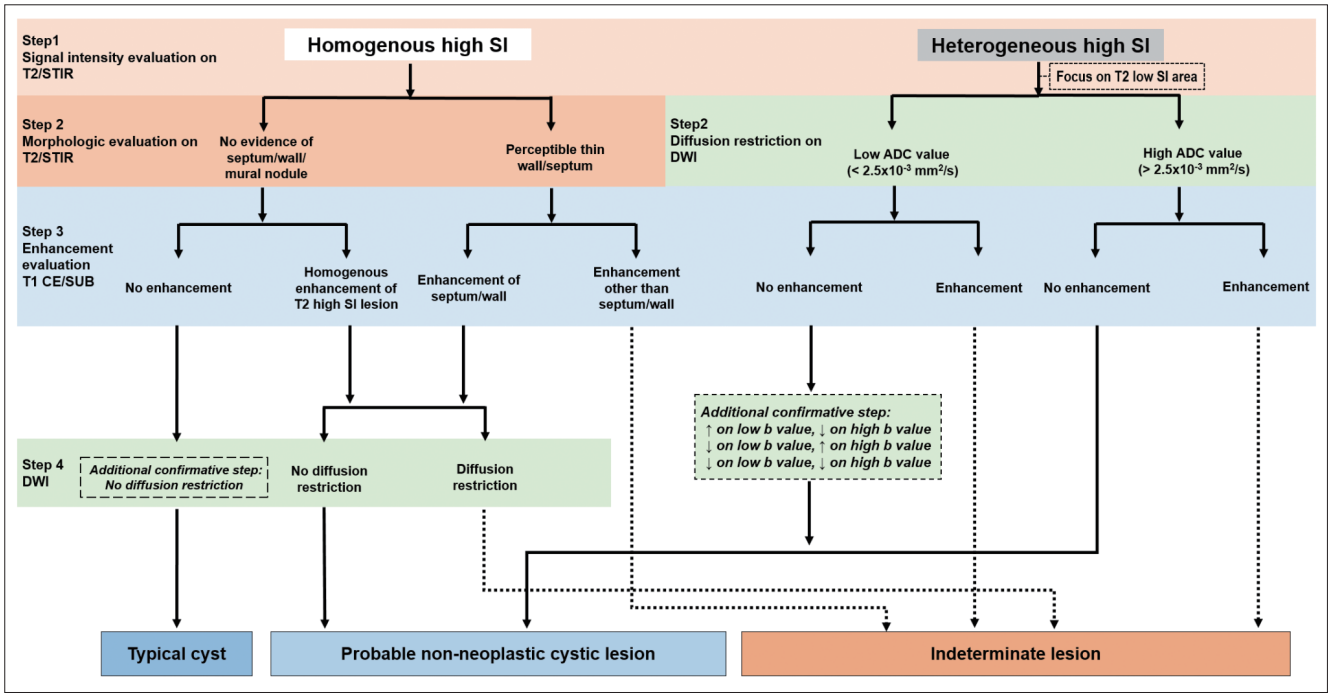

Fig. 4. Stepwise approach for the diagnostic evaluation of the anterior mediastinal cystic lesions. First step is to evaluate the homogeneity of cystic lesion. If the lesion shows homogeneity with/without thin septum, next step is to evaluate the enhancement pattern of the mass. Finally, diffusion restriction will be evaluated for determining whether the mass has solid component or not. On the other hand, if the mass shows heterogeneous SI, next step is to focus on T2 low SI area of the lesion and evaluation of ADC value, and enhancement pattern will be evaluated as the final step to differentiate indeterminate lesion with solid component from benign cystic lesion. Several examples will be demonstrated in the following Figure 5. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, SI = signal intensity, STIR = short tau inversion recovery

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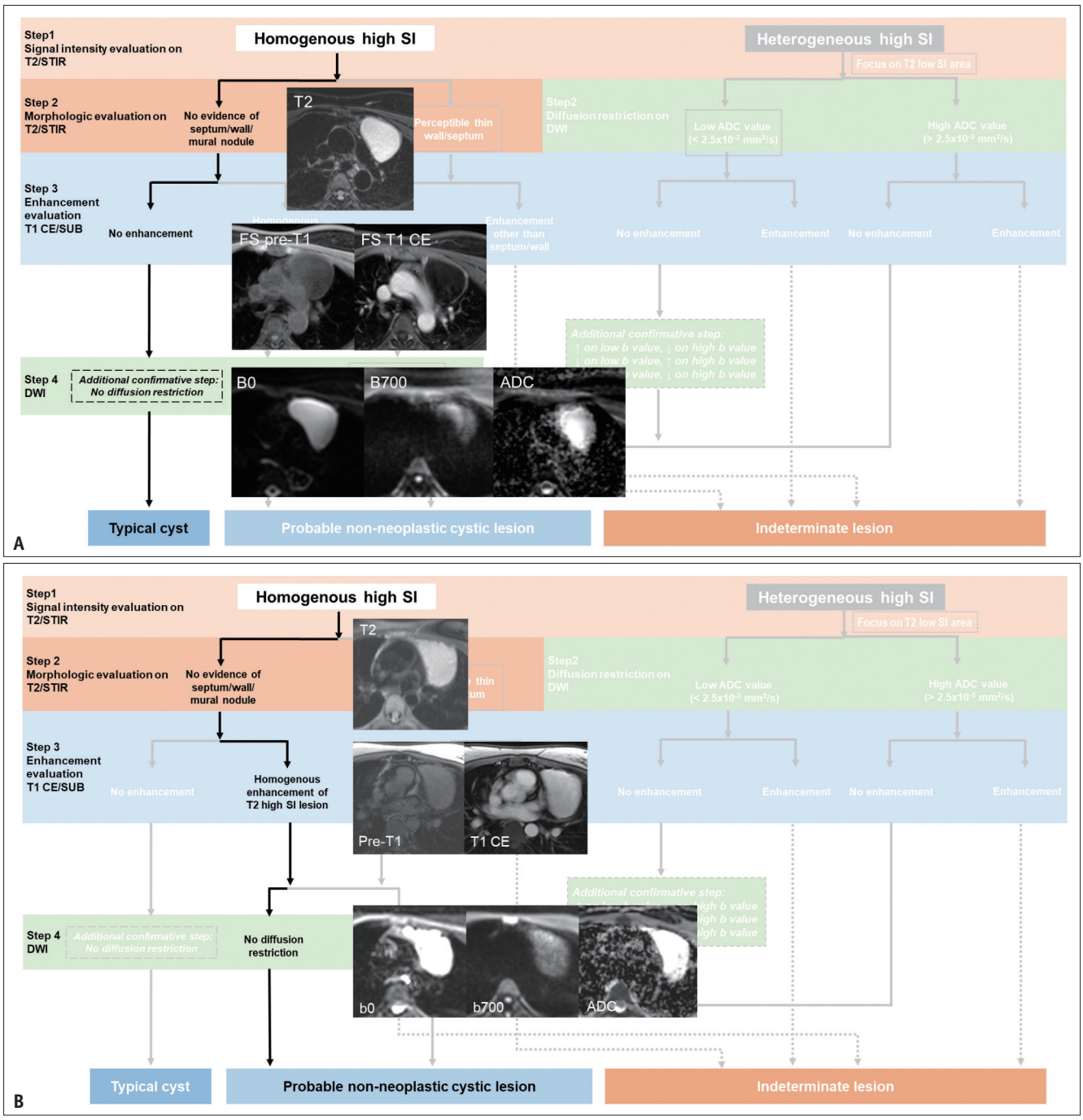

Fig. 5. Examples of stepwise approach of anterior mediastinal cystic lesion.

A. Stepwise approach for a typical cystic lesion. MR imaging of a 39-year-old female revealed a 7.3 cm sized anterior mediastinal mass. First, on the T2-weighted image, the mass shows a homogeneous high SI without a perceptible wall or septum. CE T1-weighted image shows no enhancing lesion within the mass. Finally, for confirmation, DWI and ADC maps were evaluated. No diffusion restrictions were imposed within the mass. Mass excision was performed, and the mass was confirmed as a pericardial cyst. **B.** Stepwise approach for probable non-neoplastic cystic lesions. MR imaging of a 27-year-old female revealed a 7 cm sized anterior mediastinal mass. First, on T2-weighted image, the lesion shows a homogeneous high SI without a perceptible wall or septum. On CE T1-weighted image, the mass reveals homogenous enhancement, which appears as high SI on T2-weighted images. No diffusion restrictions were imposed. This mass was categorized as a probable non-neoplastic cystic lesion. A mass excision was performed, and it was confirmed to be a cavernous hemangioma. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, SI = signal intensity, STIR = short tau inversion recovery

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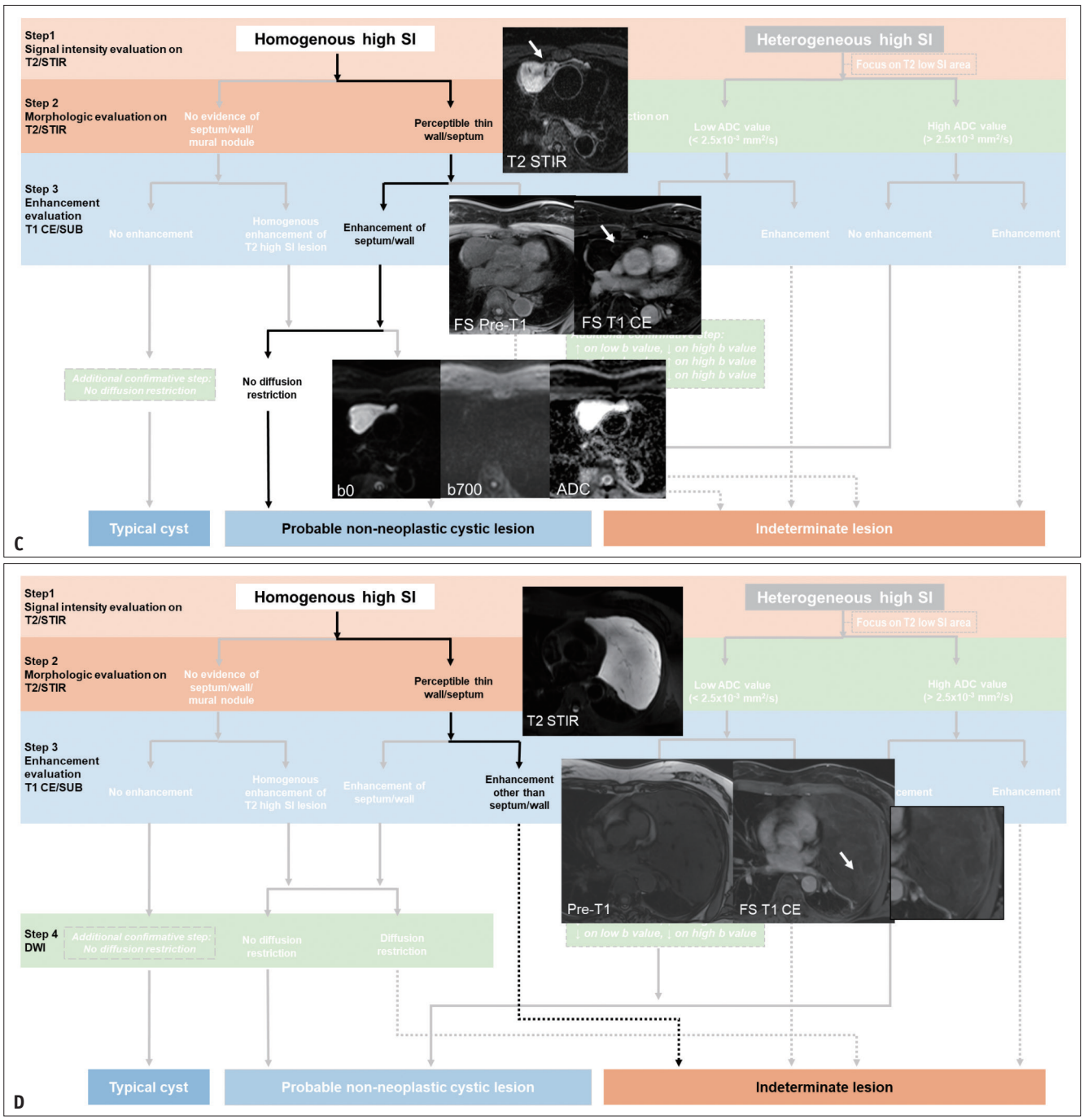

Fig. 5. Examples of stepwise approach of anterior mediastinal cystic lesion (Continued).
C. Stepwise approach for probable non-neoplastic cystic lesions. MR imaging of a 69-year-old female revealed a 9.7 cm sized anterior mediastinal mass. First, on T2-weighted image, the mass shows homogeneous high SI but contains a thin septum (arrow) with T2 low SI. CE T1-weighted image showing enhancement of the septum (arrow). However, there were no diffusion restrictions within the mass. This mass was categorized as a probable non-neoplastic cystic lesion. Mass excision was performed, and the mass was confirmed as a thymic cyst. **D.** Stepwise approach for indeterminate lesions. MR imaging of a 55-year-old female revealed a 15 cm sized anterior mediastinal mass. First, on the T2-weighted image, the mass shows a homogeneous high SI but contains multiple thin septa within the mass. On the CE T1-weighted image, there is no enhancement of the septum, but the peripheral portion of the mass (arrow) shows focal areas of enhancement. Owing to enhancement within the mass, it was categorized as an indeterminate lesion. Mass excision was performed, and myxoid liposarcoma was confirmed. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, SI = signal intensity, STIR = short tau inversion recovery

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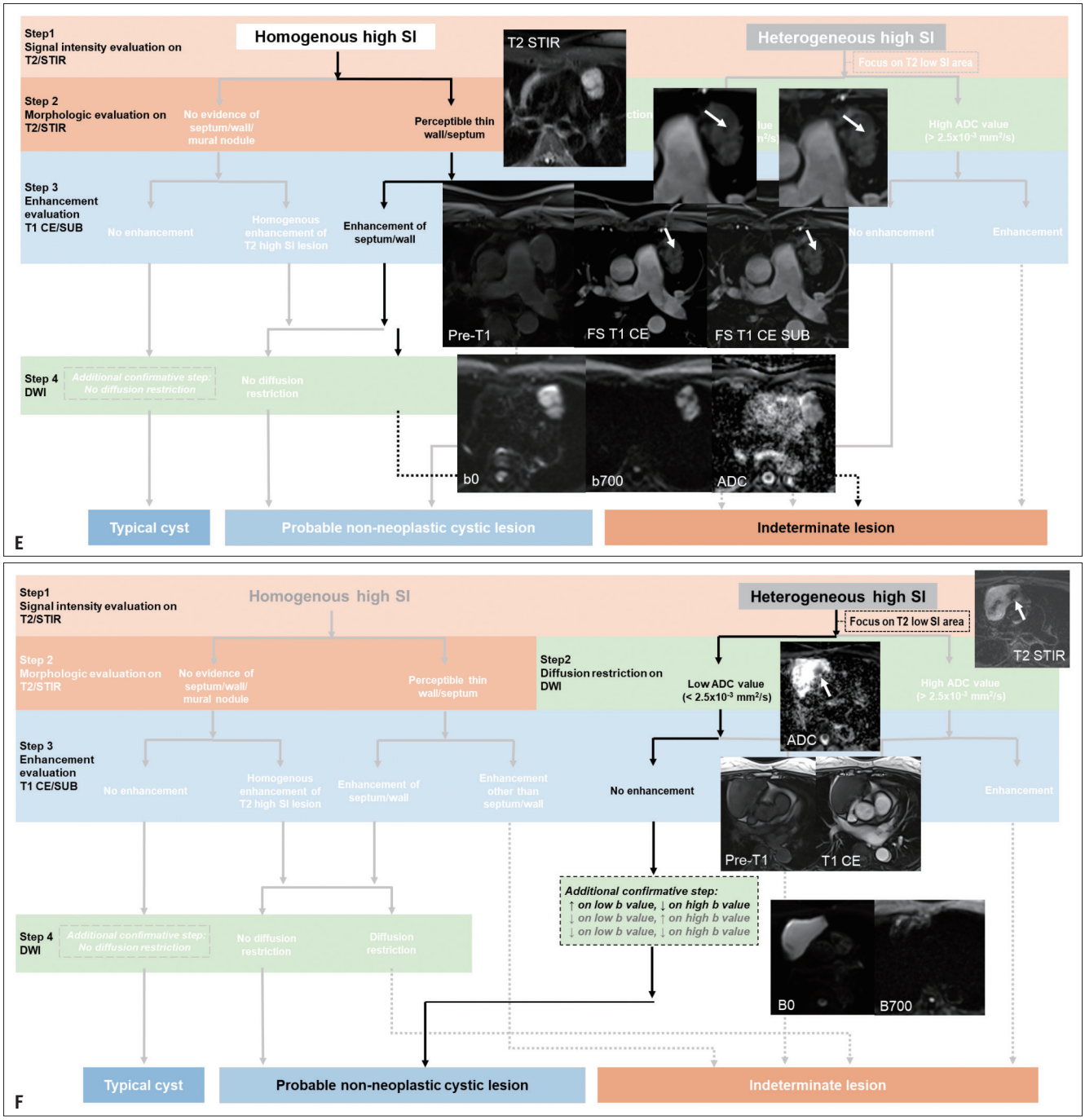

Fig. 5. Examples of stepwise approach of anterior mediastinal cystic lesion (Continued).
E. Stepwise approach for indeterminate lesions. MR imaging of a 37-year-old male revealed a 4.6 cm sized anterior mediastinal mass. First, on the T2 weighted image, the mass shows homogeneous a high SI; however, it shows a septum within the mass. On CE T1-weighted image, the septum (arrows) shows subtle enhancement, and the mass shows diffusion restriction. This mass was categorized as an indeterminate lesion. Mass excision was performed, and the mass was confirmed as a thymoma. **F.** Stepwise approach for probable non-neoplastic cystic lesions. MR imaging of a 65-year-old female revealed a 6.5 cm sized anterior mediastinal mass. First, on T2-weighted image, the mass shows a focal low-SI lesion (arrow) within a high-SI mass. By focusing on the T2 low-SI area, the focal T2 low-SI lesion also reveals a low ADC value (arrow). However, on CE T1-weighted images, there no enhancement is observed within the mass, including T2 low SI. This mass was categorized as a probable non-neoplastic cystic lesion. The mass excision was performed and it was confirmed as thymic cyst with hemorrhagic component. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, SI = signal intensity, STIR = short tau inversion recovery

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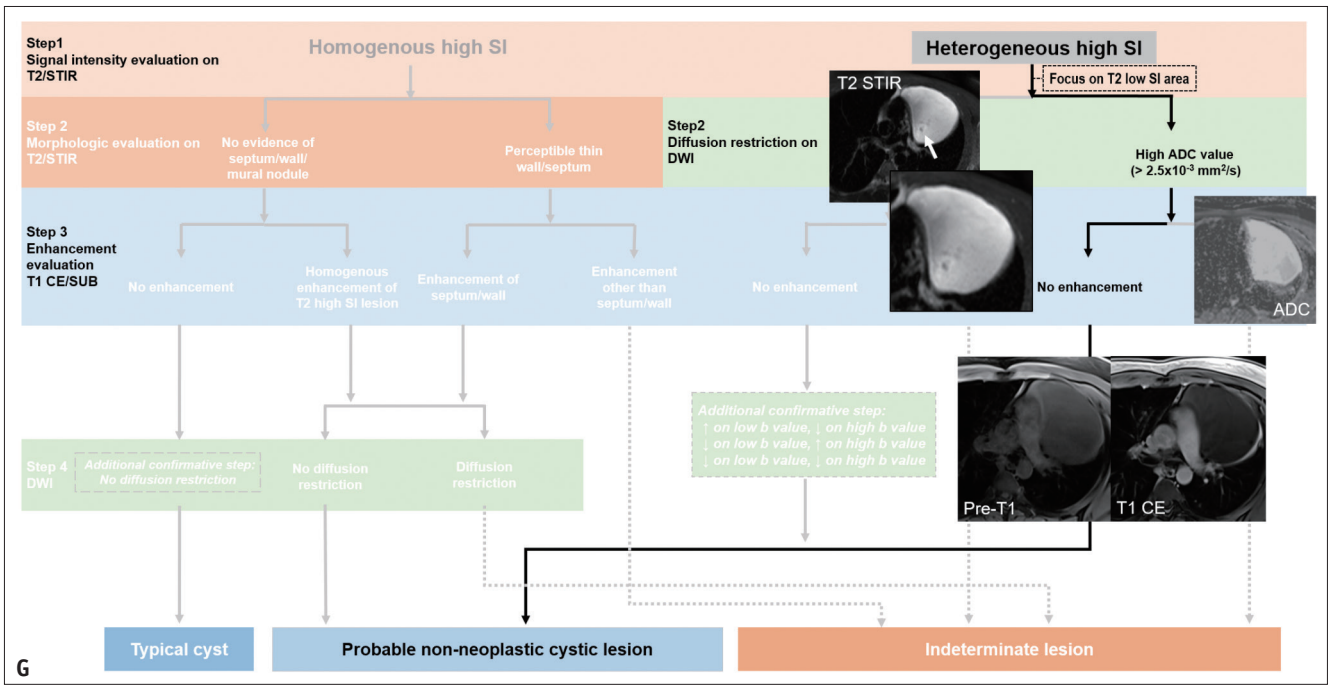

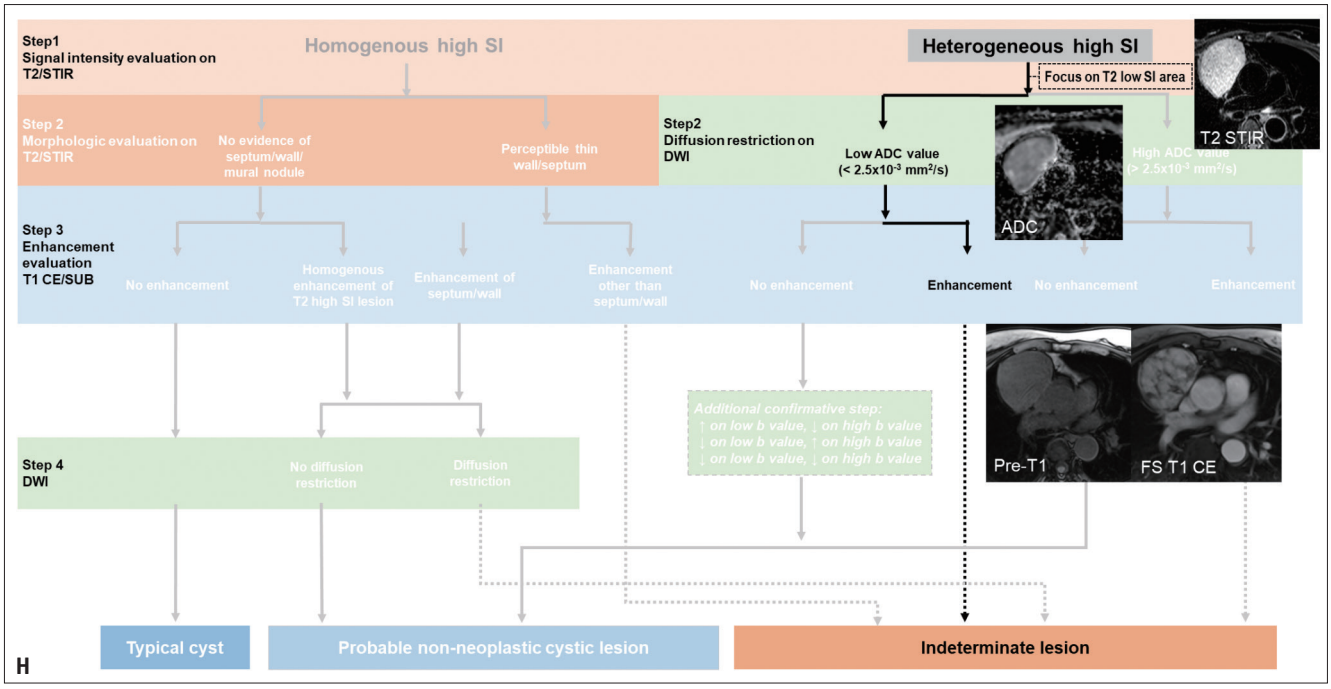

Fig. 5. Examples of stepwise approach of anterior mediastinal cystic lesion (Continued).
G. Stepwise approach for probable non-neoplastic cystic lesions. MR imaging of a 19-year-old male revealed a 12.2 cm sized anterior mediastinal mass. First, on T2-weighted image, the mass shows a small focal low-SI lesion (arrow) within a high-SI mass. T2 low-SI lesions show a high ADC value. On CE T1-weighted images, no enhancement is observed within the mass, including T2 low SI lesions. This mass was categorized as a probable non-neoplastic cystic lesion. Mass excision was performed, and the mass was confirmed as a pericardial cyst. **H.** Stepwise approach for indeterminate lesions. MR imaging of a 65-year-old female revealed a 7.8 cm sized anterior mediastinal mass. First, on T2-weighted image, the mass shows a heterogeneous high-intensity. The mass shows a diffuse, low ADC value. CE T1-weighted images show multiple areas of enhancement within the mass. The mass was categorized as an indeterminate lesion. Mass excision was performed, and the mass was confirmed as a thymoma. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, SI = signal intensity, STIR = short tau inversion recovery

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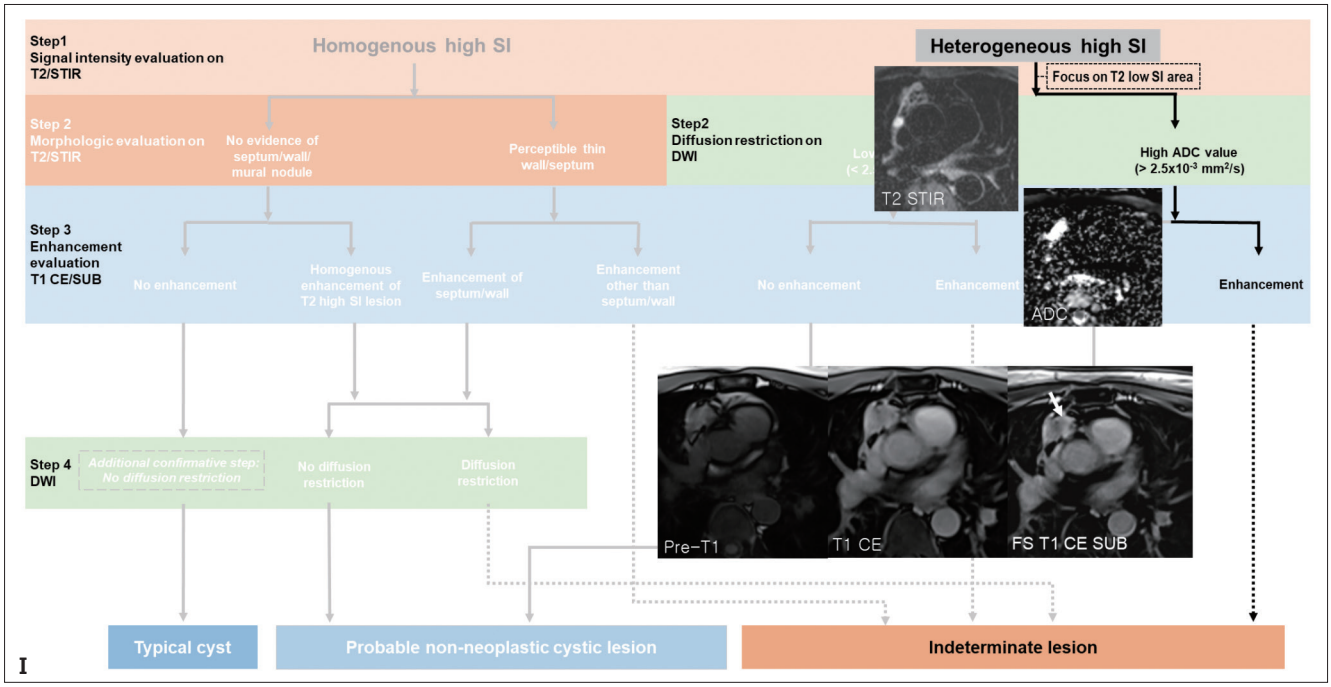

Fig. 5. Examples of stepwise approach of anterior mediastinal cystic lesion (Continued).
I. Stepwise approach for indeterminate lesions. MR imaging of a 33-year-old male revealed a 2.6 cm sized anterior mediastinal mass. First, on T2-weighted image, the mass shows multifocal low-SI lesions within the high-SI mass. However, the mass demonstrates a high ADC value. CE T1-weighted images show focal areas of enhancement within the mass. The mass was categorized as an indeterminate lesion. Mass excision was performed, and the mass was confirmed as a thymoma. ADC = apparent diffusion coefficient, CE = contrast enhanced, DWI = diffusion-weighted image, FS = fat-suppressed, SI = signal intensity, STIR = short tau inversion recovery

including the kidney and liver, do not usually require follow-up [35,36], regular or long-term follow-up for probable cystic lesions may not be needed to increase radiation exposure and health care costs in individual patients.

For patients with indeterminate lesions on chest MRI, imaging surveillance or surgical resection can be considered to exclude malignancy. According to a recent study that analyzed follow-up outcomes of anterior mediastinal cystic lesions, although the number of patients with indeterminate lesions on chest MRI was small, 40% of them showed a marked reduction in size after a median follow-up period of four months, suggesting that they were complicated cysts rather than malignant tumors [3]. Therefore, a conservative patient-tailored approach with short-term follow-up imaging and deciding whether to perform surgery after a short follow-up period may be an appropriate management option. We recommend a short-term follow-up CT or MRI at three months for indeterminate lesions based on MRI. If the lesion increases in size of the solid component or shows aggravation of wall thickening on follow-up, surgical resection is recommended; if the lesion shows stability or decrease in size at the 3-month follow-up, further follow-up with longer interval, 6 months, and then 12 or 24 months can be recommended, considering the possibility of complicated cysts rather than cystic tumors (Fig. 6). Surgical management is recommended for patients with probable or definite tumors.

CONCLUSION

MRI has become a valuable tool for evaluating mediastinal masses, particularly for differentiating cystic from solid lesions. The evaluation of incidentally detected anterior mediastinal lesions is one of the most common purposes of implementing chest MRI in clinical practice. Understanding the pitfalls of chest MRI for interpreting anterior mediastinal cystic lesions and possible differential diagnoses is imperative for chest MRI to be used as a valuable tool for improving patient management in clinical practice. In this article, we demonstrated a stepwise algorithm for interpreting anterior mediastinal cystic lesions on chest MRI. Differentiating cysts on MRI with a high confidence level from others, including cystic tumors or complicated cysts, and clearly reporting these findings is essential to guide further management after chest MRI. Less conclusive or indeterminate imaging features should be managed based on a conservative patient-tailored

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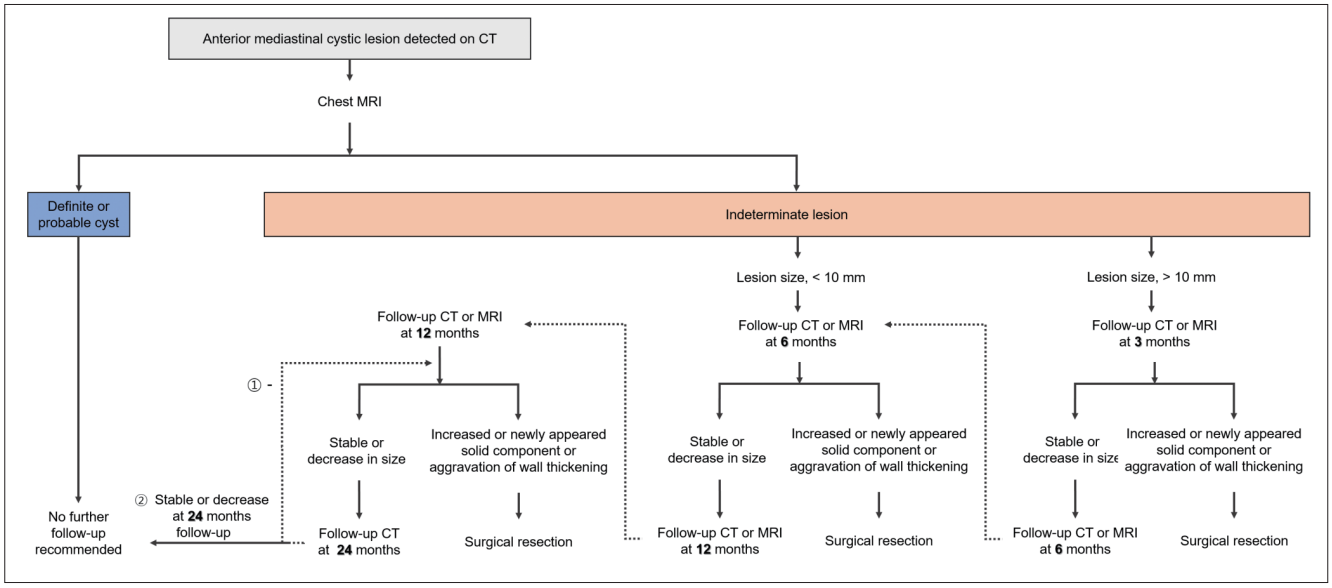

Fig. 6. Management of anterior mediastinal lesion based on MRI findings. Flowchart showing the follow-up scheme for an anterior mediastinal cystic lesion detected incidentally on CT. For definite or probable cysts on MRI, further follow-up is not required. For indeterminate lesions based on MRI findings, short-term follow-up CT or MRI can be recommended at 3 months. If the lesion increases in size of the solid component or shows aggravation of the wall thickening on follow-up, surgical resection is recommended. For those lesions that show stability or decrease in size at the 3-month follow-up, further follow-up with longer interval, 6 months, and then 12 or 24 months can be recommended, considering the possibility of complicated cysts rather than cystic tumors. Dotted lines indicate the continuation of imaging surveillance. For those lesions showing stability or decrease in size at 24 months follow-up, which will be the fourth follow-up (after 48 months from the time of baseline CT scan), no further follow-up might be necessary.

approach with short-term follow-up imaging, and deciding whether to perform surgery after a short follow-up period might be an appropriate management option. This structured MRI-based approach to patients with an anterior mediastinal cystic lesion might narrow and focus on diagnostic evaluation, eliminating unnecessary steps in the process, and ultimately improving and standardizing patient care.

Availability of Data and Material

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Ho Yun Lee. Data curation: Jong Hee Kim, Jooae Choe. Formal analysis: Ho Yun Lee, Jong Hee Kim, Jooae Choe. Funding acquisition: Ho Yun Lee. Investigation: Ho Yun Lee, Jong Hee Kim, Jooae Choe. Methodology: Ho Yun Lee. Project administration: Ho Yun Lee. Resources: Jong Hee Kim, Jooae Choe. Software: Ho Yun Lee, Jong Hee Kim, Jooae Choe. Supervision: Ho Yun Lee, Hong Kwan Kim. Validation: Ho Yun Lee, Hong Kwan Kim. Visualization: Jong Hee Kim, Jooae Choe. Writing—original draft: Ho Yun Lee, Jong Hee Kim, Jooae Choe. Writing—review & editing: all authors.

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REFERENCES

1. Henschke CI, Lee IJ, Wu N, Farooqi A, Khan A, Yankelevitz D,

et al. CT screening for lung cancer: prevalence and incidence of mediastinal masses. *Radiology* 2006;239:586-590
2. Smith-Bindman R, Miglioretti DL, Johnson E, Lee C, Feigelson HS, Flynn M, et al. Use of diagnostic imaging studies and associated radiation exposure for patients enrolled in large integrated health care systems, 1996-2010. *JAMA* 2012;307:2400-2409
3. Araki T, Nishino M, Gao W, Dupuis J, Washko GR, Hunninghake GM, et al. Anterior mediastinal masses in the Framingham Heart Study: prevalence and CT image characteristics. *Eur J Radiol Open* 2015;2:26-31
4. Yoon SH, Choi SH, Kang CH, Goo JM. Incidental anterior mediastinal nodular lesions on chest CT in asymptomatic subjects. *J Thorac Oncol* 2018;13:359-366
5. Araki T, Sholl LM, Gerbaudo VH, Hatabu H, Nishino M. Intrathymic cyst: clinical and radiological features in surgically resected cases. *Clin Radiol* 2014;69:732-738
6. Ackman JB, Verzosa S, Kovach AE, Louissaint A Jr, Lanuti M, Wright CD, et al. High rate of unnecessary thymectomy and its cause. Can computed tomography distinguish thymoma, lymphoma, thymic hyperplasia, and thymic cysts? *Eur J Radiol* 2015;84:524-533
7. Yoon SH. Management of incidental anterior mediastinal lesions: summary of relevant studies. *Mediastinum* 2019;3:9
8. Jeung MY, Gasser B, Gangi A, Bogorin A, Charneau D, Wihlm JM, et al. Imaging of cystic masses of the mediastinum. *Radiographics* 2002;22 Spec No:S79-S93
9. Tomiyama N, Honda O, Tsubamoto M, Inoue A, Sumikawa H, Kuriyama K, et al. Anterior mediastinal tumors: diagnostic accuracy of CT and MRI. *Eur J Radiol* 2009;69:280-288
10. Lee SH, Yoon SH, Nam JG, Kim HJ, Ahn SY, Kim HK, et al. Distinguishing between thymic epithelial tumors and benign cysts via computed tomography. *Korean J Radiol* 2019;20:671-682
11. Maki DD, Birnbaum BA, Chakraborty DP, Jacobs JE, Carvalho BM, Herman GT. Renal cyst pseudoenhancement: beam-hardening effects on CT numbers. *Radiology* 1999;213:468-472
12. Jung W, Cho S, Yum S, Lee YK, Kim K, Jheon S. Differentiating thymoma from thymic cyst in anterior mediastinal abnormalities smaller than 3 cm. *J Thorac Dis* 2020;12:1357-1365
13. Suster S, Rosai J. Cystic thymomas. A clinicopathologic study of ten cases. *Cancer* 1992;69:92-97
14. Carter BW, Okumura M, Detterbeck FC, Marom EM. Approaching the patient with an anterior mediastinal mass: a guide for radiologists. *J Thorac Oncol* 2014;9(9 Suppl 2):S110-S118
15. Gümüştaş S, Inan N, Sarisoy HT, Anik Y, Arslan A, Ciftçi E, et al. Malignant versus benign mediastinal lesions: quantitative assessment with diffusion weighted MR imaging. *Eur Radiol* 2011;21:2255-2260
16. Shin KE, Yi CA, Kim TS, Lee HY, Choi YS, Kim HK, et al. Diffusion-weighted MRI for distinguishing non-neoplastic cysts from solid masses in the mediastinum: problem-solving in mediastinal masses of indeterminate internal characteristics on CT. *Eur Radiol* 2014;24:677-684
17. Hwang EJ, Paek M, Yoon SH, Kim J, Lee HY, Goo JM, et al. Quantitative thoracic magnetic resonance criteria for the differentiation of cysts from solid masses in the anterior mediastinum. *Korean J Radiol* 2019;20:854-861
18. Ackman JB, Chintanapakdee W, Mendoza DP, Price MC, Lanuti M, Shepard JO. Longitudinal CT and MRI characteristics of unilocular thymic cysts. *Radiology* 2021;301:443-454
19. Choe J, Lee SM, Ahn Y, Kim CH, Seo JB, Lee HY. Characteristics and outcomes of anterior mediastinal cystic lesions diagnosed on chest MRI: implications for management of cystic lesions. *Insights Imaging* 2022;13:136
20. Ackman JB, Gaissert HA, Lanuti M, Digumarthy SR, Shepard JA, Halpern EF, et al. Impact of nonvascular thoracic MR imaging on the clinical decision making of thoracic surgeons: a 2-year prospective study. *Radiology* 2016;280:464-474
21. Kitami A, Sano F, Ohashi S, Suzuki K, Uematsu S, Suzuki T, et al. The usefulness of positron-emission tomography findings in the management of anterior mediastinal tumors. *Ann Thorac Cardiovasc Surg* 2017;23:26-30
22. Zambudio AR, Lanzas JT, Calvo MJ, Fernández PJ, Paricio PP. Non-neoplastic mediastinal cysts. *Eur J Cardiothorac Surg* 2002;22:712-716
23. Kim JH, Goo JM, Lee HJ, Chung MJ, Jung SI, Lim KY, et al. Cystic tumors in the anterior mediastinum. Radiologic-pathological correlation. *J Comput Assist Tomogr* 2003;27:714-723
24. Kar SK, Ganguly T. Current concepts of diagnosis and management of pericardial cysts. *Indian Heart J* 2017;69:364-370
25. Park JW, Jeong WG, Lee JE, Lee HJ, Ki SY, Lee BC, et al. Pictorial review of mediastinal masses with an emphasis on magnetic resonance imaging. *Korean J Radiol* 2021;22:139-154
26. Hirano S, Motohara T, Nishibe T, Narita Y, Ohkubo T, Takahashi T, et al. Cystic mediastinal tumor; a clinical study. *Journal of the Japanese Association for Chest Surgery* 1997;11:13-19
27. Marom EM. Imaging thymoma. *J Thorac Oncol* 2010;5(10 Suppl 4):S296-S303
28. Benveniste MF, Rosado-de-Christenson ML, Sabloff BS, Moran CA, Swisher SG, Marom EM. Role of imaging in the diagnosis, staging, and treatment of thymoma. *Radiographics* 2011;31:1847-1861; discussion 1861-1863
29. Takahashi K, Al-Janabi NJ. Computed tomography and magnetic resonance imaging of mediastinal tumors. *J Magn Reson Imaging* 2010;32:1325-1339
30. Hopper KD, Diehl LF, Cole BA, Lynch JC, Meilstrup JW, McCauslin MA. The significance of necrotic mediastinal lymph nodes on CT in patients with newly diagnosed Hodgkin disease. *AJR Am J Roentgenol* 1990;155:267-270
31. McAdams HP, Kirejczyk WM, Rosado-de-Christenson ML, Matsumoto S. Bronchogenic cyst: imaging features with clinical and histopathologic correlation. *Radiology*

 https://doi.org/10.3348/kjr.2022.0606

2000;217:441-446
32. Kang BK, Na DG, Ryoo JW, Byun HS, Roh HG, Pyeun YS. Diffusion-weighted MR imaging of intracerebral hemorrhage. *Korean J Radiol* 2001;2:183-191
33. Kim JH, Kang WY, Cho BS, Yi KS. A potential diagnostic pitfall in the differentiation of hemorrhagic and fatty lesions using short inversion time inversion recovery: a case report. *Investig Magn Reson Imaging* 2016;20:181-184
34. Munden RF, Carter BW, Chiles C, MacMahon H, Black WC, Ko JP, et al. Managing incidental findings on thoracic CT: mediastinal and cardiovascular findings. A white paper of the ACR incidental findings committee. *J Am Coll Radiol* 2018;15:1087-1096
35. Silverman SG, Pedrosa I, Ellis JH, Hindman NM, Schieda N, Smith AD, et al. Bosniak classification of cystic renal masses, version 2019: an update proposal and needs assessment. *Radiology* 2019;292:475-488
36. Marrero JA, Ahn J, Rajender Reddy K; Americal College of Gastroenterology. ACG clinical guideline: the diagnosis and management of focal liver lesions. *Am J Gastroenterol* 2014;109:1328-1347; quiz 1348
37. Alkharabsheh S, Gentry Iii JL, Khayata M, Gupta N, Schoenhagen P, Flamm S, et al. Clinical features, natural history, and management of pericardial cysts. *Am J Cardiol* 2019;123:159-163
38. Drevelegas A, Palladas P, Scordalaki A. Mediastinal germ cell tumors: a radiologic-pathologic review. *Eur Radiol* 2001;11:1925-1932

https://doi.org/10.3348/kjr.2022.0606