The normal and pathologic thymus - a pictorial review in computed tomography

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Learning objectives

• Demonstrate the normal thymus on computed tomography (CT), highlighting its changes over time.
• Illustrate the CT characteristics of the most common thymic diseases (benign and malignant).
• Review the classification system for thymic epithelial tumors.
Background

The thymus is a lymphoid organ located in the antero-superior mediastinum, anteriorly to the great vessels and posteriorly to the sternum. It originates from the third and fourth branchial pouches, and contains elements derived from all three germinal layers. The main function is the generation, differentiation and maturation of T lymphocytes, being one of the central lymphoid organs and playing an important role in cellular immunity.

The normal thymus is a dynamic organ that changes during life, making differentiation of normal thymus from thymic disorders difficult for radiologists. It grows until reaching its maximum absolute weight in adolescence (35g), starting thereafter a process of involution in which the number of epithelial cells decrease and the amount of adipose tissue increases (15g at 60 years of age).
Findings and procedure details

CT is the most common imaging technique used to evaluate the thymus, therefore radiologists should be familiar with the normal and pathologic CT aspects of this organ.

Normal thymus

At CT, the young adult thymus consists of two lateral lobes (usually asymmetric in size) touching the midline and forming a triangle in the anterior mediastinum. In children the gland has a more quadrilateral configuration with convex borders. It is located posteriorly to the sternum and anteriorly to the pericardium, aortic arch and great vessels, extending from the thyroid to the fourth costal cartilage. Normally it has attenuation similar to surrounding muscles and a smooth contour. Generally the maximal thickness of the gland under 20 years is 1.8 cm and over 20 years is 1.3 cm.

Thymic hyperplasia

There are two histologic types of thymic hyperplasia: true and lymphoid hyperplasia. In true thymic hyperplasia the gland is large (increased size and weight) for a given age but remains histologically normal. It occurs when the patient is recovering from chemotherapy, corticosteroid therapy or irradiation (rebound hyperplasia). In lymphoid hyperplasia (also called lymphofollicular/autoimmune thymitis) there are increased lymphoid secondary follicles. This often occurs in association with myasthenia gravis (85% of patients have follicular hyperplasia) but also with other immune mediated diseases including systemic lupus erythematosus (SLE), rheumatoid arthritis, scleroderma, vasculitis, thyrotoxicosis, and Graves disease.

Both types of hyperplasia manifest as diffuse symmetric enlargement of the thymus with homogeneous soft tissue attenuation, being indistinguishable on the basis of CT findings (although the gland enlarges more prominently in true hyperplasia). The most important feature is to distinguish hyperplasia from neoplasm which manifests as a focal mass.

Thymic cyst

Thymic cysts are uncommon lesions that represent approximately 3% of anterior mediastinal masses. They can be congenital, acquired, iatrogenic (thoracotomy, chemotherapy or radiotherapy) or inflammatory. Cysts are normally detected in children or young adults, the diagnosis being usually incidental. CT findings include well-defined anterior mediastinal cystic masses (water attenuation), uni or multilocular, with no
contrast enhancement. The most important differential diagnosis is cystic thymoma (which normally demonstrates mural nodules).

**Thymic epithelial tumors**

Thymic epithelial tumors include thymoma and thymic carcinoma. Although rare, they are the most common primary neoplasms of the thymus and antero-superior mediastinum.

**Thymoma**

Thymoma is the most common primary thymic neoplasm. Usually (70%) it presents during the fifth or sixth decade, with no gender predilection. Most patients are asymptomatic but 25-30% have symptoms of compression or invasion of adjacent structures like chest pain, cough or dyspnea.

A lot of entities are seen in association with thymoma (the causal mechanism being poorly understood). The most common is myasthenia gravis: 15% of patients with myasthenia gravis have thymoma and of all patients with thymoma, 30-50% have myasthenia gravis. Pure red cell aplasia, hypogammaglobulinemia, SLE, rheumatoid arthritis, and nonthymic cancers, occur less frequently than myasthenia gravis but are relatively well recognized associated conditions.

CT imaging of thymomas reveals a unilateral anterior mediastinal mass of soft tissue attenuation with smooth or lobular contour and variable size. They tend to be homogeneous in density but large thymomas may be heterogeneous as the result of necrosis and cystic degeneration. Calcification can be present, commonly curvilinear and peripheral, corresponding to calcium deposits in the tumor capsule.

Invasive thymoma may show involvement of mediastinal structures, infiltration of fat planes, and lung parenchyma. Generally there is no detectable lymphadenopathy. Pleural implants are sometimes present and may cause diffuse pleural thickening. Pleural effusion is uncommon.

**Thymic carcinoma**

Thymic carcinoma is a rare malignant epithelial neoplasm. Patients are frequently symptomatic and the prognosis is poor. There is a male predilection and the mean age of presentation is the fifth decade.

CT findings are similar to those of invasive thymoma with some aspects being characteristic of thymic carcinoma namely crossing the midline and the presence of
lymphadenopathy. Pleural and pericardial implantation or effusion and metastases are more frequent.

**Classification of thymic epithelial tumors**

Two major classification systems are normally used. The World Health Organization (WHO) classification, based on histological appearance, correlates with the behavior of tumors (likelihood of invasiveness), contributing to preoperative treatment decisions:

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Medullary</td>
</tr>
<tr>
<td>AB</td>
<td>Mixed</td>
</tr>
<tr>
<td>B1</td>
<td>Lymphocyte rich, predominantly cortical</td>
</tr>
<tr>
<td>B2</td>
<td>Cortical</td>
</tr>
<tr>
<td>B3</td>
<td>Epithelial (well-differentiated thymic carcinoma)</td>
</tr>
<tr>
<td>C</td>
<td>Thymic carcinoma</td>
</tr>
</tbody>
</table>

Types A and AB - usually clinically benign and encapsulated.

Type B - greater likelihood of invasiveness (especially B3).

Type C - almost always invasive.

Some imaging aspects that suggest specific histologic types can help predicting tumor invasiveness (keeping in mind the WHO classification). CT findings more common in high-risk thymomas and thymic carcinomas include lobulated contour, mediastinal fat invasion and great vessel invasion. CT findings associated with significantly more recurrence and metastasis include lobulated or irregular contour, oval shape, mediastinal fat invasion or great vessel invasion, and pleural seeding.

The Masaoka-Koga staging system is based on surgical findings. It assesses invasion and the presence of metastasis, being able to predict 5-year survival:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Encapsulated/no microscopic capsular invasion</td>
</tr>
</tbody>
</table>
IIa  Microscopic capsular invasion

IIb  Macroscopic invasion of surrounding fat, adherence to but no invasion of pleura or pericardium

III  Macroscopic invasion of adjacent organs; pericardium, great vessels, lung

IVa  Pleural/pericardial dissemination

IVb  Lymphatic/hematogenous dissemination

**Uncommon Thymic Neoplasms**

**Thymic carcinoid**

Thymic carcinoid is a rare malignant neuroendocrine tumor of the thymus, with a poor prognosis. It has a male predilection (3:1). The median age of presentation is 43 years.

In approximately 50% of patients, thymic carcinoid is functionally active. When it produces ACTH, Cushing syndrome is the final result. In 19-25% of patients it is a part of type 1 MEN syndrome.

CT findings of this tumor overlap those from thymic carcinoma, often demonstrating invasion of adjacent structures and metastasis. Octreotide radionuclide imaging can be useful in the detection of occult lesions.

**Thymolipoma**

Thymolipoma is a rare benign thymic neoplasm that accounts for 2-9% of all thymic neoplasms. The mean age of presentation is 28 years and there is no gender predilection. Half of patients are asymptomatic. Usually symptoms occur when the tumor reaches large dimensions.

CT imaging features of this tumor consist of a unilateral or bilateral well-defined anterior mediastinal mass with slow growth. It may conform to the shape of adjacent structures and change its shape with different body positions, due to its pliable nature. Normally thymolipoma shows a discernible anatomic connection to the thymus (pedicle). It demonstrates mixed fat and soft tissue attenuation.

**Lymphoma**
Thymic lymphoma may occur as part of disseminated disease but isolated involvement is also possible. Hodgkin lymphoma is the most common form of thymic lymphoma with nodular sclerosis being the most frequent histologic type.

CT findings include enlargement of the gland, normally forming single or multiple masses and difficult to distinguish from thymoma or from thymic hyperplasia. A homogeneous enlargement of the thymus in the presence of mediastinal or hilar lymphadenopathy suggests lymphoma.
Fig. 1: Normal thymus. (A) 2.5 months old infant; (B) 5 years old girl; (C) 10 years old boy; (D) 25 years old man. In these axial CT views it is clear the normal development of the thymus. The quadrilateral morphology of younger ages is gradually replaced by a triangular form in older ages. The thickness of the gland decreases over time and by the third decade of life the thymus is reduced to a thin amount of tissue.

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**Fig. 2:** True thymic hyperplasia. Four different patients showing enlargement of the thymus (arrows) without a discernible focal mass. (A and B) Rebound hyperplasia following chemotherapy. (C and D) Rebound hyperplasia after corticosteroid therapy.

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**Fig. 3:** Lymphoid thymic hyperplasia. (A) In this young adult man with Wegener granulomatosis, a heterogeneous unilateral enlargement of the thymus is observed (arrow), which prompted a biopsy that revealed follicular thymic hyperplasia, characteristic in patients with vasculitis. (B) In this young adult woman with myasthenia gravis, an enlarged thymus preserving its triangular morphology is identified (arrow), compatible with lymphoid hyperplasia.

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Fig. 4: Thymoma. These axial CT views of three different patients depict pre-vascular anterior mediastinal nodules of variable size and shapes, representing WHO type A thymomas (arrows). (A) Round contour centrally located. (B) Oval shape, lateralized to the left. There is also bilateral small volume pleural effusion, more expressive on the left. (C) Lobular contour, lateralized to the right.

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**Fig. 5:** Thymoma. Axial CT views revealing more examples of patients with thymoma (arrows) of variable sizes and shapes. (A) A lobular mass in the anterior mediastinum representing a WHO type AB thymoma. There is a small calcification within the mass. (B) A large mass protruding into the right lung from the mediastinum represents a WHO type B1 thymoma. The mass is only slightly heterogeneous. (C) Another large mass protruding into the right lung depicting a WHO type B2 thymoma. There is a significant area of low attenuation (*) that corresponds to necrosis.

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Fig. 6: Thymoma. Axial CT views exhibit two examples of WHO type B3 thymomas (arrows). (A) A large mass lateralized to the left with lobulated borders showing mainly peripheral calcifications and a central area of decreased attenuation, probably necrotic. There is invasion of mediastinal fat, an imaging finding that is suggestive of a more invasive histologic type. (B) In this patient there is a smaller lobulated anterior mediastinal mass that shows tiny calcifications and heterogeneous enhancement. Mediastinal fat invasion is also present.

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Fig. 7: Thymic carcinoma. (A) PA chest radiograph of this middle-age woman with dyspnea shows obliteration of the two inferior thirds of the right lung and the meniscus sign, suggesting the presence of pleural effusion. (B) The corresponding CT scan demonstrates a bulky homogeneous mass (arrow) pushing the heart to the left with associated pleural effusion (*) and atelectasis of the right lung.

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Fig. 8: Pleural metastases. (A and B) These two patients had surgery for an invasive thymoma (WHO type B3). Pleural implants (arrows) were detected during follow-up CT scans. No pleural effusion is seen. (C) In this middle-age man, pleural metastasis from thymic carcinoma (arrow) was detected during follow-up.

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Fig. 9: Thymolipoma. (A and B) Axial and coronal CT views show a mediastinal mass lateralized to the right (arrows) demonstrating predominantly fat attenuation, with some strands of soft tissue attenuation. Despite its large size, the mass does not deflect the mediastinum, conforming to the shape of adjacent structures.

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Fig. 10: Thymic lymphoma. Four images of a 20 year old woman with a histologic diagnosis of nodular sclerosis Hodgkin lymphoma involving the thymus. (A) Chest PA radiograph demonstrates enlargement of the mediastinal shadow. (B and C) Coronal and axial CT views depict a heterogeneous bulky mediastinal mass with areas of low attenuation suggestive of necrosis (arrows) compressing the heart and great vessels. (D) The presence of mediastinal adenopathy (arrowhead) also suggests the diagnosis of thymic lymphoma.

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Conclusion

Presently, naming the thymus "organ of mystery" as Galen once did has little meaning.

Familiarity with the most frequent CT aspects of benign and malignant conditions involving the thymus is necessary to improve the diagnostic accuracy, preventing additional exams or invasive procedures thus improving patient management.

Knowledge of the classification systems for thymic epithelial tumors (especially the WHO classification) can provide a more detailed report with special focus on tumor characteristics that may influence prognosis, thereby contributing to the physician’s treatment decisions.
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