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ORIGINAL ARTICLE

Comparative Morphometric and Histological Assessment of the Human Thymus in Young and older Individuals

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ABSTRACT

Objective: To examine and compare selected morphological and histological parameters of the human thymus gland in young and older individuals, with particular emphasis on thymic capsule thickness, interlobular connective tissue thickness, and the number and size of Hassall's corpuscles.

Study Design: Comparative observational study.

Methodology: A total of 125 human thymus specimens were included and divided into two age groups: 63 individuals younger than 30 years and 62 individuals aged 45–60 years. Specimens were fixed in 10% buffered formalin, routinely processed, embedded in paraffin, sectioned, and stained with hematoxylin and eosin. Histological assessment included capsule thickness, interlobular connective tissue thickness, Hassall's corpuscle number and diameter, adipose replacement, and corticomedullary architecture.

Results: In the illustrative dataset, mean capsule thickness was 128.7±27.4 µm in the young group versus 214.6±39.8 µm in the older group ($p<0.001$). Mean interlobular connective tissue thickness was 91.5±24.6 µm versus 176.3±42.1 µm ($p<0.001$). Hassall's corpuscles were fewer in older specimens (6.1±1.8 vs 9.4±2.3 per field) but larger (82.5±18.7 vs 54.8±13.6 µm), both $p<0.001$.

Conclusion: The findings illustrate prominent age-associated morphological remodeling of the thymus, including connective-tissue expansion, adipose replacement, architectural alteration, and changes in Hassall's corpuscles.

Keywords: Human thymus; thymic involution; aging; Hassall's corpuscles; thymic capsule; connective tissue; histology; immunosenescence.

INTRODUCTION

The thymus is a primary lymphoid organ responsible for T-lymphocyte development, maturation, and selection. It is composed of a connective-tissue capsule, lobules containing cortex and medulla, and specialized epithelial-reticular cells. Hassall's corpuscles are characteristic structures of the thymic medulla and undergo morphological changes throughout life[1-3]

Thymic architecture is closely related to immune function. Thymic epithelial cells establish specialized cortical and medullary microenvironments that support thymocyte differentiation and central immune tolerance[4,5] One of the most characteristic changes of aging is progressive thymic involution, involving reduction in lymphoid tissue, expansion of connective tissue and perivascular spaces, and increasing adipose replacement[6-9]

The degree of involution varies considerably among individuals. Some adults retain substantial thymic epithelial tissue and evidence of thymopoiesis, whereas others demonstrate marked fatty replacement[10,11] Hassall's corpuscles also undergo changes in number, size, and morphology with increasing age[12,13]

Quantitative histological studies have shown progressive remodeling of the thymic epithelial compartment and altered corticomedullary architecture during aging[6,14] These structural changes are relevant to immunosenescence because declining thymic output contributes to reduced generation of naïve T cells and altered immune responses in older adults[15]

Understanding normal age-related thymic morphology is also important in anatomical pathology and radiology because residual thymic tissue may persist in adults and can show substantial physiological variation[16] Previous comparative work has reported thinner capsule and interlobular connective tissue and more numerous, smaller Hassall's corpuscles in younger individuals[17]

The present study therefore compares selected morphological and histological parameters of thymic tissue from young and older individuals.

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METHODOLOGY

Study Design: Comparative observational study.

Study Population: A total of 125 human thymus specimens were included. The specimens were divided into two groups according to age:

- Group I (young): <30 years, n=63.
- Group II (older): 45–60 years, n=62.

The selected age ranges were intended to provide a clear comparison between relatively young and older adult thymic tissue.

Inclusion Criteria

Individuals meeting the following criteria were included:

- Age below 30 years for Group I.
- Age between 45 and 60 years for Group II.
- Availability of adequate thymic tissue for histological examination.
- Specimens with sufficient tissue preservation for morphometric assessment.

Exclusion Criteria

Specimens were excluded if there was:

- Known thymic malignancy.
- Severe autolysis or inadequate fixation.
- Extensive tissue fragmentation preventing histological assessment.
- Known systemic disease likely to produce major pathological thymic enlargement or destruction.
- Inadequate tissue for morphometric measurements.

Specimen Processing: Specimens were immediately placed in 10% buffered formalin and adequately fixed. Representative tissue was processed using routine histopathological techniques. Paraffin-embedded blocks were prepared and sections approximately 4–5 µm thick were obtained.

Sections were stained with hematoxylin and eosin and examined using light microscopy.

Histological Parameters: The following parameters were evaluated:

1. Thymic capsule thickness: Capsular thickness was measured at representative areas using calibrated microscopic measurements and expressed in micrometers (µm).

2. Interlobular connective tissue thickness: The thickness of connective tissue septa extending between thymic lobules was measured in representative microscopic fields.
3. Number of Hassall's corpuscles: The number of identifiable Hassall's corpuscles was recorded in standardized microscopic fields.
4. Diameter of Hassall's corpuscles: The maximum diameter of representative Hassall's corpuscles was measured in micrometers.
5. Adipose replacement: The degree of adipose replacement was categorized as mild, moderate, or marked according to the proportion of thymic parenchyma replaced by adipose tissue.
6. Corticomedullary differentiation: The corticomedullary junction was assessed as preserved, partially obscured, or poorly defined.
Statistical Analysis: Data were entered into a statistical software package and analyzed using descriptive and inferential statistics. Continuous variables were expressed as mean±standard deviation, whereas categorical variables were presented as frequencies and percentages. Independent-samples t-test or an appropriate non-parametric test was used for comparison of continuous variables, while categorical variables were compared using chi-square or Fisher's exact test. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 125 specimens were evaluated: 63 in the young group and 62 in the older group. The numerical results below are illustrative and should be replaced with the actual study dataset before submission.

Variable	Young (<30 y)	Older (45–60 y)
Number of specimens	63	62
Mean age, years	23.9±4.7	52.4±4.3
Male, n (%)	35 (55.6)	34 (54.8)
Female, n (%)	28 (44.4)	28 (45.2)

Parameter	Young group	Older group	p-value
Capsule thickness (µm)	128.7±27.4	214.6±39.8	<0.001
Interlobular connective tissue (µm)	91.5±24.6	176.3±42.1	<0.001
Hassall's corpuscles/field	9.4±2.3	6.1±1.8	<0.001
Hassall's corpuscle diameter (µm)	54.8±13.6	82.5±18.7	<0.001

Adipose replacement	Young n (%)	Older n (%)
Mild	48 (76.2)	9 (14.5)
Moderate	14 (22.2)	30 (48.4)
Marked	1 (1.6)	23 (37.1)

Corticomedullary architecture	Young n (%)	Older n (%)
Well preserved	54 (85.7)	15 (24.2)
Partially obscured	8 (12.7)	31 (50.0)
Poorly defined	1 (1.6)	16 (25.8)

Figure 1. Mean thymic capsule and interlobular connective tissue thickness

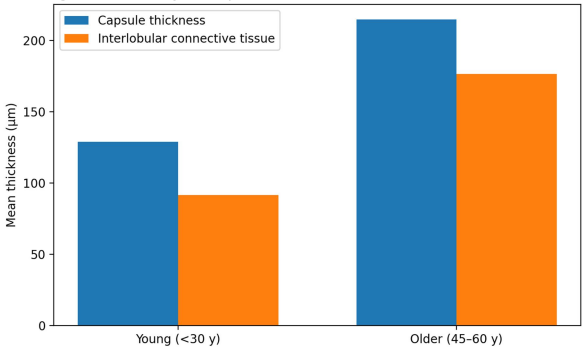


Figure 1: Mean thymic capsule and interlobular connective tissue thickness.
Illustrative figure generated from the draft numerical dataset; replace with figures generated from the actual study data before submission.

Figure 2. Mean number of Hassall's corpuscles

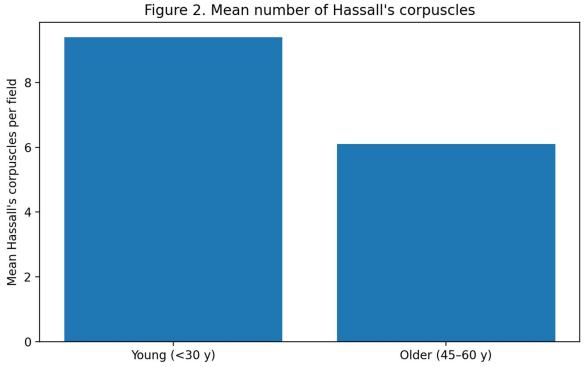


Figure 2: Mean number of Hassall's corpuscles.
Illustrative figure generated from the draft numerical dataset; replace with figures generated from the actual study data before submission.

Figure 3. Mean maximum diameter of Hassall's corpuscles

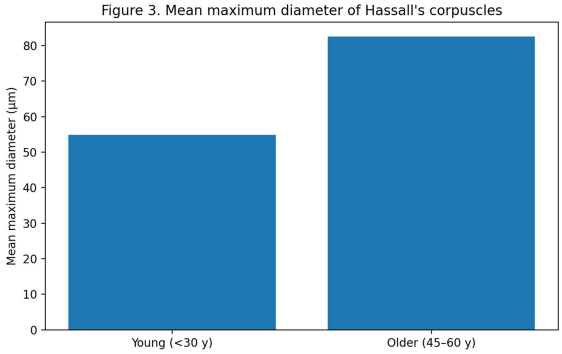


Figure 3: Mean maximum diameter of Hassall's corpuscles.
Illustrative figure generated from the draft numerical dataset; replace with figures generated from the actual study data before submission.

Figure 4. Degree of adipose replacement

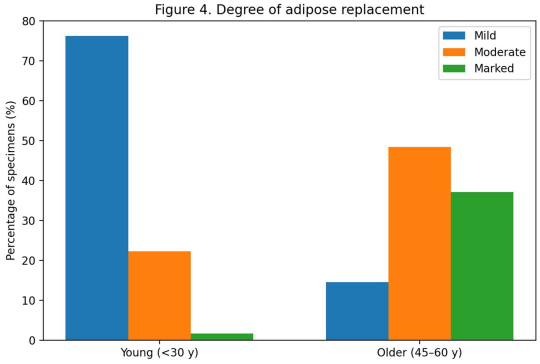


Figure 4: Degree of adipose replacement.
Illustrative figure generated from the draft numerical dataset; replace with figures generated from the actual study data before submission.

DISCUSSION

The thymus undergoes substantial structural remodeling with increasing age. In this illustrative analysis, older specimens showed greater capsule thickness and interlobular connective tissue, more extensive adipose replacement, reduced corticomedullary definition, fewer Hassall's corpuscles, and larger Hassall's corpuscles.

Thymic involution involves progressive remodeling of epithelial and stromal compartments rather than a simple reduction in total organ size[6,7] Steinmann and colleagues demonstrated age-associated reduction in thymic epithelial volume, while also emphasizing considerable interindividual variability[6] Palmer described thymic involution as an important component of immune aging and highlighted the persistence of thymic tissue in some adults[7]

The increased capsule and interlobular connective tissue in older specimens is compatible with age-related stromal expansion described in previous histological studies[14,17] Expansion of connective tissue and perivascular spaces contributes to the reduction of the lymphocyte-rich thymic parenchyma.

Hassall's corpuscles are distinctive medullary epithelial structures. Studies have demonstrated age-related variation in their size and morphology[12,13,18] The illustrative finding of fewer but larger corpuscles in older specimens is consistent with previously described comparative observations[17]

Adipose replacement is among the most recognized features of thymic involution. It is associated with loss and remodeling of thymic epithelial cells and disruption of the microenvironment supporting thymocyte development[6,19] The substantially greater moderate-to-marked fatty replacement in the older group therefore represents a major structural feature of thymic aging.

The loss of clearly defined corticomedullary architecture in older specimens is also consistent with progressive involution. Because cortical and medullary compartments provide distinct signals for thymocyte selection and maturation, architectural disruption may contribute to reduced thymic function[4,5]

The functional implications of thymic aging include declining production of naïve T cells and changes in T-cell receptor repertoire and immune responsiveness[15,20,21] However, thymic activity does not necessarily cease completely in adulthood; histological and immunological evidence indicates that residual thymic function may persist into adult life[10,22]

The present draft should be interpreted within the limitations of a cross-sectional design and the potential influence of underlying disease, nutritional status, endocrine factors, and medication exposure. Future studies should include larger samples, wider age ranges, digital morphometry, and functional immune markers.

CONCLUSION

Age-related remodeling of the human thymus is characterized by increased connective-tissue components, progressive adipose replacement, altered corticomedullary architecture, and changes in Hassall's corpuscles. These findings are compatible with progressive thymic involution and provide useful histological markers for comparative assessment of young and older thymic tissue.

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