Deep Learning Solution for the Automated Assessment of the Rodent Thymus

Rajesh Ugalmugle [1], Deb Tokarz [2], Dev Kumar Das [1], Gunjan Deotale [1], Tijo Thomas [1], Uttara Joshi [1]

[1] AIRA Matrix, Mumbai, India. [2] Experimental Pathology Laboratories, Inc., Durham, NC, USA

Objective

To develop a Deep Learning (DL) algorithm for automated segmentation of cortex and medulla followed by detection and quantification of lymphocyte apoptotic changes in Whole Slide Images (WSI) of Hematoxylin and Eosin (H&E) stained sections of rodent thymus.

Introduction

Thymus, a primary lymphoid organ, is a sensitive target following exposure to immunotoxins. Reduction in cortical lymphocytes is a major histopathological finding in compound induced effects. Hence, evaluating the corticomedullary ratio, and assessing the cortical lymphocytes is important.

Manual histopathological assessment of these features is time-consuming and qualitative. We developed a deep learning solution for the automated assessment of the rodent thymus. The solution separately identifies the cortex and medulla, computes the corticomedullary ratio, and quantifies lymphocytes and apoptotic cells in these compartments.

Materials & Methods

- WSIs of 320 H&E-stained Wistar rat thymus sections from seven sources were used.
- Training patches were generated from 240 WSI, while the remaining 80 WSIs were retained for blind testing.
- Separate U-Net based models were trained to segment the cortex, medulla, lymphocytes and apoptotic cells.
- Data from seven laboratories (5 labs were used for training and 2 labs were used for testing) was included to make the model more robust and generalized.
- Models have been tested on both control and treated data separately to estimate threshold based on box plot (Figure. 2).
- Table 1 describes Precision and Recall numbers based on ground truth data marked. Whereas, Table 2 numbers are based on validation provided by Pathologist 1 (P1) and Pathologist 2 (P2).

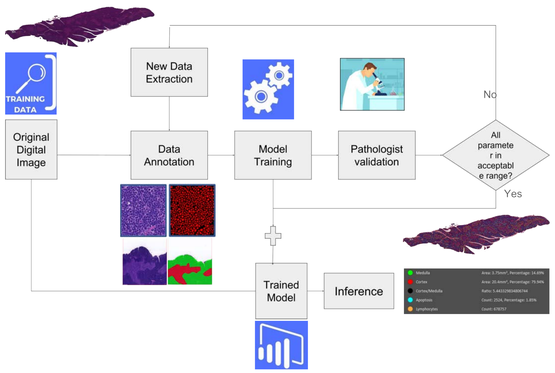


Figure 1 : Workflow diagram of training and inference pipeline for the proposed approach.

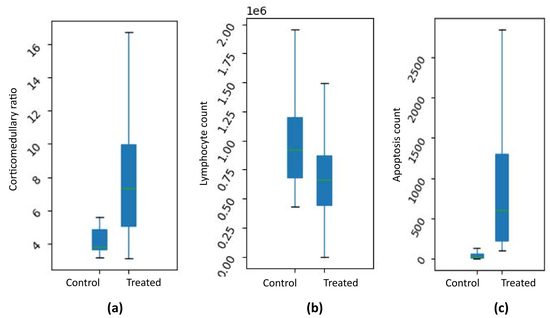
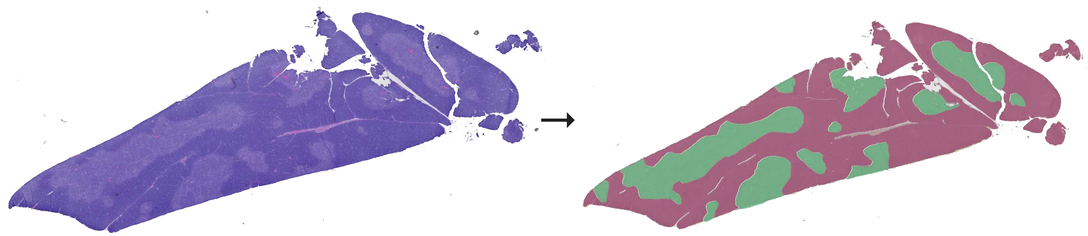
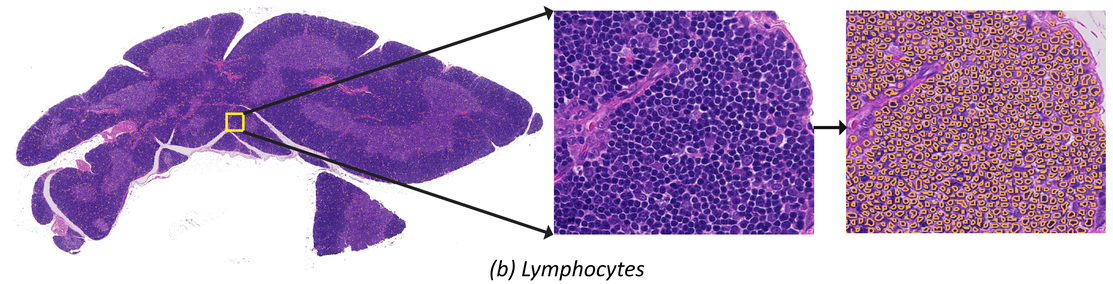


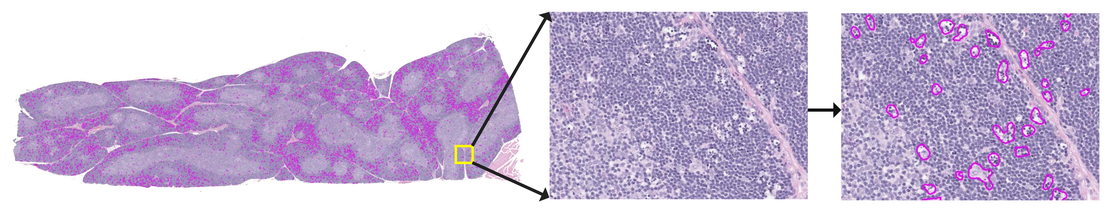
Figure 2 : Box whisker plot showing data distribution for corticomedullary ratio
(a), lymphocyte count
(b) and apoptosis count
(c) in control and treated group.



(a) Cortex vs Medulla



(b) Lymphocytes



(c) Apoptotic cells

Figure 3 : WSI level detection for Cortex vs Medulla (a), Lymphocytes (b) and Apoptotic cells (c).

Results

- The DICE scores (F1-scores) were: 94% for the cortex, 98% for the medulla, 85% for apoptosis and 88% for lymphocytes.
- The trained model achieved a precision of 97% and recall of 91% averaging over four parameters when compared with pathologist's observations.

	Training performance (F-score)		
Parameter	Training WSI	Training	Validation
Apoptosis	80	0.90	0.85
Lymphocytes	30	0.86	0.77
Cortex/Medulla	130	0.98/0.95	0.97/0.94

Table 1 : Model performances on training dataset

	Training performance (F-score)					
Parameter	Test WSI		Precision (%)		Recall (%)	
	P1	P2	P1	P2	P1	P2
Apoptosis	50	25	95.8	97.9	90.1	96.7
Lymphocytes	50	25	83.7	99	78.5	98.5
Cortex/Medulla	80	25	95/98	98/99	93/95	98/97

Table 2 : Model performances on blind test dataset

Conclusion

- The proposed deep-learning solution can accurately segment and quantify cortex and medulla. The solution can also quantify lymphocytes and apoptotic cells.
- This solution can be used as a supportive tool for detecting decreased cortical lymphocyte cellularity in the thymus.

Impact Statement

This solution has the potential to be used as an adjunct in the enhanced histopathological evaluation of the thymus.

Objective

Susan A. Elmore. Enhanced Histopathology of the Thymus. Toxicol Pathol. 2006;34: 656-665.