Title
Deep Learning for Parotid Tumor Segmentation and Screening

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Introduction and Clinical Significance

Introduction

Parotid tumors represent over 70% of all salivary gland masses. Automated, accurate segmentation of parotid tumors is a critical step in computational image analysis and incidental parotid tumor screening can be a valuable diagnostic aid in busy clinical practices. This study proposes a deep learning solution for parotid tumor segmentation and screening.

Clinical Significance

The proposed automated algorithm can accurately: (1) detect incidental parotid masses on routine CT exam; (2) segment parotid tumors for calculation of tumor volume.

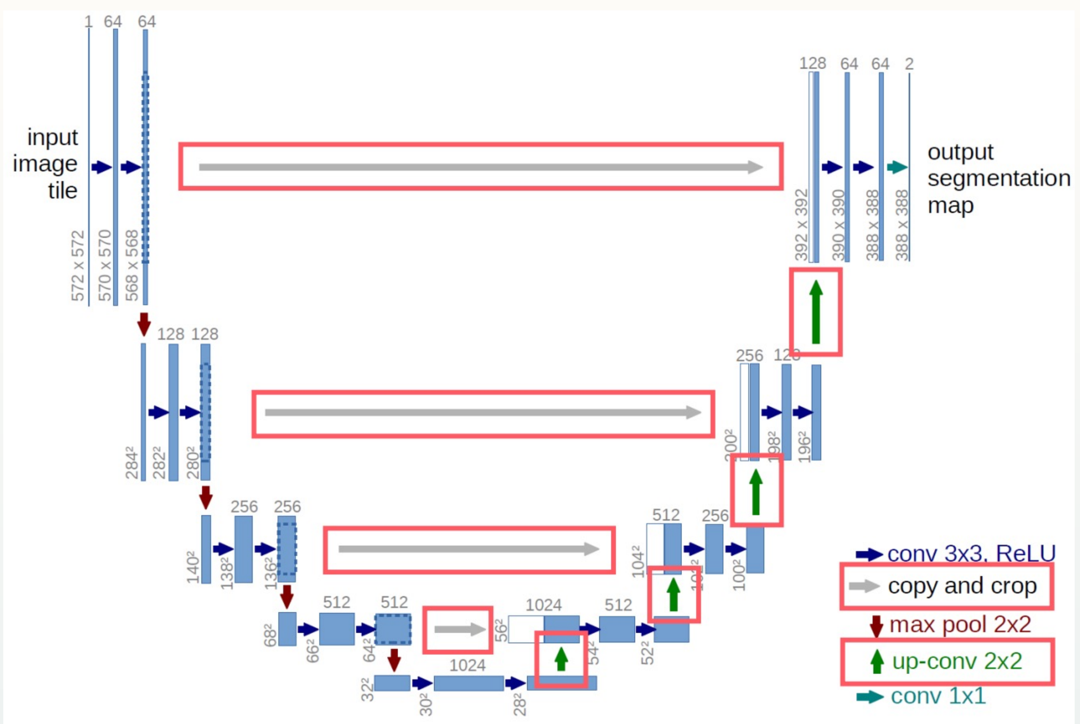

Figure 1. Structure of contracting-expanding (U-Net) segmentation model.

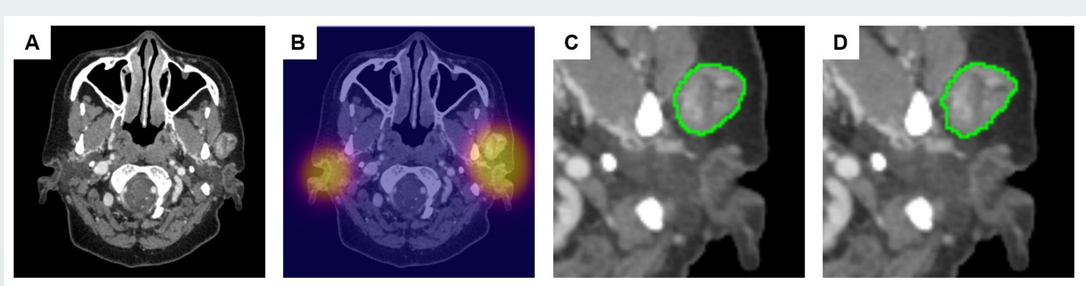

Figure 2. Overview of two-step deep learning algorithm for parotid mass detection and segmentation. (A) Original full resolution CT exam is used by initial deep learning localization algorithm to generate prediction heatmaps (B) isolating the right and left parotid glands. The initial localization algorithm outputs are used to generate cropped volumes of each individual parotid gland, after which a second segmentation algorithm is used to identify parotid masses. (C) Final algorithm output, and (D) corresponding ground-truth annotation show high consensus.

Methods

- **Segmentation task: outlining the tumor**
  - Correctly identifying the boundaries
- **Screening task: binary identification**
  - Tumor or no tumor anywhere in the scan
- CT scans visually inspected for the presence of a parotid mass > 10 mm
  - Histopathology used to verify diagnosis
- Ground truth 3D tumor masks generated for each patient
  - Gold standard: all annotations were performed by a CAQ-certified neuroradiologist
  - CT neck protocols and routine exams (including head CT) included to maximize algorithm generalizability
- Two serial 3D deep learning algorithms were developed.
  - Algorithm localizes the right/left parotid glands individually
  - Cropped volumes generated by the first algorithm are inputs into a 3D contracting-expanding (U-Net) segmentation model
  - 5-10% boost from deep supervision incorporated into a standard U-Net model
  - Both models implemented using an identical 3D network comprised of 15 convolutional layers and 578,089 parameters

References

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Results

Study results: positive cases only

201 patients with parotid masses identified from two academic medical centers (N=100 for first site, N=101 from second site)

- Median tumor volume of 4.62 cm3
- Segmentation yielded a Dice score of 0.725
  - (IQR 0.500-0.788; test on N=40 hold-out patients)
- Excellent test performance
  - AUC: 0.956
  - Accuracy: 0.900
  - Sensitivity: 0.884
  - **Specificity: 0.919**
  - **PPV: 0.927**
  - NPV: 0.872
- No significant differences in performance between different academic centers or imaging protocols ($p > 0.05$)

Study results: incorporating negative cases

401 scans (201 original positive scans, 200 new negative scans)

- **Deep learning model yielded 8 positive predictions not identified in the original radiology report**
- Parotid mass segmentation yielded a Dice score of 0.65
- Binary classification performance excellent
  - Given Gamma=5, specificity > 95% and PPV > 90% with tumor threshold size of 500 pixels
- Specificity and PPV are highest priority
  - Flag likely cases without causing notification fatigue
  - Incremental amount of definitive gain