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Classification of Endotracheal Tube Positioning on Chest XR using a Convolutional Neural Net Trained with Annotated Images

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Introduction

Endotracheal tube intubation is often used when patients are ill and require respiratory assistance. These tubes must be positioned properly in relation to the carina; too high and the lungs may not be respirated, too low and only one lung may be respirated. Our institution receives approximately 4,000 XR Chest images every day, 5% of which contain an endotracheal tube. If the tube is determined to be malpositioned by the reading radiologist, this information is relayed back to the site for tube adjustment.

Hypothesis

We hypothesized that by training a convolution neural net using annotations of Chest XR images, we could localize both the endotracheal tube and the carina on prospective Chest XR data and use this information to classify images as having a malpositioned tube or not, along with the distance in cm that the tube must be adjusted if malpositioned.

Methods

In total, 1,750 XR Chest studies with endotracheal tubes present were annotated on our viewing platform by one of five radiologists. Bounding boxes were drawn around both the tube and the carina and the coordinate information of these boxes was saved. In addition, each study was generally classified as malpositioned or not malpositioned. The image and box data for 1,670 patients was used to train a convolutional neural net model based on the yolo-v3 template. This model was then applied to a test set of the remaining 80 patients. To calculate our tube positioning metric, the distance in pixels from the bottom of the tube box to the center of carina box was calculated and multiplied by the pixel spacing. These measurements were compared to the qualitative classification of malpositioned or not malpositioned. The model was then integrated into our teleradiology platform for a 24 hour period and natural language processing (NLP) of clinical reports was used to compare model results against report descriptions of endotracheal tubes.

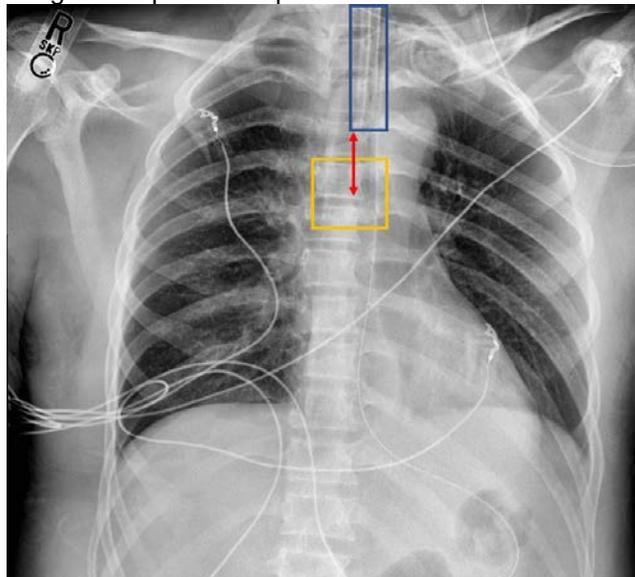


Figure 1: Automated localization of the endotracheal tube (blue box) and the carina (yellow box) on a Chest XR image as generated by the trained bounding box model. The tube distance in cm is calculated from these boxes (red arrow).

Results

For the test set, the optimal cutoff values for maximizing tube malpositioning accuracy were 1.4 cm and 5.2 cm. At these thresholds the sensitivity, specificity, and accuracy for the model detecting tube malpositioning were 87.5%, 97.5%, and 92.5%, respectively. For prospective data passing through our platform, the accuracy for the model detecting endotracheal tube presence was 99.1%. The median difference between model distance calculations and distance extracted from the clinical report was 0.72 cm.

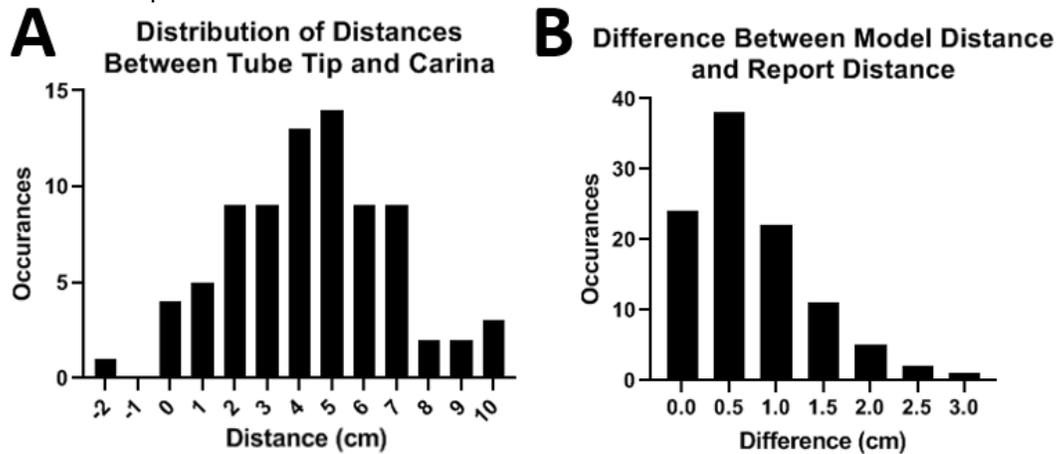


Figure 2: A) Histogram of distance values between the tube and carina for the test set. B) Histogram of differences between the model measurement and the report measurement for prospective data passing through the platform.

Conclusion

This technique utilizes machine learning and annotated image data to provide automated distance measurements between the tip of the endotracheal tube and the carina in intubated patients. These accuracy metrics can potentially be improved as we continue to collect annotated data.

Statement of Impact

To our knowledge, this project describes the first use of annotated Chest XR data to create an endotracheal tube positioning model. These results show our method can be used to automatically indicate the distance in cm to adjust the tube when provided an image. Obtaining this information immediately without waiting for a radiologist read can improve patient care and treatment efficiency.

Keywords

endotracheal tube, carina, machine learning, yolo, convolutional neural net, bounding boxes