Catheter Placement

Group 2.

This is our team.

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01

Introduction

Context

- Medical devices using in medical procedures to perform functions such as removing fluids or delivering medication
- Placed in veins connecting to stomach or heart
- Medical complications can arise due to malpositioned lines/tubes in patients
- Early detection can be extremely beneficial

Benefits and implications

Benefits

- Mitigate risk of human error
- Early detection of complications
- Faster decision making

implications

- Increased reliance of ai use for diagnostics
- Ethical and legal considerations

Benefits to Everyday Person

Specific to catheters:

- Classifying the catheter type
- Determining if position is correct

In general:

- Can be applied to other X-rays such as broken bones
- Automating detection can reduce wait times
- Process will be faster and cheaper

Project goals

- Create a range of binary classification models that detects each catheter type
- Create a multi-label classification model that can determine the positioning of a certain type of catheter
- This will allow incorrectly positioned catheters to be identified faster, speeding up processes and ensuring procedures are done correctly.

02

What is a Catheter?

Catheter Classifications

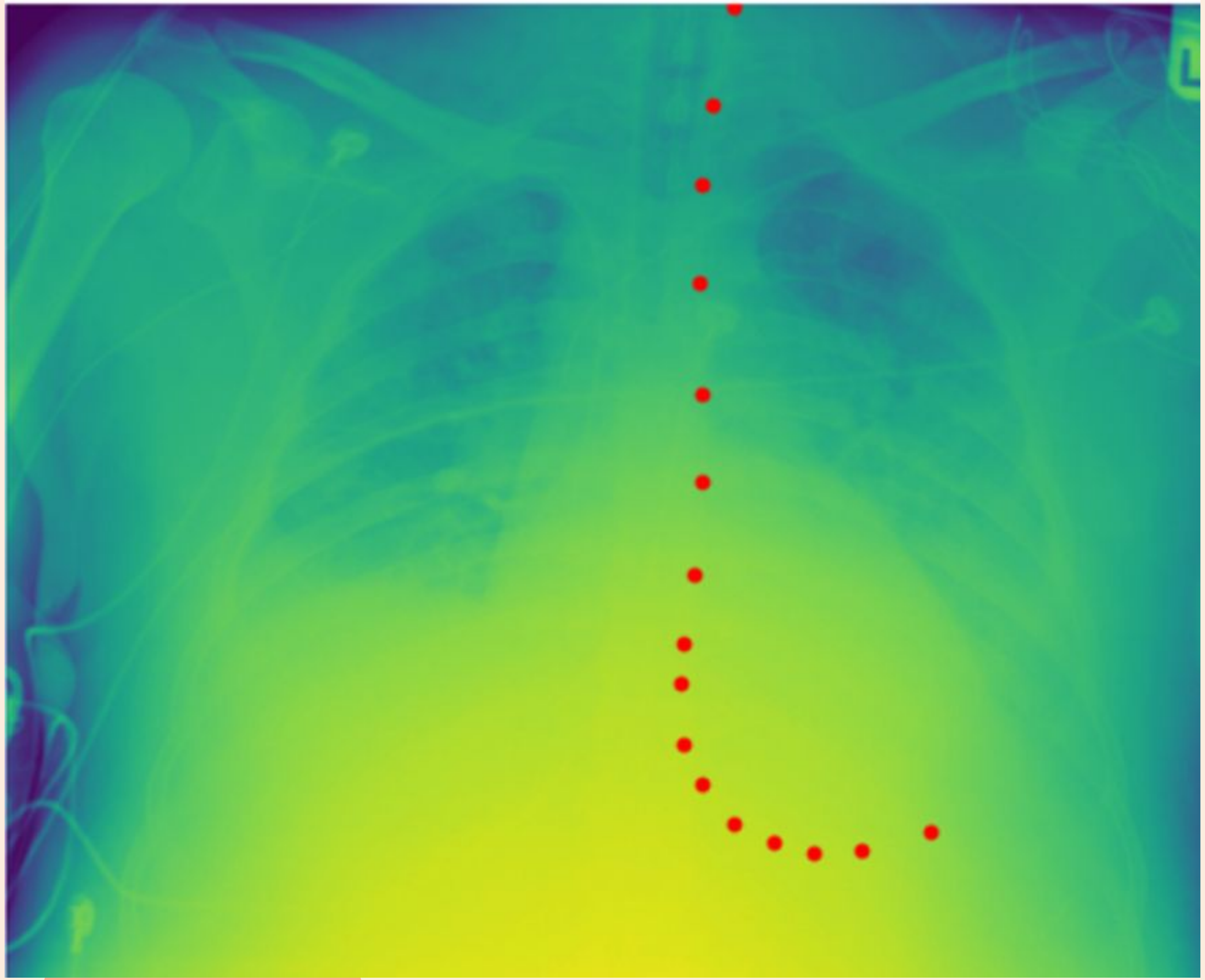
Types of catheters:

- NGT
- ETT
- CVC

Classifications:

- Normal
- Abnormal
- Borderline
- Incompletely Imaged

NGT – Nasogastric Tube (Normal)



Place of insertion:

- Nostril
- Mouth

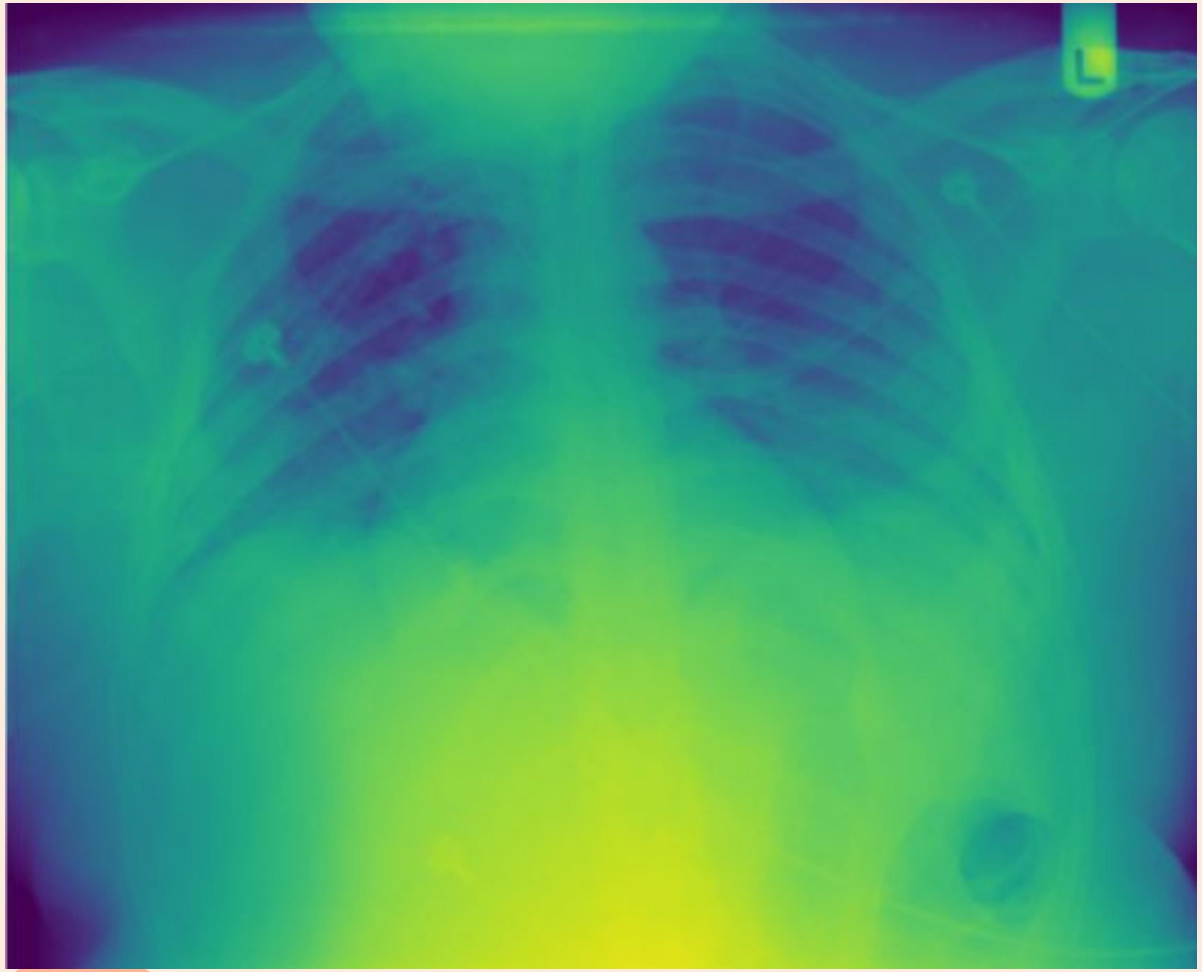
Where it sits:

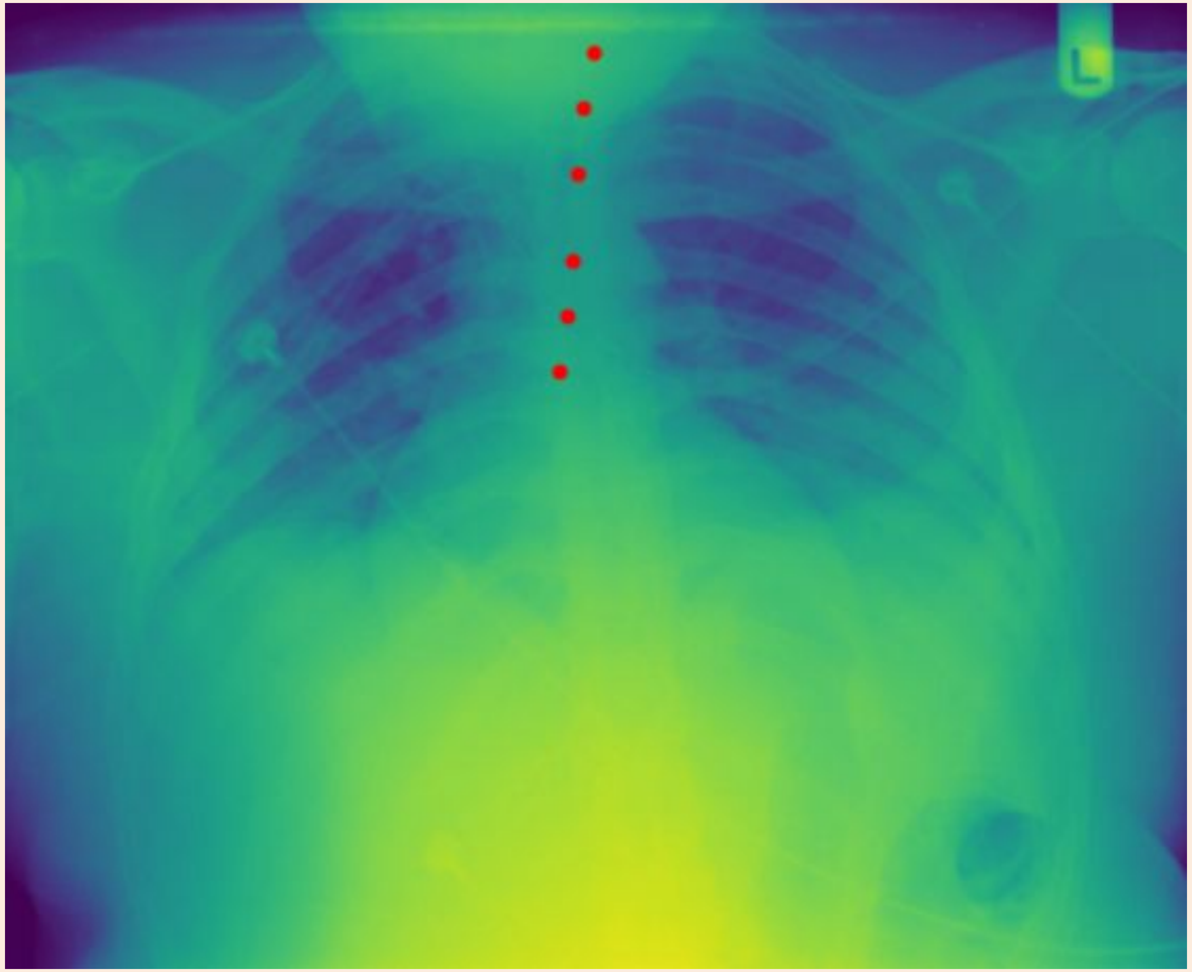
- Down the esophagus, in the stomach

What it does:

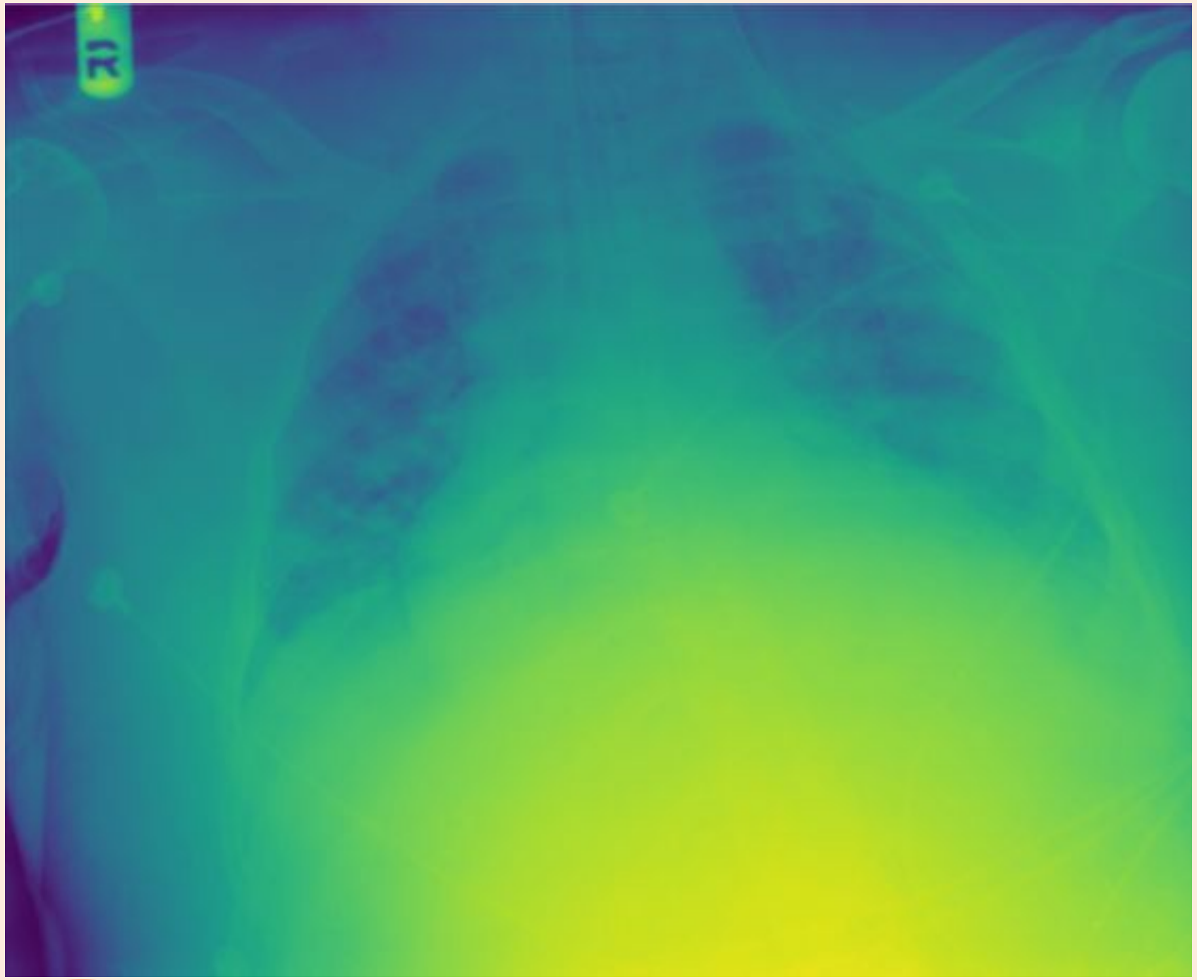
- Delivers food or medicine
- Draw substances out, e.g. poisons

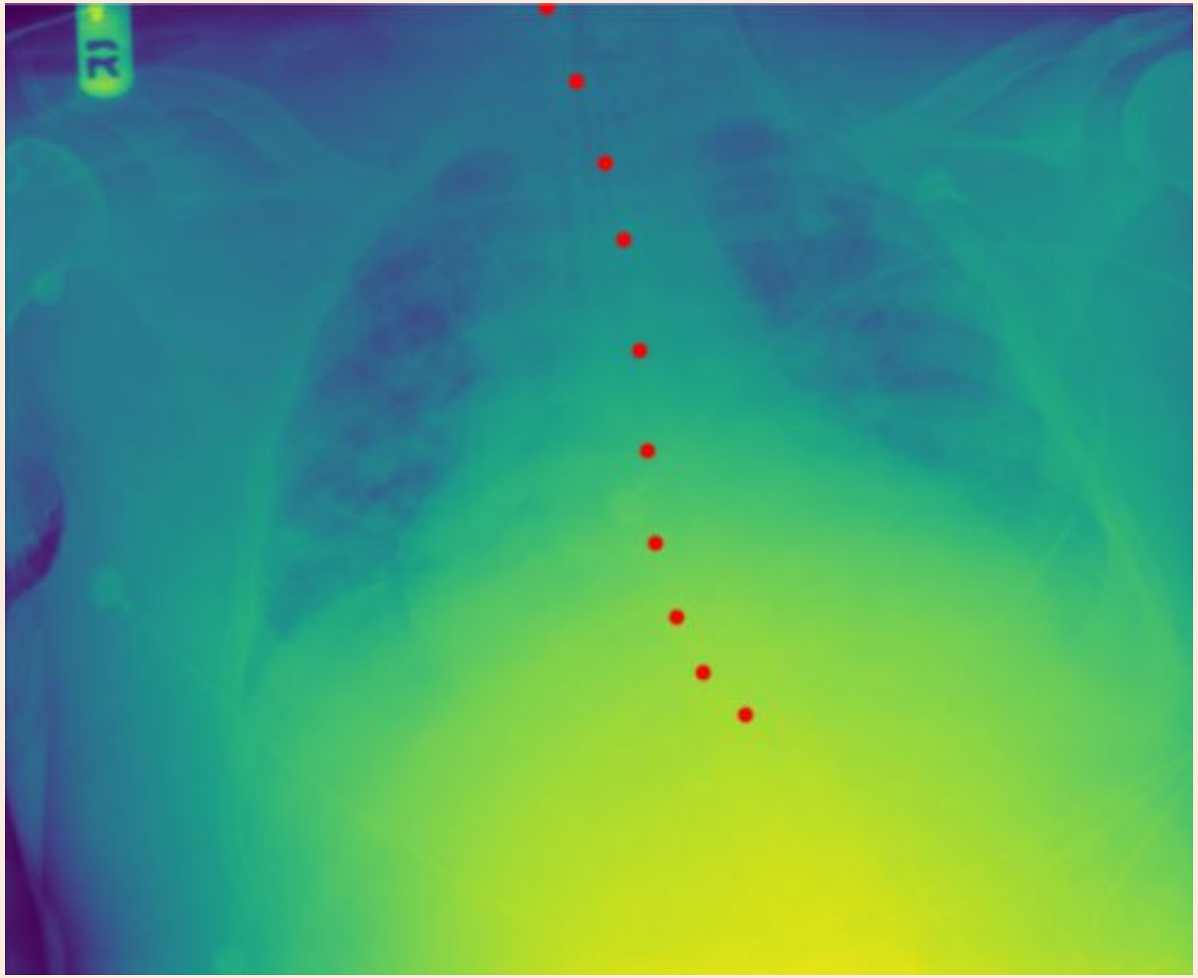
NGT Abnormal



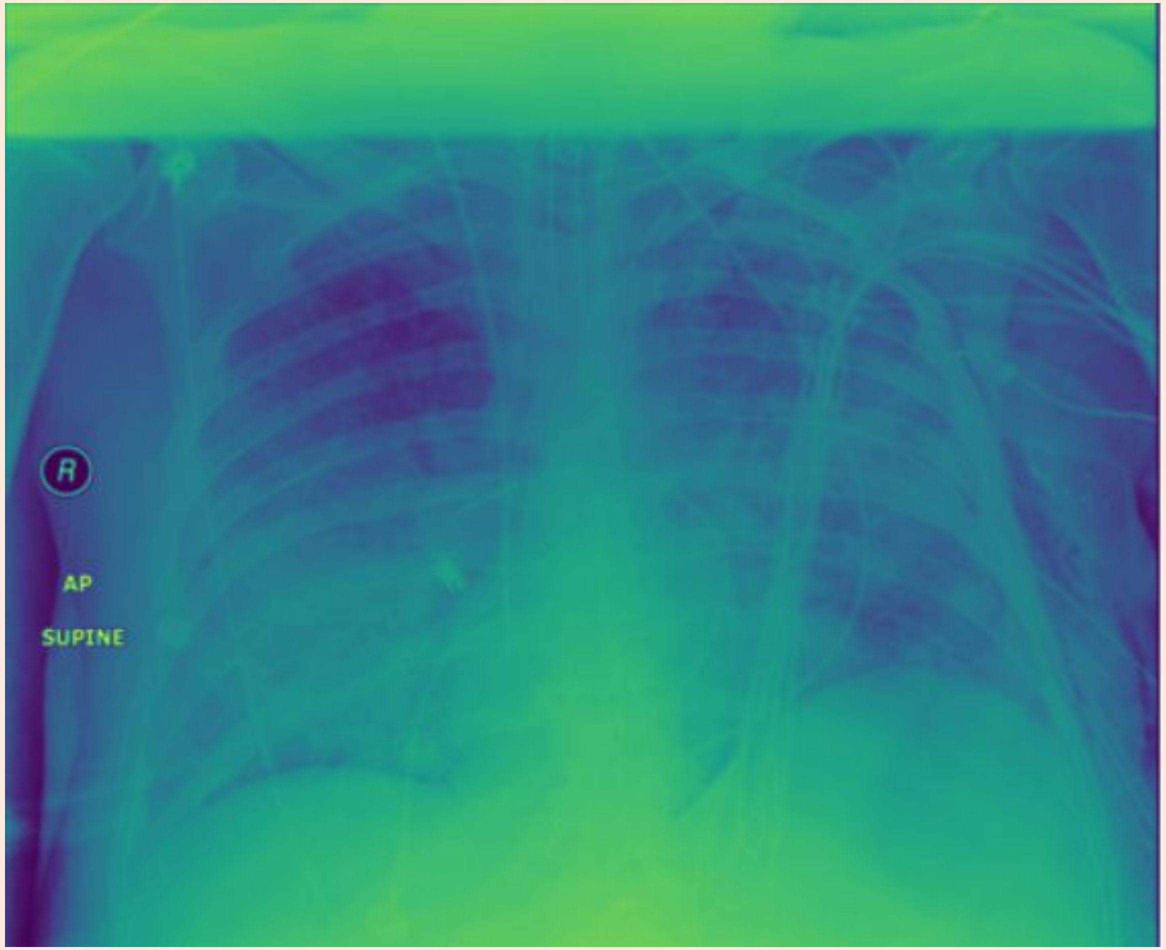


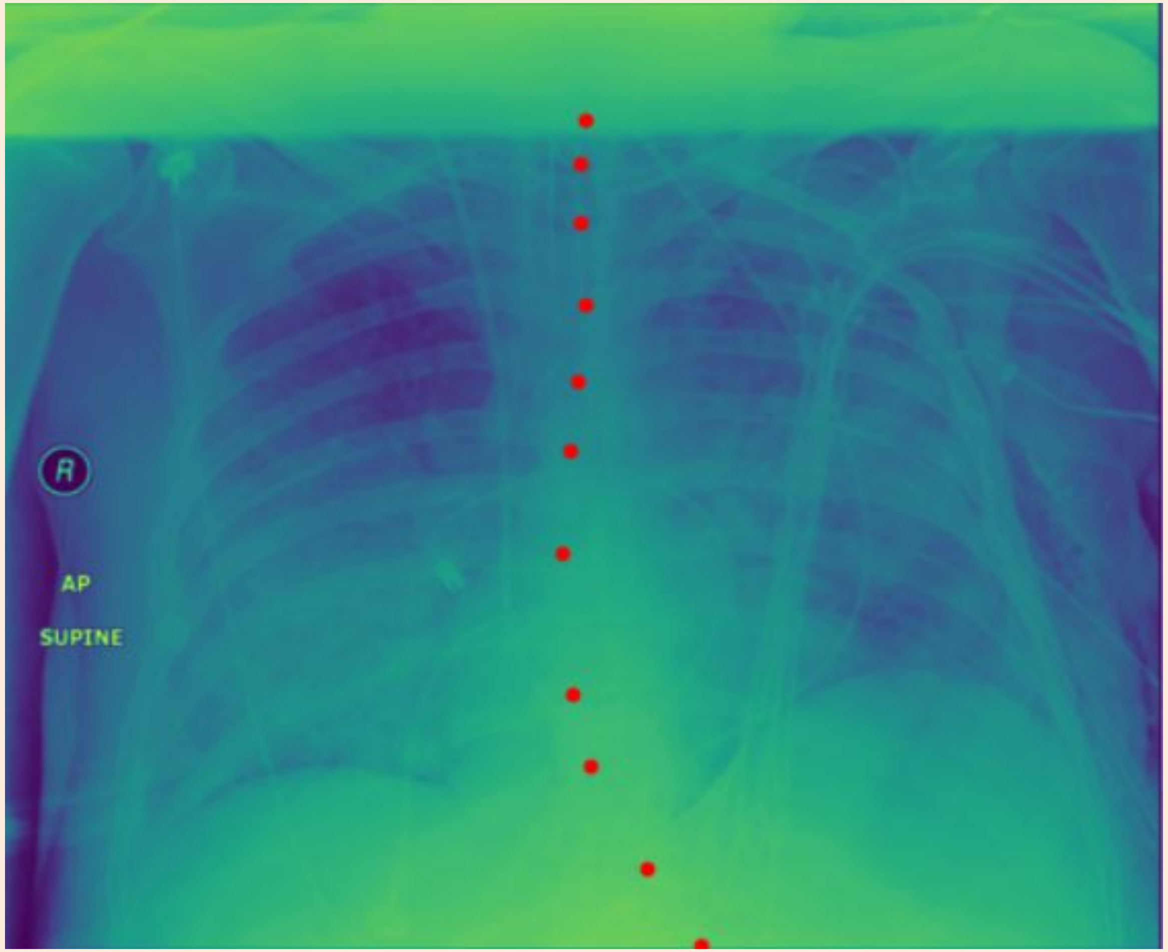
NGT Borderline



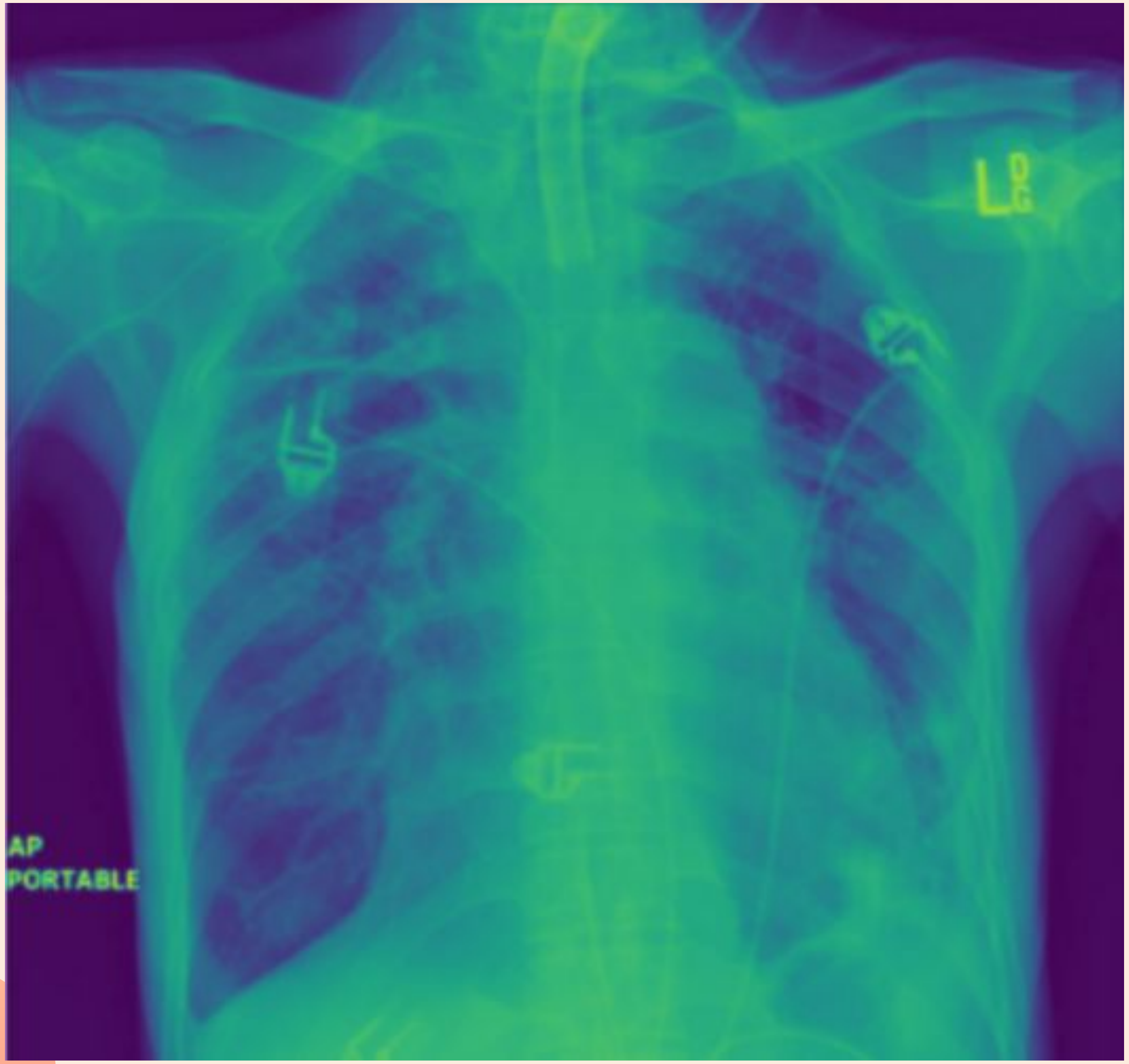


NGT Incompletely Imaged





ETT – Endotracheal Tube (Normal)

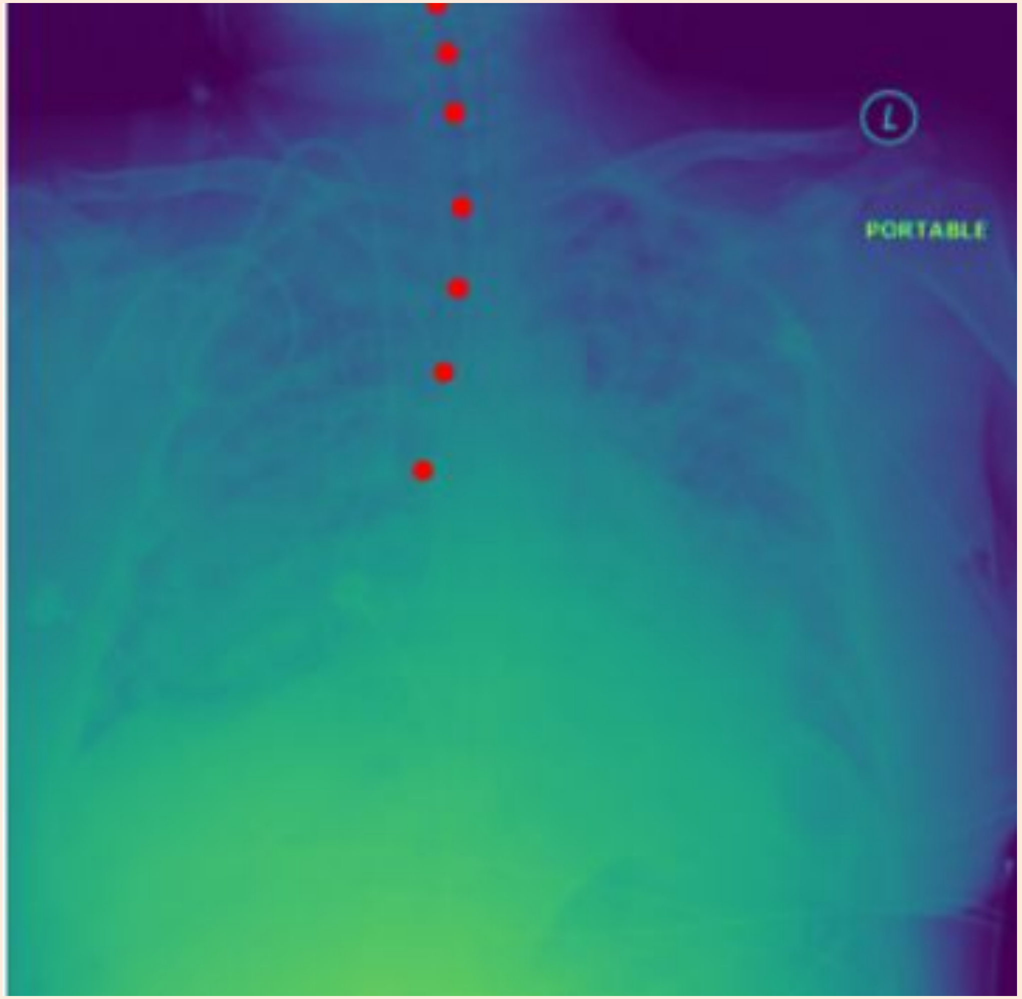


Place of insertion:
- Mouth (common in emergencies) or nose

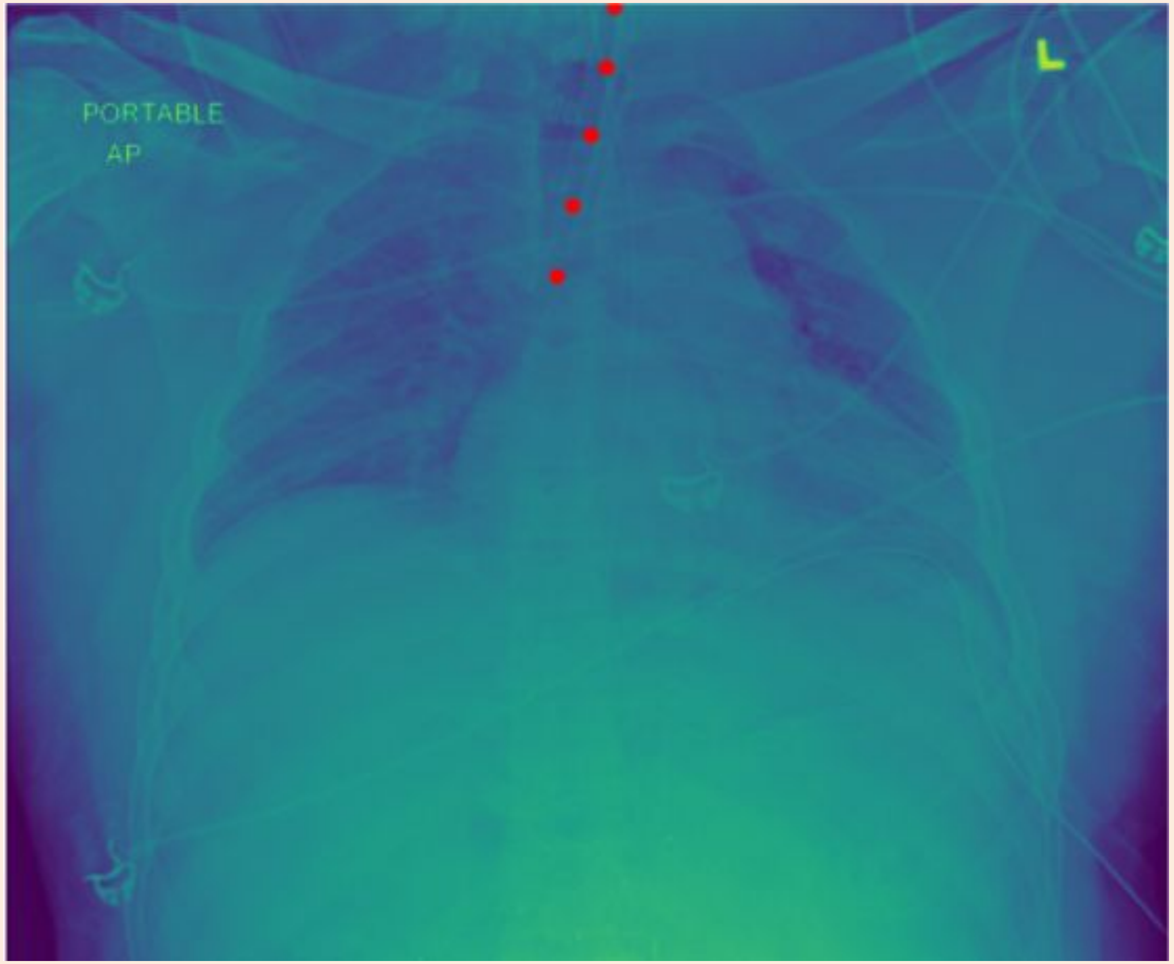
Where it sits:
- In the windpipe
- Just below the collarbones

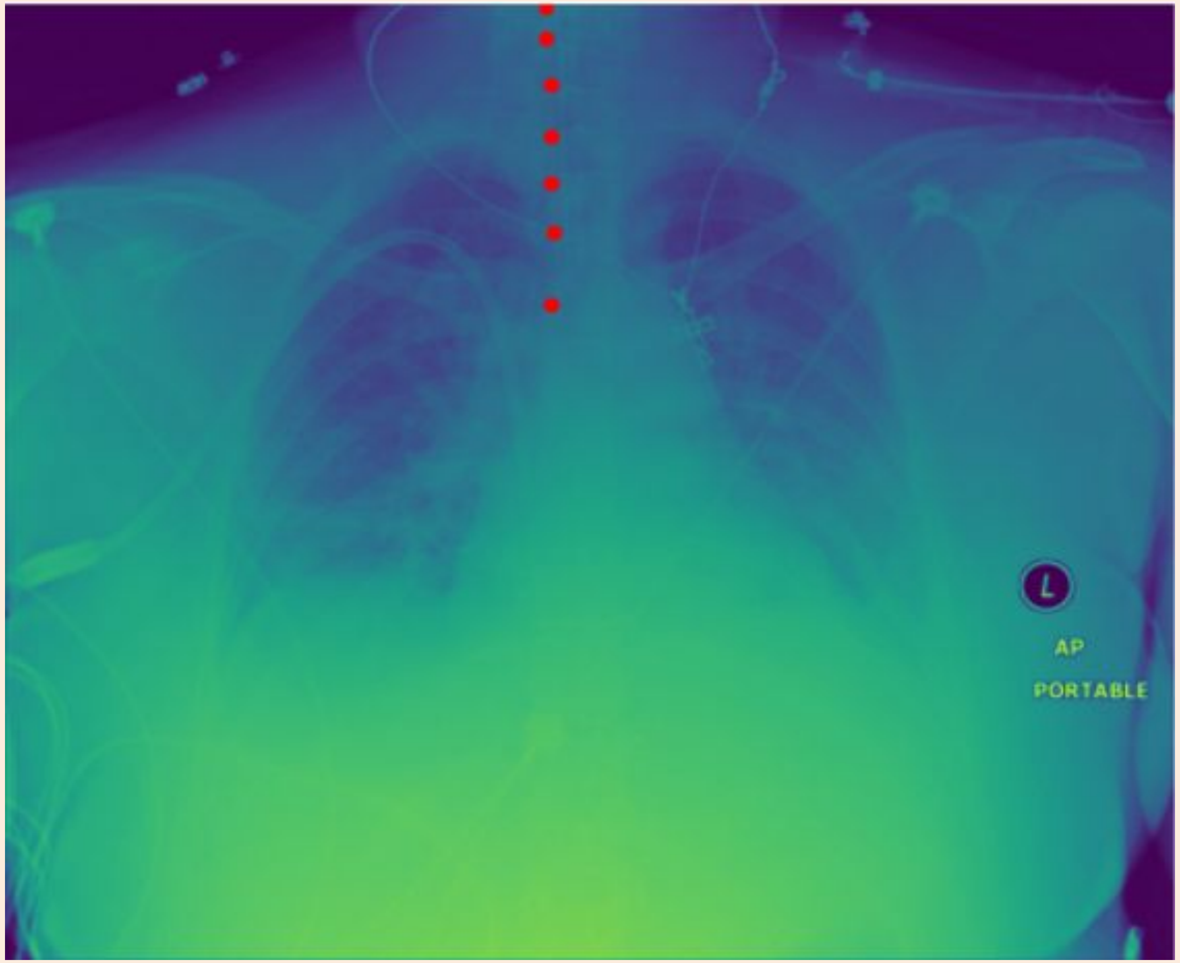
What it does:
- Keeps the airway open
- Provides uncontaminated oxygen, medicine or anesthesia

ETT Abnormal



ETT Borderline





CVC – Central Venous Catheter (Normal)

Place of insertion:

- PICC (Peripherally inserted central catheter) inserted in arm
- Subclavian vein or neck

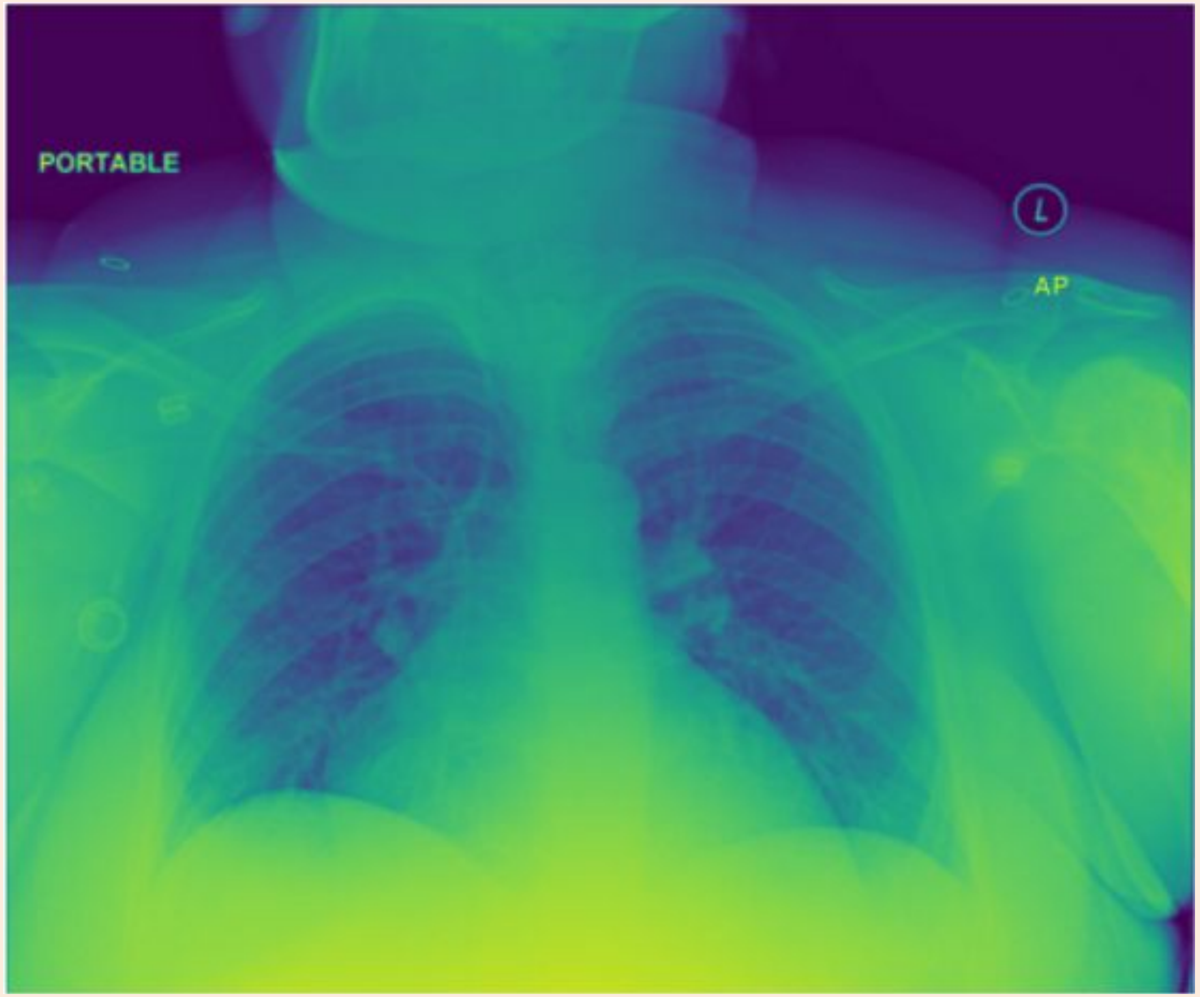
Where it sits:

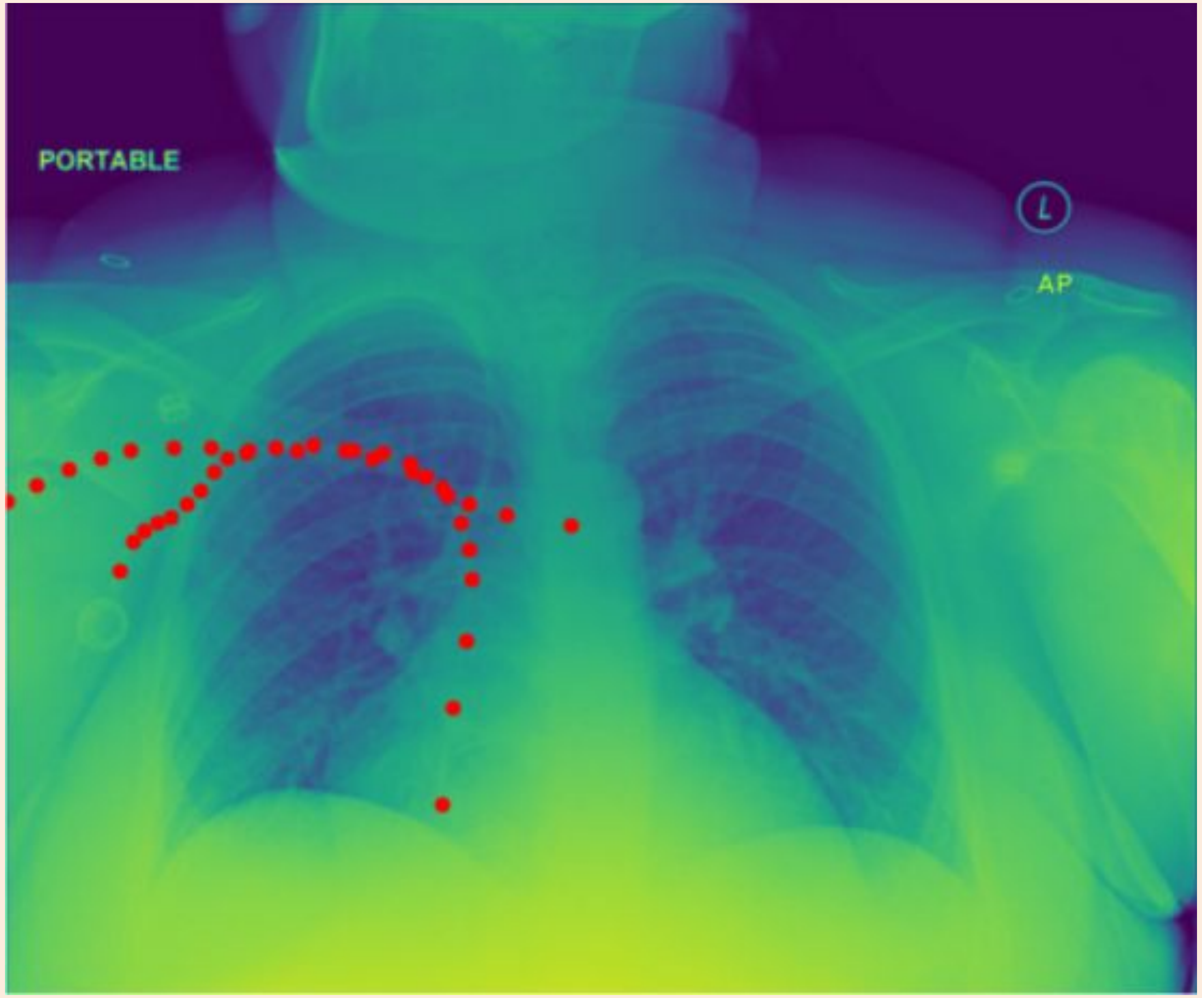
- Ideally the vena cava (large vein just before the right atrium)
- This is so intravenous fluids can be pumped through the body as quickly as possible

What it does:

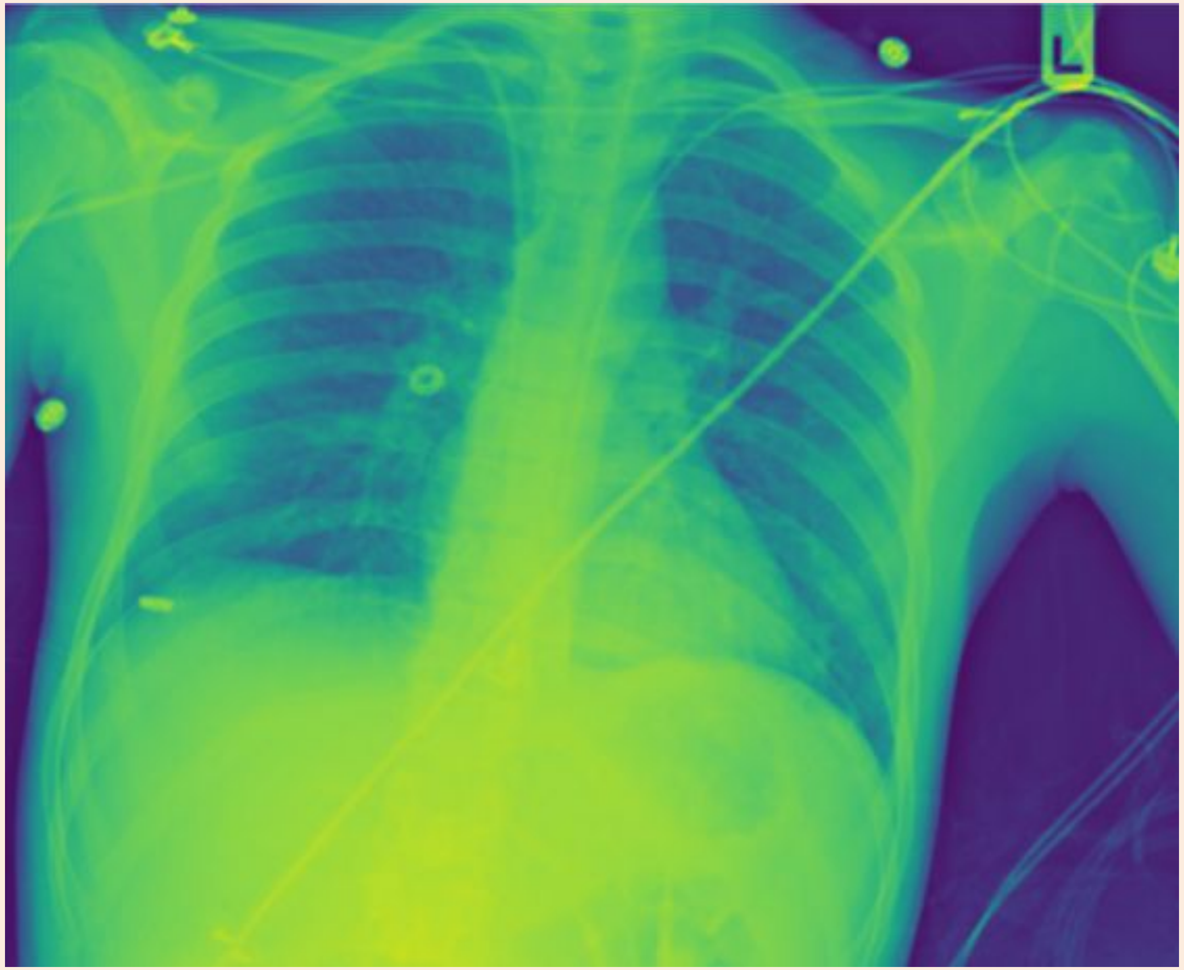
- Mainly administers medication

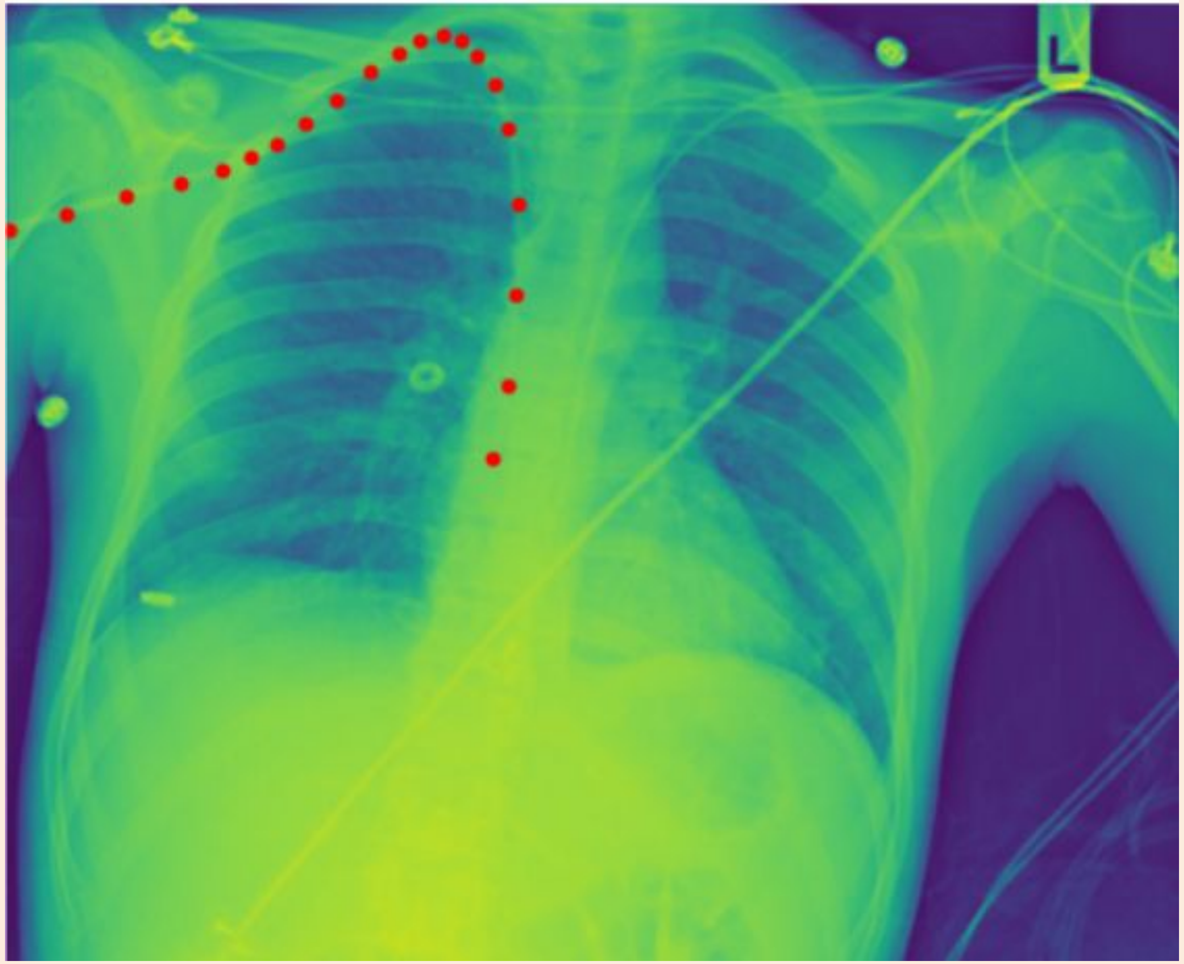
CVC Abnormal



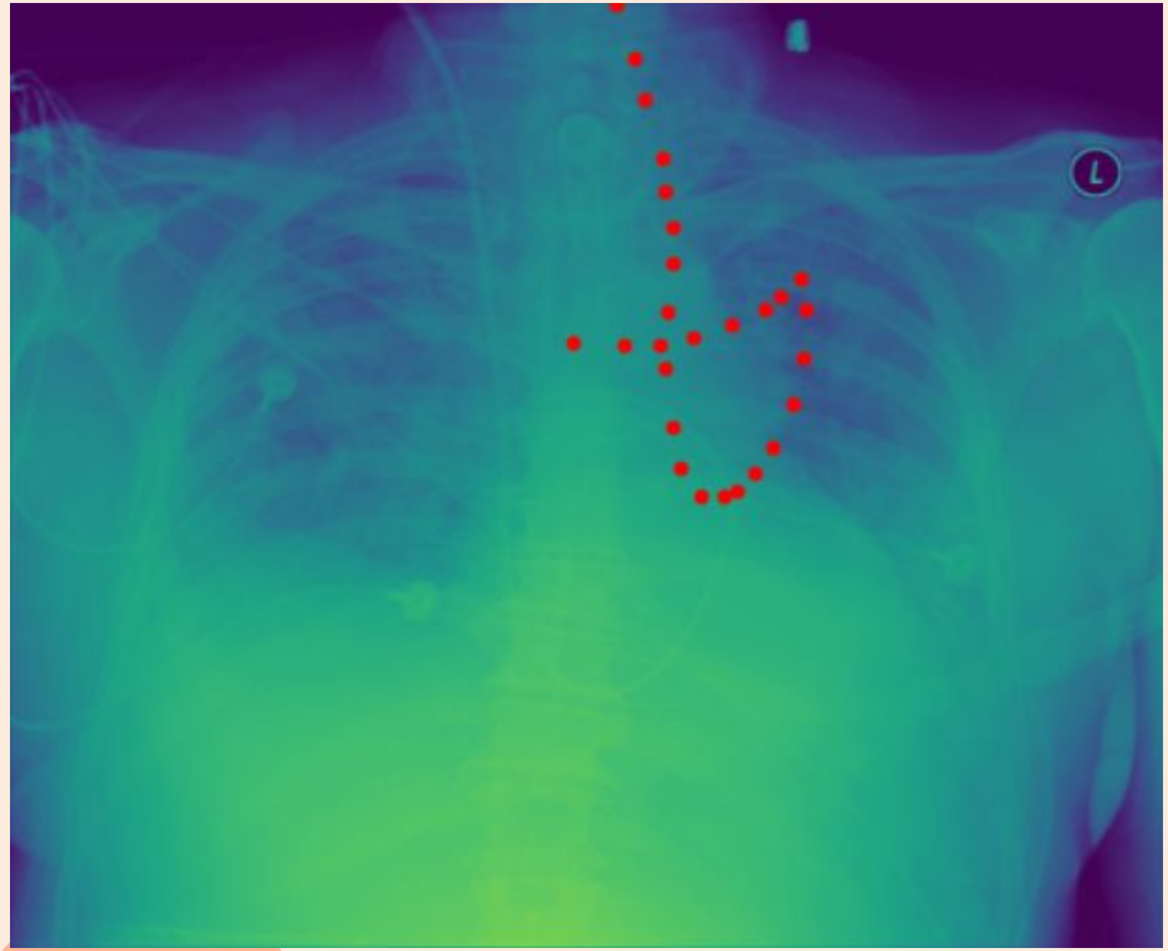


CVC Borderline





Swan Ganz – Type of CVC



Does more than a normal cvc, it can measure:

- Cardiac Output
- Left atrial pressure
- Pulmonary artery pressure

Where it sits:

- Pulmonary artery - between right ventricle and lungs

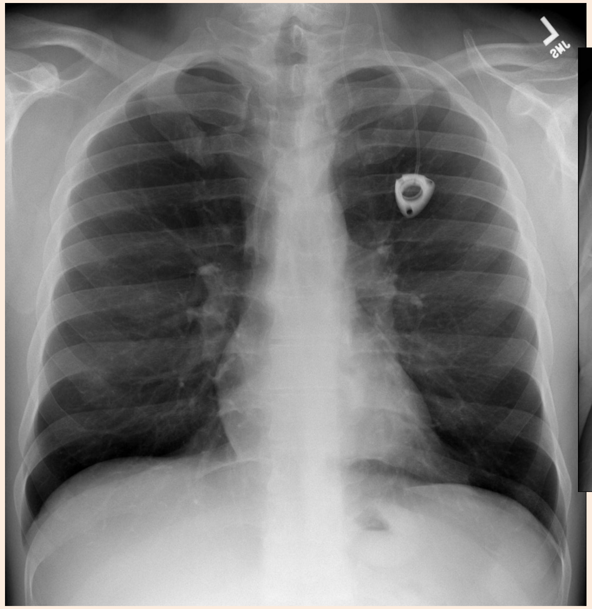
Provides information about heart strength and health

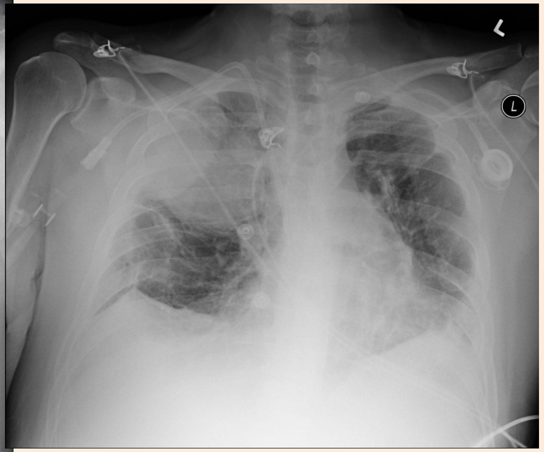
Data We Received

Images:
- Folder with 30083 images
- Each image is a medical scan that contains a number of catheters

Train CSV:
- CSV that indicates what catheter types are present in a particular image

Annotations:
- Each row provides the coordinates of a catheter present in an image
- 18000 annotations
- 9095 unique images





Data

The data received was already clean:

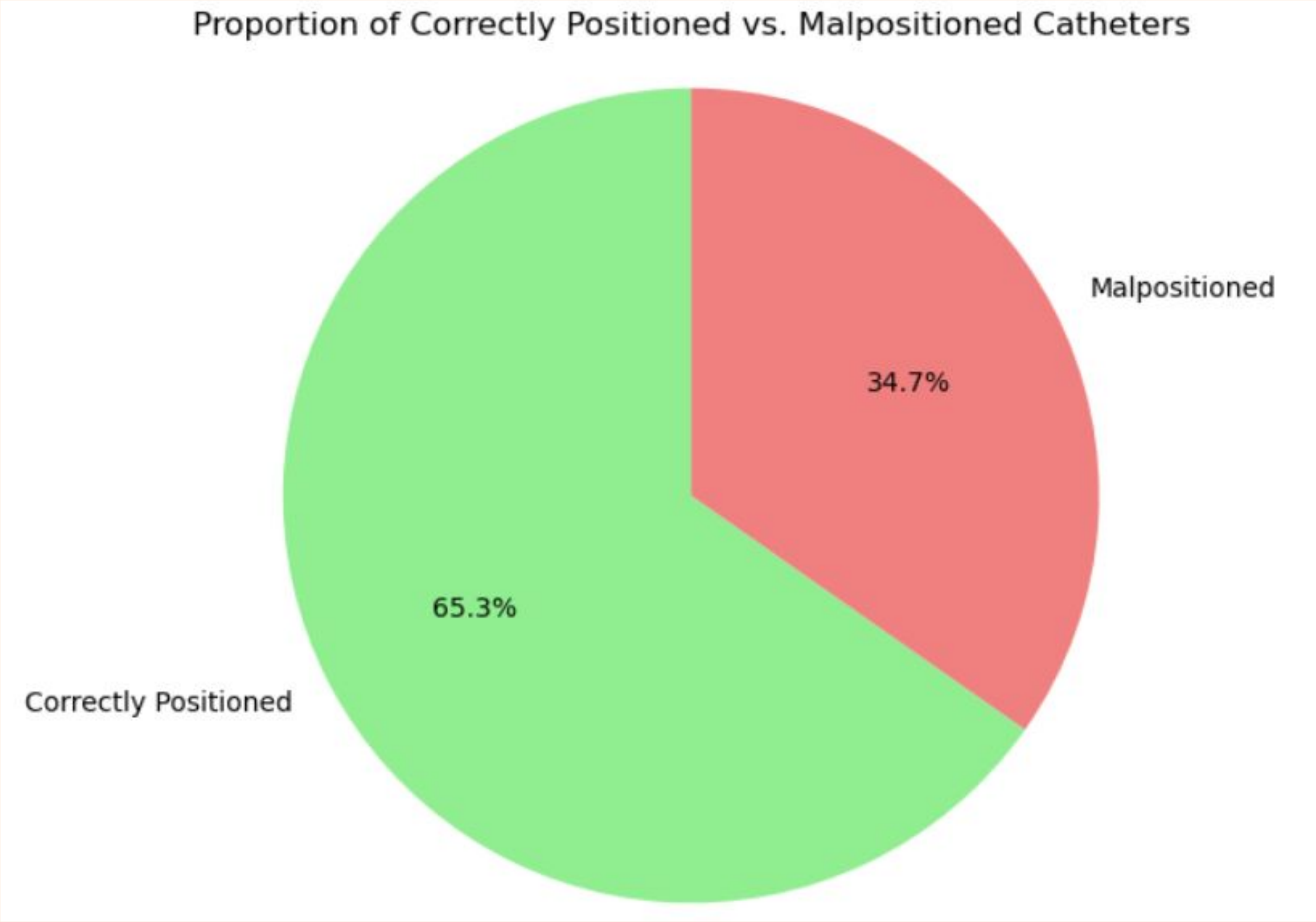
- No duplicates
- No missing values

```
Duplicates present: 0
```

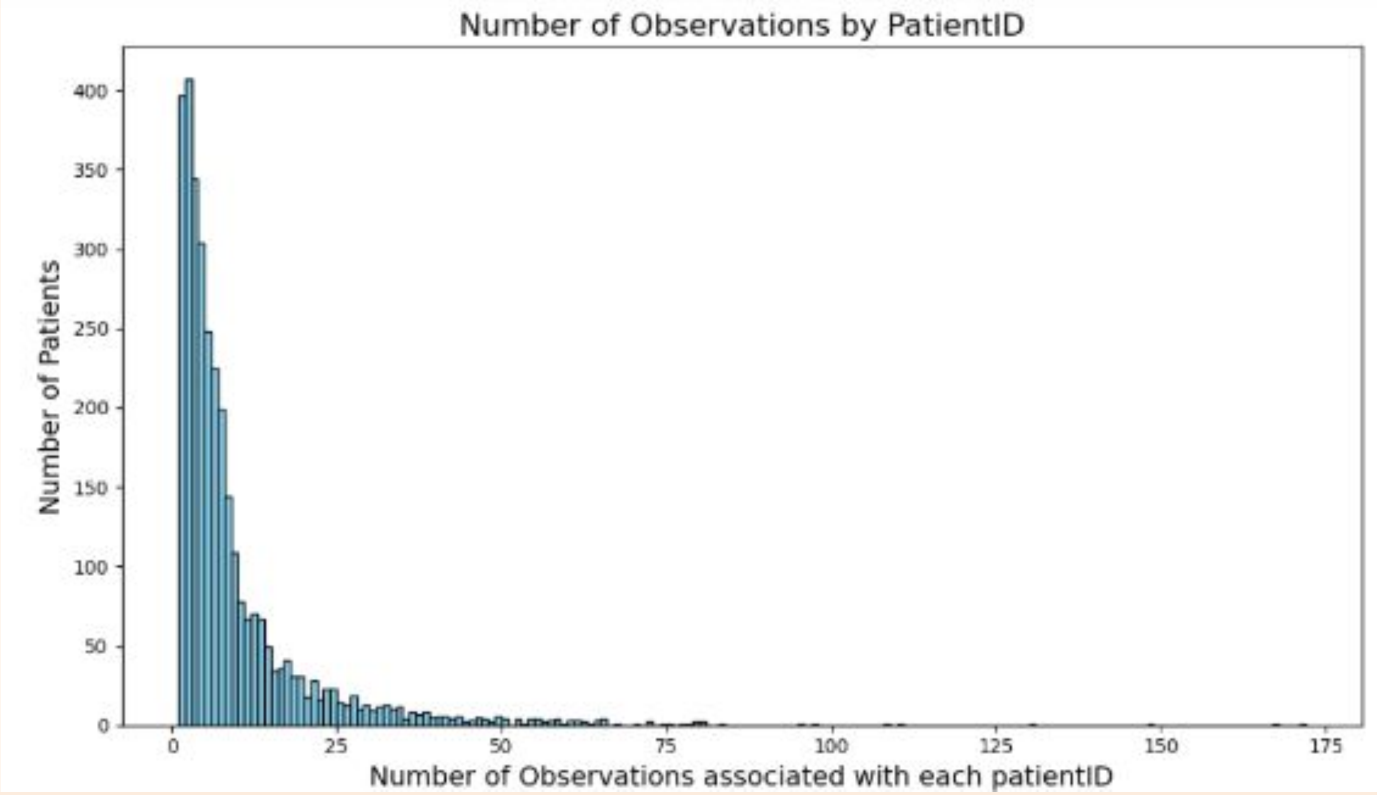
03

Exploratory Data Analysis

Positioned vs Malpositioned

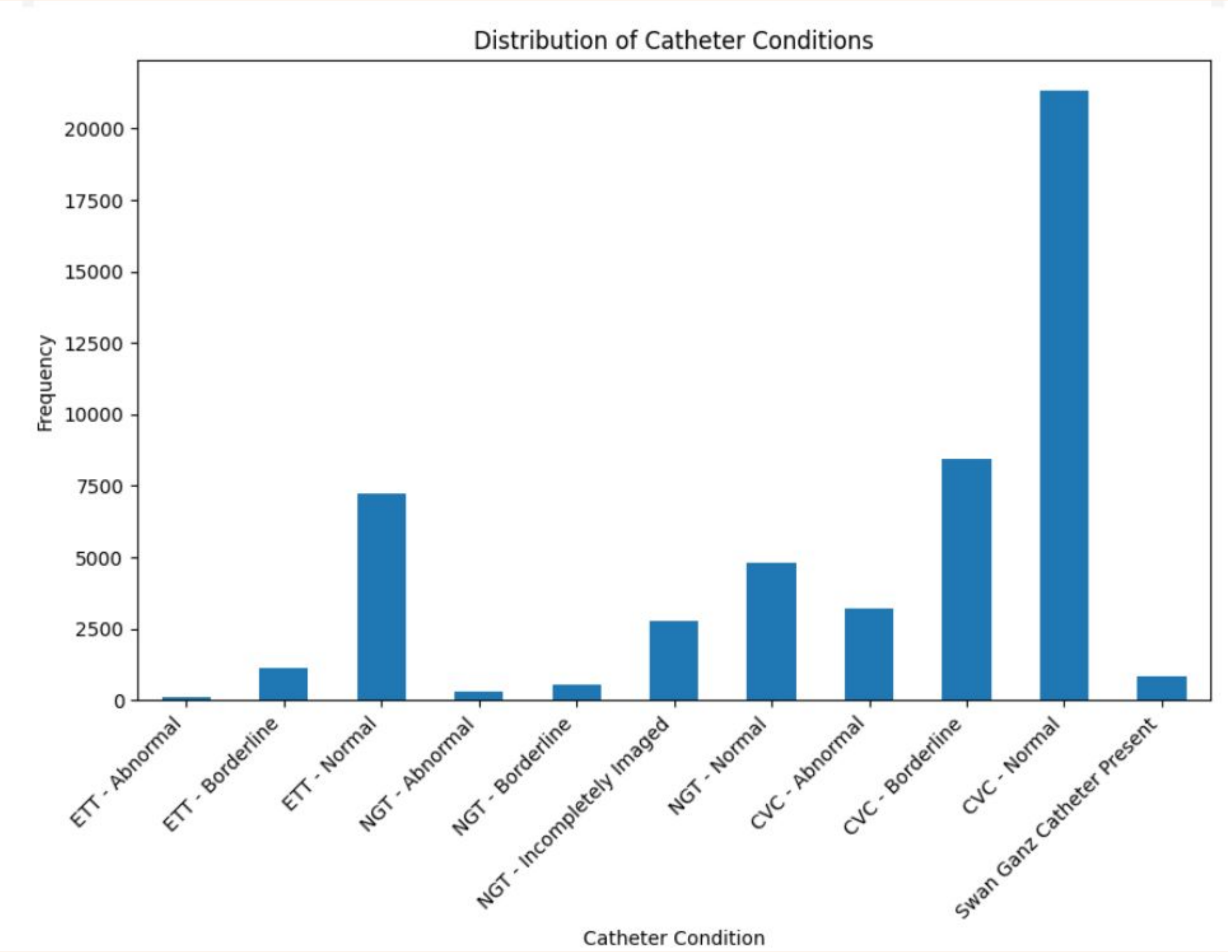


Number of Observations



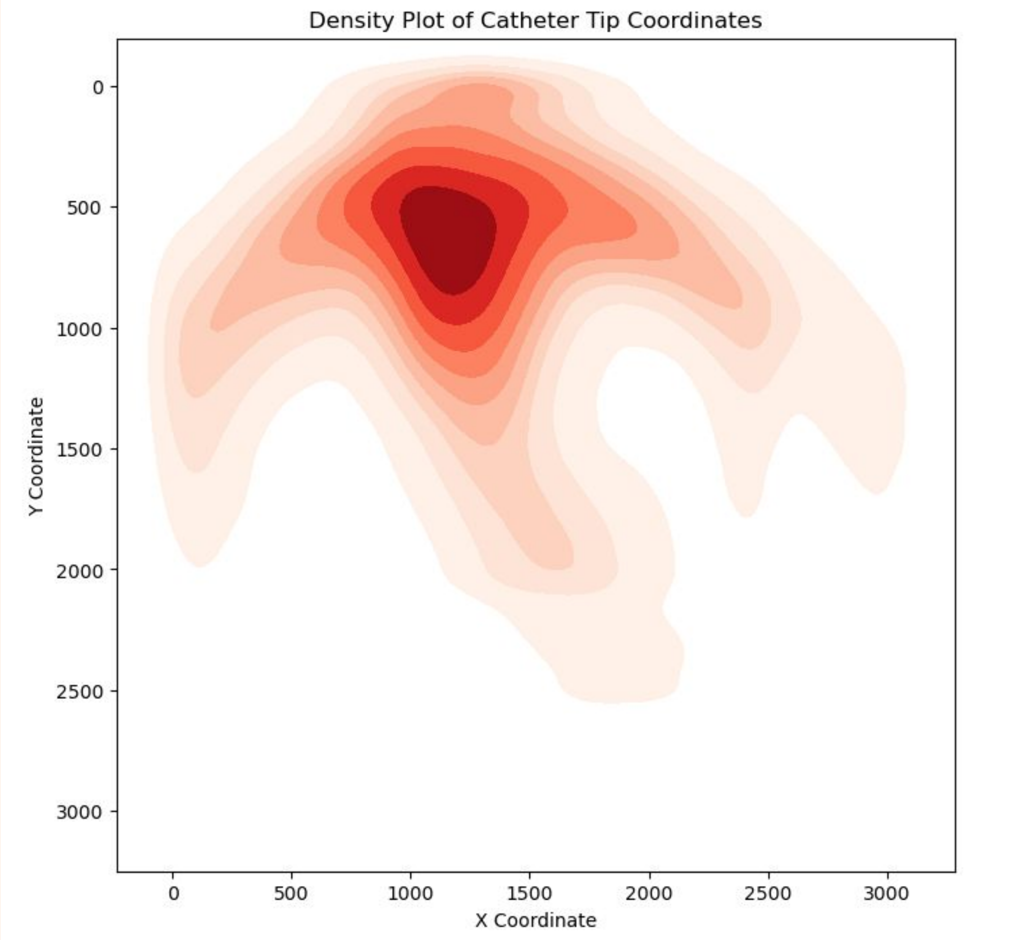

```
Total number of unique patients: 3255
Number of patients with more than one observation: 2858
```

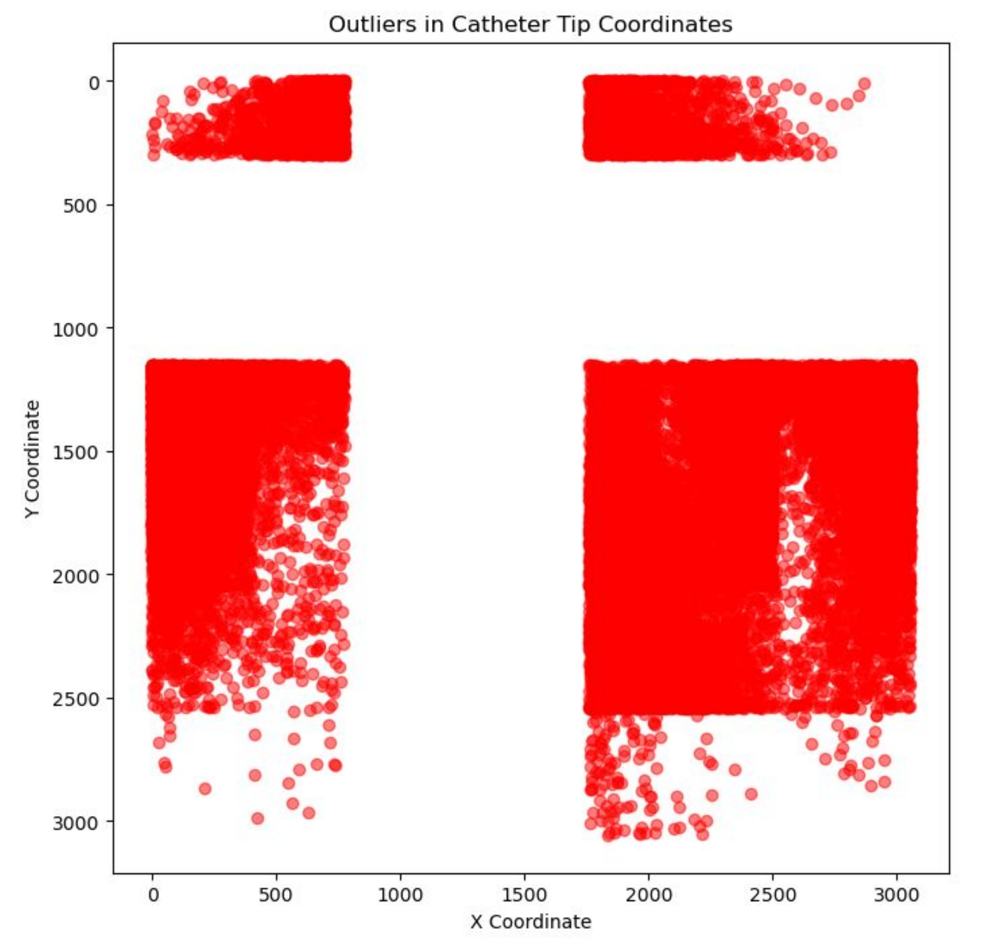
Distribution of Catheters



	0
ETT - Abnormal	79
ETT - Borderline	1138
ETT - Normal	7240
NGT - Abnormal	279
NGT - Borderline	529
NGT - Incompletely Imaged	2748
NGT - Normal	4797
CVC - Abnormal	3195
CVC - Borderline	8460
CVC - Normal	21324
Swan Ganz Catheter Present	830

Concentration and Outliers





04

Preprocessing and Data Manipulation + Modelling

Deep Neural Network architecture

For modelling we decided to predominantly use the pre-built model in **ResNet50**:

- Other CNN models performed worse or the same
- ResNet is more suitable:
    - In medical image classification, small details can be crucial for distinguishing between different types of abnormalities in catheters (utilises 50 layers)
    - Stronger learning capabilities
    - Most efficient

ResNet50 Architecture

- Custom layers on top include a **global average pooling layer**, a **dense layer** with 128 units, **dropout layer** to prevent overfitting, and a **dense output layer**.
- Overall using 50 layers from ResNet and 4 custom layers

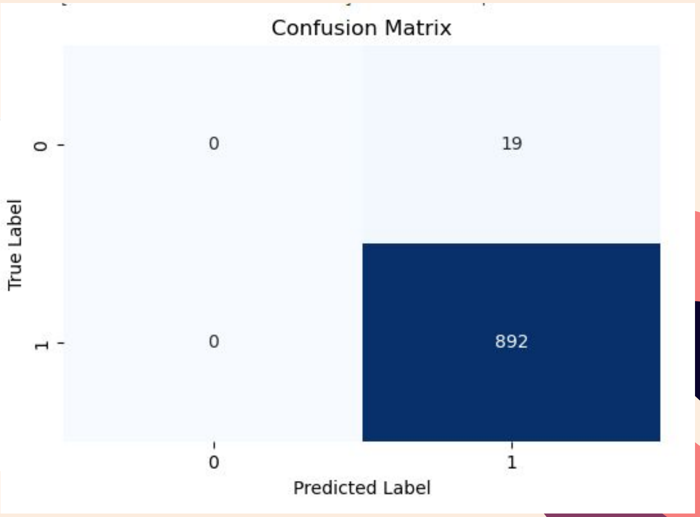
```
Layer (type)                Output Shape              Param #
=================================================================
resnet50 (Functional)       (None, 7, 7, 2048)        23587712

global_average_pooling2d (G  (None, 2048)             0
lobalAveragePooling2D)

dense (Dense)               (None, 128)               262272

dropout (Dropout)           (None, 128)               0

dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 23,851,274
Trainable params: 263,562
Non-trainable params: 23,587,712
```

Binary Classification: CVC

As CVC catheters were the most prevalent, we first looked at categorising catheters as CVC or non-CVC

- Trained on the whole data set (30083 images)
- Obtained extremely high accuracies
- Confusion matrix is from a smaller subset however reflects what is occurring

```
Epoch 1/10
114/114 [==============================] - 1151s 10s/step - loss: 0.1143 - accuracy: 0.9827 - val_loss: 0.1004 - val_accuracy: 0.9791
Epoch 2/10
114/114 [==============================] - 774s 7s/step - loss: 0.0947 - accuracy: 0.9830 - val_loss: 0.1040 - val_accuracy: 0.9791
Epoch 3/10
114/114 [==============================] - 573s 5s/step - loss: 0.0907 - accuracy: 0.9830 - val_loss: 0.1002 - val_accuracy: 0.9791
Epoch 4/10
114/114 [==============================] - 571s 5s/step - loss: 0.0889 - accuracy: 0.9830 - val_loss: 0.1019 - val_accuracy: 0.9791
Epoch 5/10
114/114 [==============================] - 1072s 9s/step - loss: 0.0899 - accuracy: 0.9830 - val_loss: 0.1062 - val_accuracy: 0.9791
Epoch 6/10
114/114 [==============================] - 1125s 10s/step - loss: 0.0898 - accuracy: 0.9830 - val_loss: 0.1061 - val_accuracy: 0.9791
```



Binary Classification 2: CVC

Due to the imbalance between CVC and non-CVC the model was biased and inaccurate

- Applying weights to the model
- Upsampling non-CVC catheters

Original

CVC_numeric	
1	29333
0	750

Upsampled

CVC_numeric	
1	14666
0	14666

Second attempt:

- Filtered data to only images with annotations
- 20% validation split

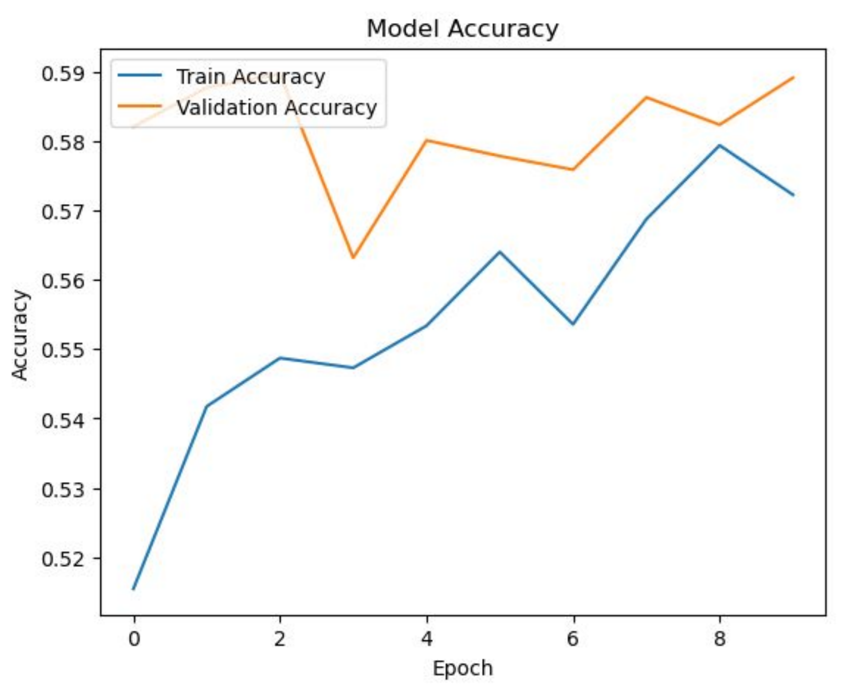
Original

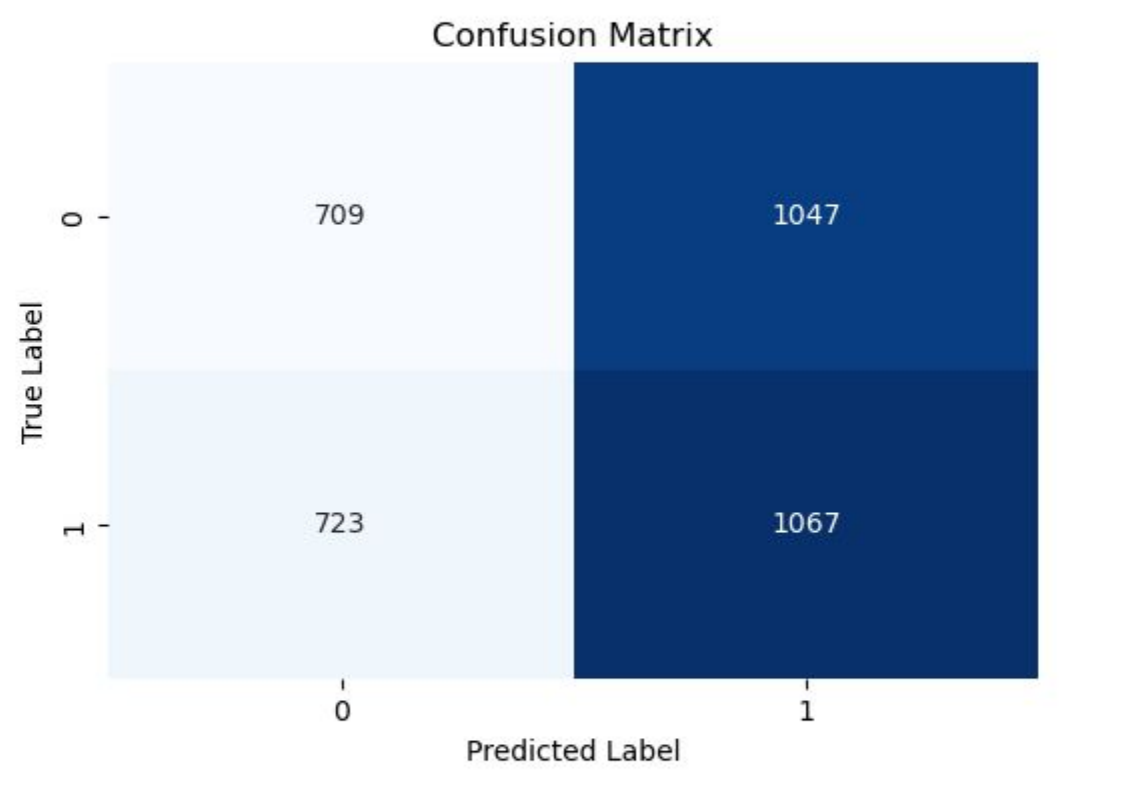
CVC_numeric	
1	8866
0	229

Upsampled

CVC_numeric	
0	8866
1	8866

Binary Classification: CVC results






```
111/111 [==============================] - 442s 4s/step - loss: 0.6705 - accuracy: 0.5964
Validation Loss: 0.6705045700073242
Validation Accuracy: 0.596446692943573
```

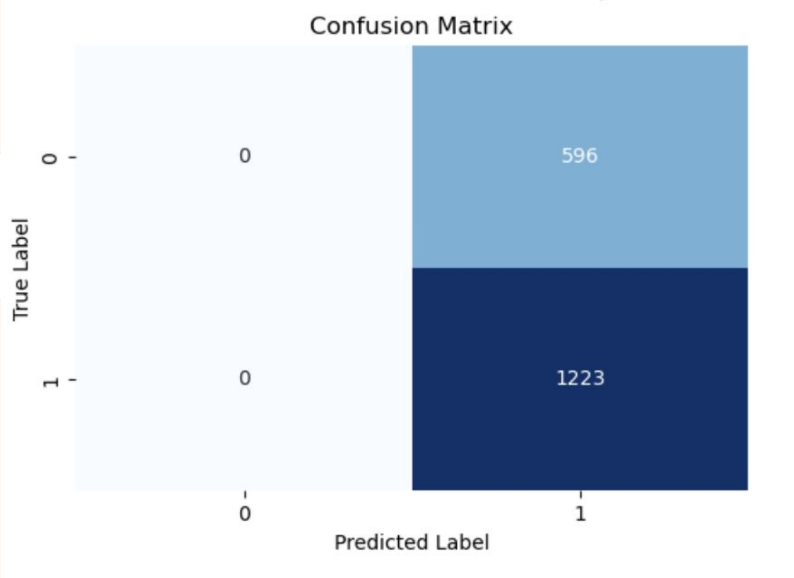
Binary Classification: ETT

We also looked at classifying ETT catheters as ETT or non-ETT

ETT_numeric	
0	6101
1	2994

- ETT catheters were less prevalent
- Ratio between ETT and non-ETT seemed more balanced than CVC (expected a higher accuracy)

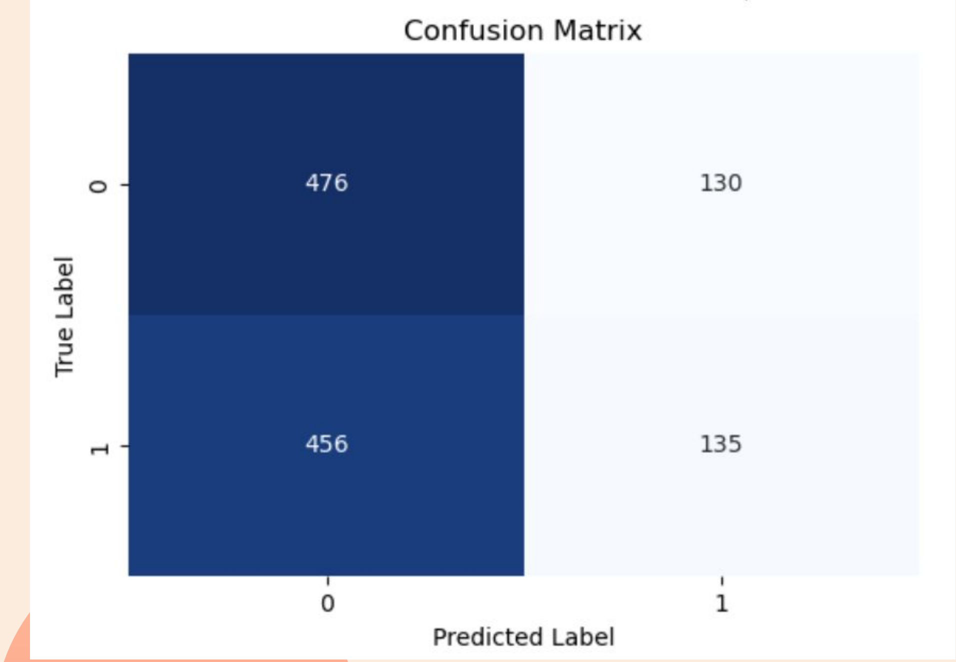
```
57/57 [==============================] - 226s 4s/step - loss: 0.6089 - accuracy: 0.6723
Validation Loss: 0.6089034080505371
Validation Accuracy: 0.6723474264144897
```

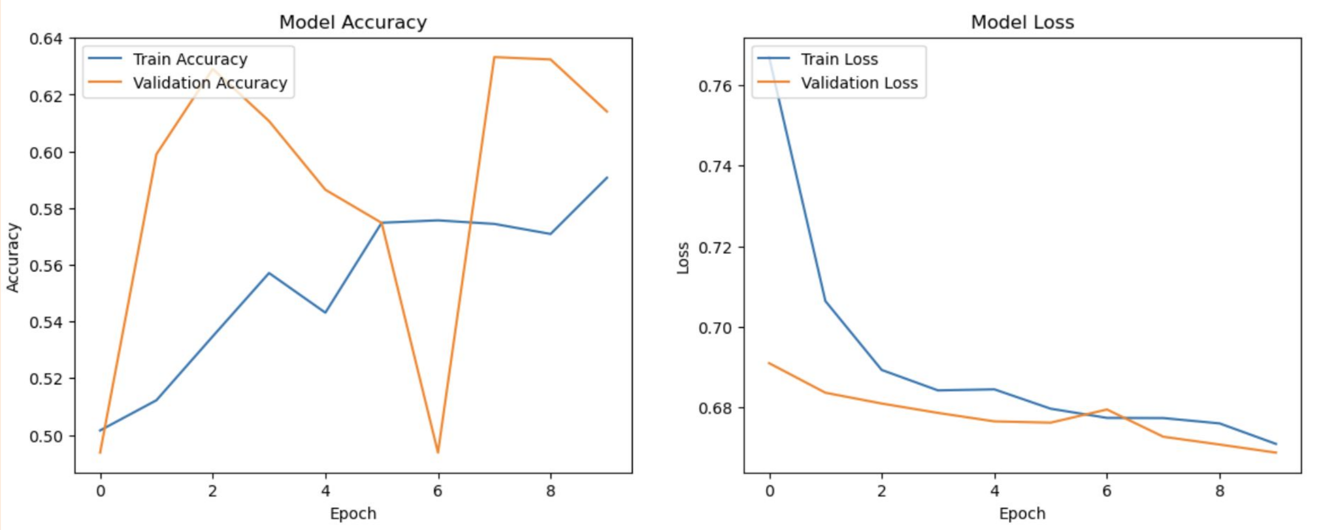


Binary Classification: ETT 2

Down-sampled

ETT_numeric	
0	2994
1	2994






```
38/38 [==============================] - 146s 4s/step - loss: 0.6691 - accuracy: 0.6182
Validation Loss: 0.6691277027130127
Validation Accuracy: 0.6182122230529785
```

Binary Classification: NGT

Built a model to classify images as 'NGT' or 'non-NGT'

- The distribution of NGT to non-NGT images was much more even compared to CVC and ETT

```
NGT_numeric
0     5918
1     3177
```

```
57/57 [==============================] - 193s 3s/step - loss: 0.6139 - accuracy: 0.6537
File Browser n Loss: 0.613928496837616
Validation Accuracy: 0.6536558270454407
```

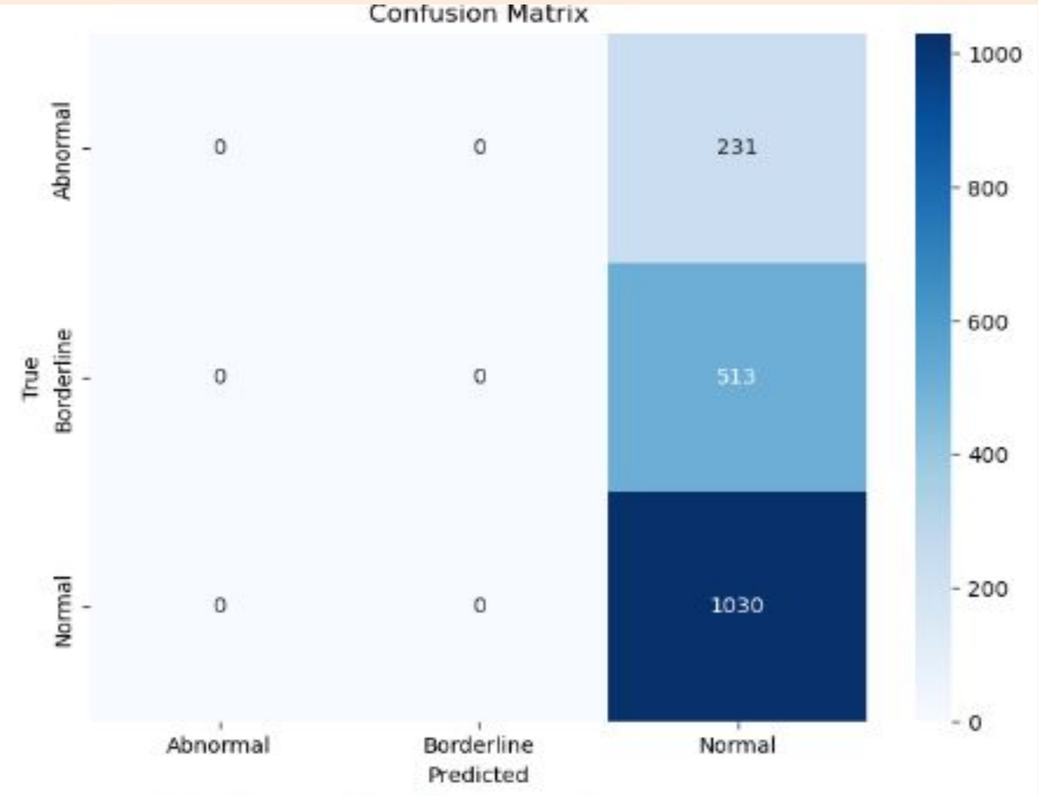
Categorical: Multi-label CVC Catheter Classification Setup

- Due to software limitations, we only worked with X-ray images with only one catheter present
- Created categorical columns classifying the catheters
- Removed multiple catheter instances for software efficiency
- Upsampled abnormal and borderline data for balancing
- Only focussed on annotated data

```
CVC_type
normal        5147
borderline    1619
abnormal       751
Name: count, dtype: int64
```

```
CVC_type
normal        5147
borderline    5147
abnormal      5147
Name: count, dtype: int64
```

Categorical: Multi-label CVC Catheter Classification Initial results



Validation Loss: 0.9419806003570557
Validation Accuracy: 0.5806087851524353

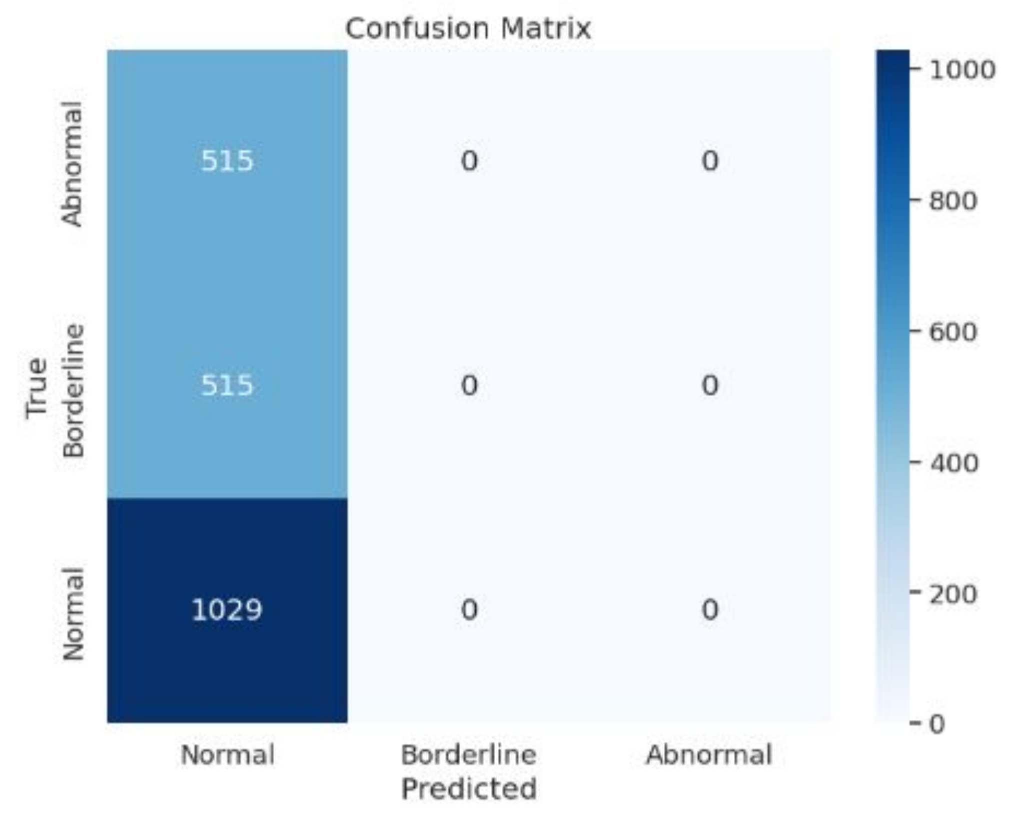
	precision	recall	f1-score	support
abnormal	0.00	0.00	0.00	231
borderline	0.00	0.00	0.00	513
normal	0.58	1.00	0.73	1030
accuracy			0.58	1774
macro avg	0.19	0.33	0.24	1774
weighted avg	0.34	0.58	0.43	1774

Categorical: Multi-label CVC Catheter Classification Balanced Results

	precision	recall	f1-score	support
abnormal	0.25	1.00	0.40	515
borderline	0.00	0.00	0.00	515
normal	0.00	0.00	0.00	1029
accuracy			0.25	2059
macro avg	0.08	0.33	0.13	2059
weighted avg	0.06	0.25	0.10	2059

Validation Loss: 0.636571645736694З

Validation Accuracy: 0.6666667461395264



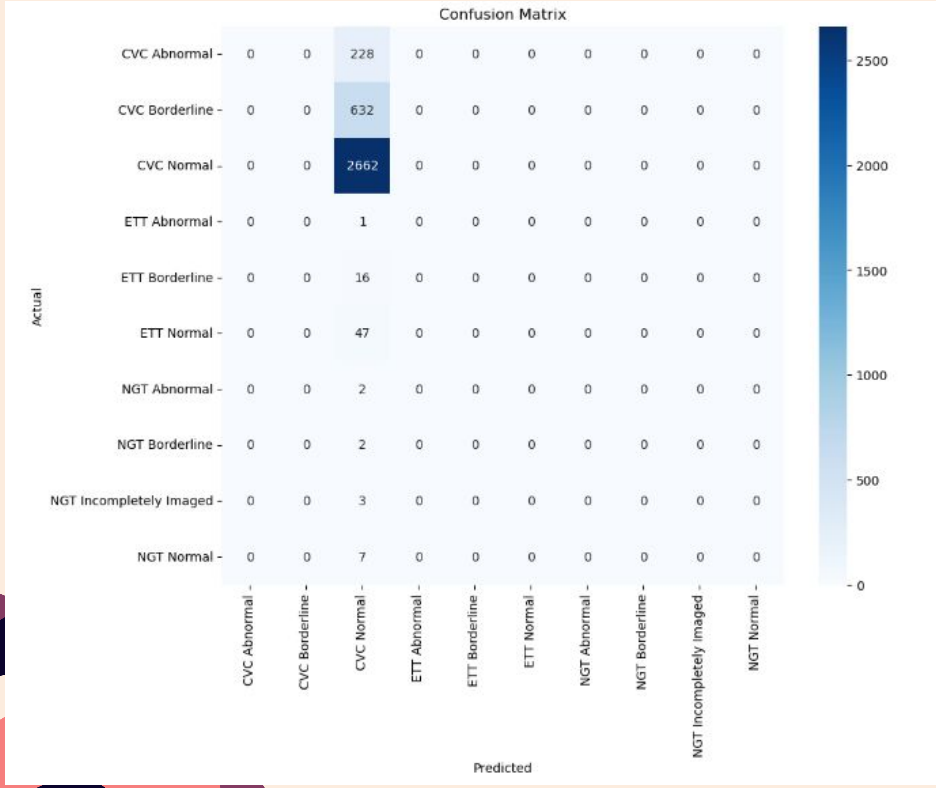
Categorical: Multi-label Catheter Classification setup

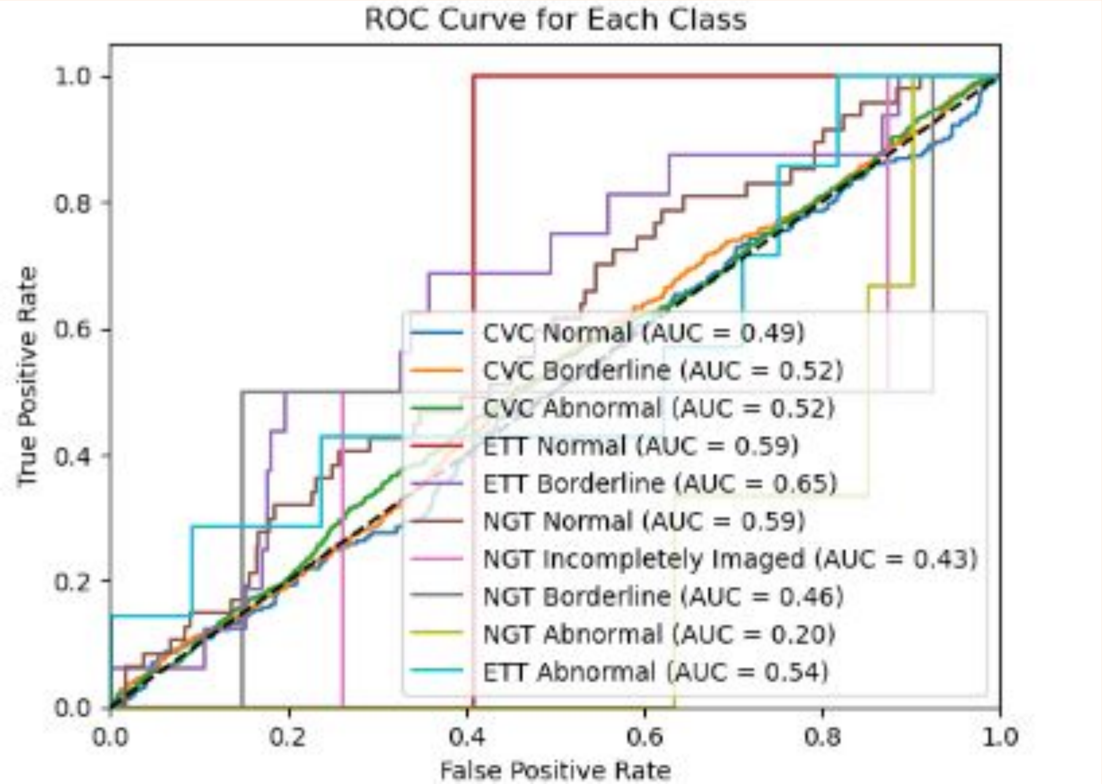
- 17999 studies
- Due to software limitations, we only worked with X-ray images with only one catheter present
- With significant undersampling, we added class weights
- Created categorical columns classifying the catheters

CVC - Normal	13312
ETT - Normal	8532
CVC - Borderline	6453
NGT - Normal	6087
NGT - Incompletely Imaged	3480
CVC - Abnormal	2421
ETT - Borderline	1432
NGT - Borderline	659
Swan Ganz Catheter Present	555
NGT - Abnormal	336
ETT - Abnormal	92
dtype: int64	

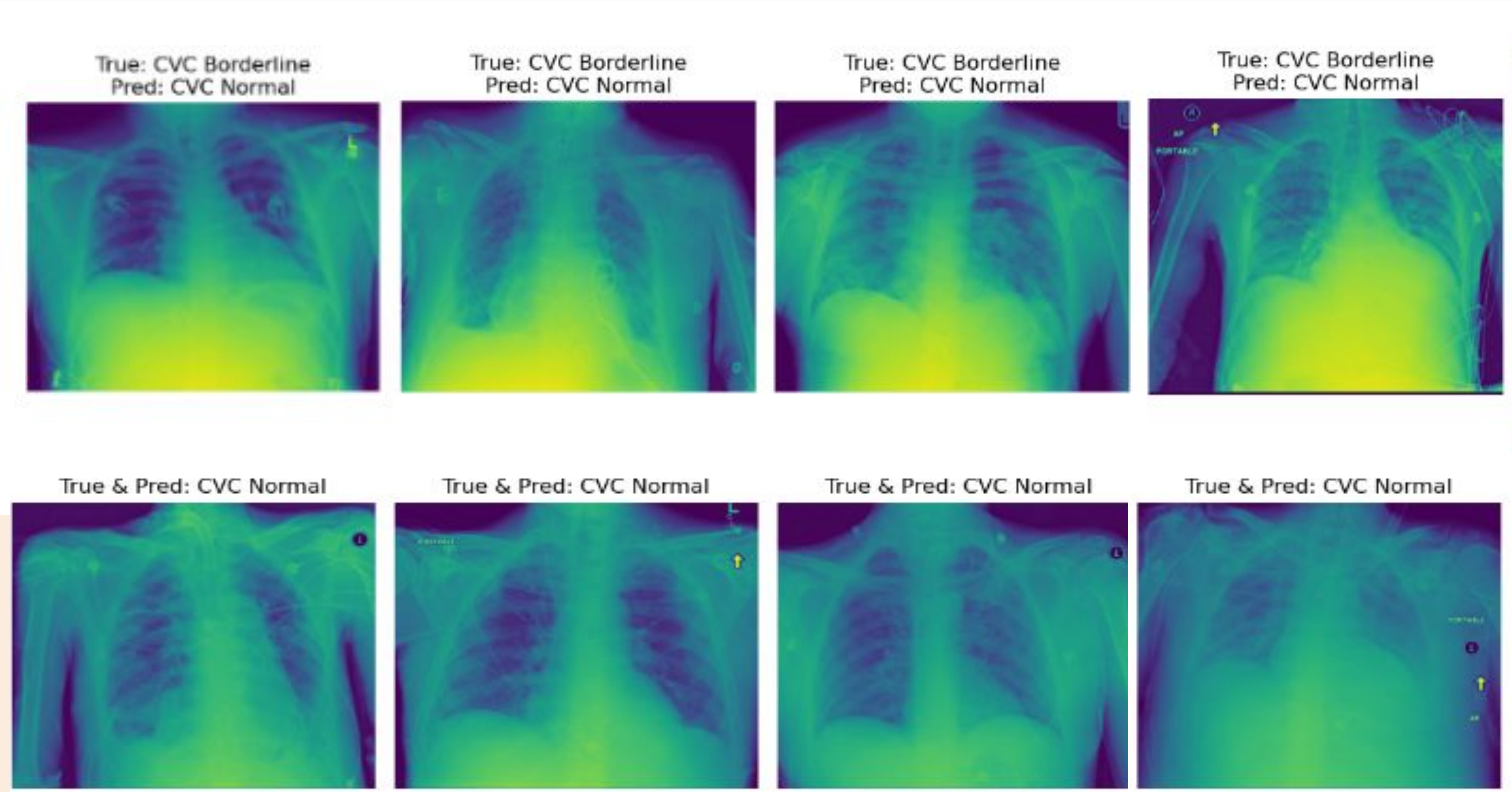
CVC - Normal	3689
CVC - Borderline	1145
CVC - Abnormal	569
NGT - Normal	37
NGT - Incompletely Imaged	17
ETT - Normal	10
NGT - Abnormal	8
NGT - Borderline	7
ETT - Borderline	3
ETT - Abnormal	1
Swan Ganz Catheter Present	0
dtype: int64	

Multi-label Catheter Classification Results






```
Validation Loss: 0.8148368000984192
Validation Accuracy: 0.7393973469734192
```



Categorical: Multi-label Catheter Classification True vs Predicted

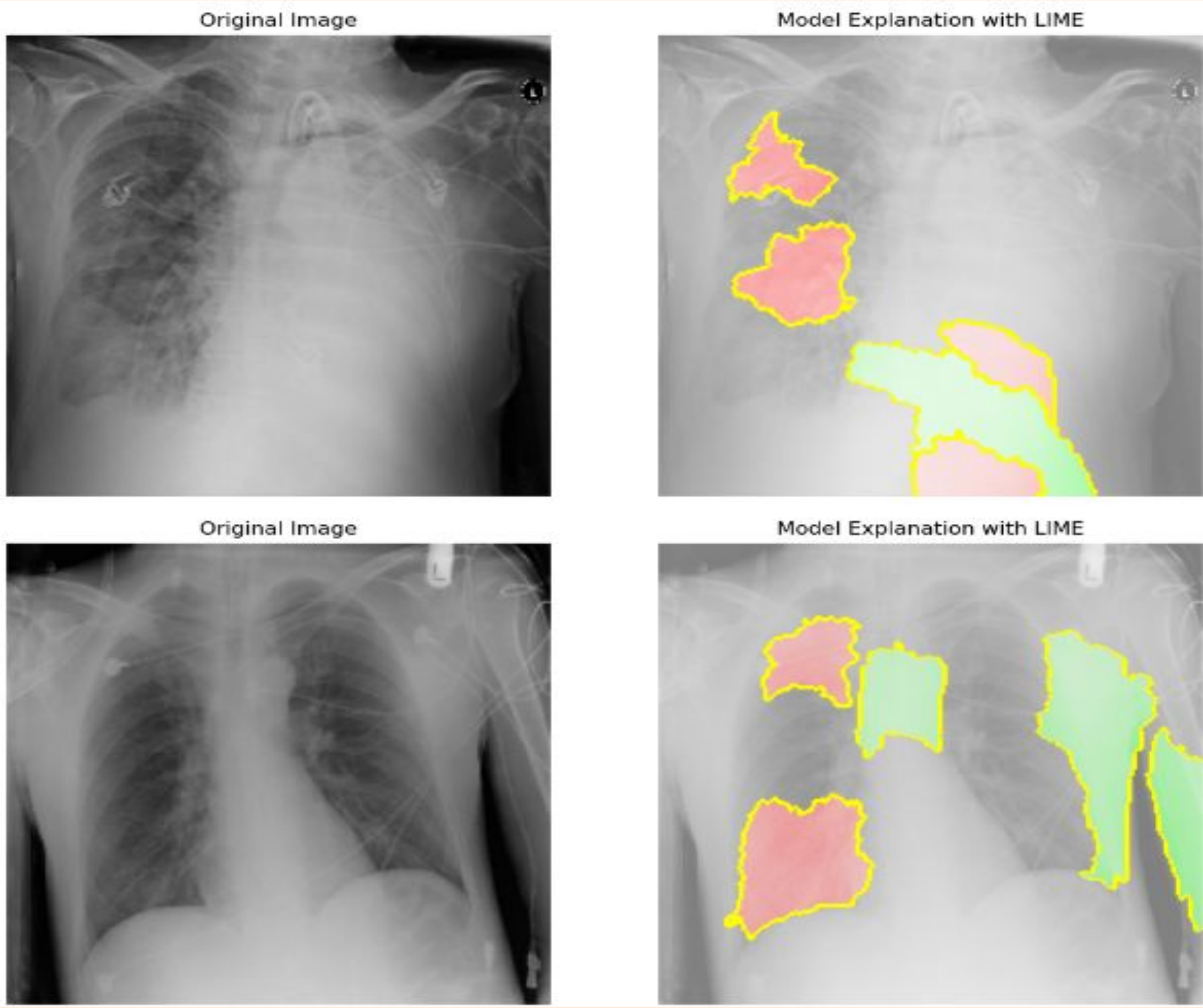
Model Interpretation – LIME

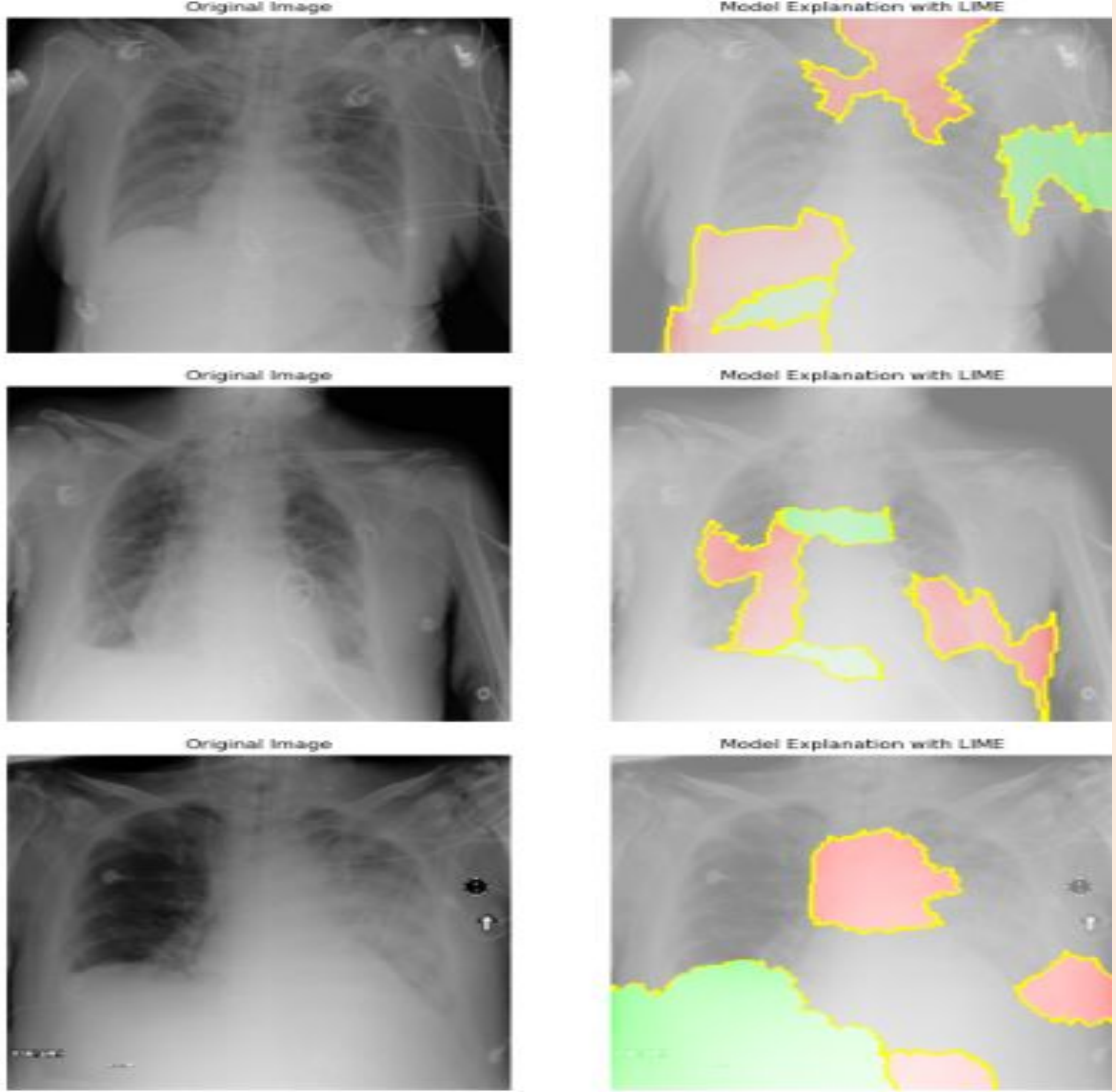
Highlights - the parts that most influence the models prediction. Shows that the model is focusing on the correct anatomical features related to the catheter type.

Green - positive influence.

Red - negative influence

LIME (Local Interpretable Model-agnostic Explanations) explains individual predictions by identifying parts of the input (like regions in an image) that most influence the model's decision.




Original Image
Model Explanation with LIME
Original Image
Model Explanation with LIME
Original Image
Model Explanation with LIME

05

Conclusion

Results

- Models must be refined before being implemented into hospitals and clinics
- Fixed one issue of unbalanced data, however poor accuracies could be due to:
  - Data quality
  - Poor choice of model
  - Overfitting

Summary

- Over 30,000 images of chest x-rays
- Research on the types of catheters.
- ⅓ of the catheters were malpositioned
- CVC is most common type of catheter
- We used ResNet50 and the Multi-label Catheter Classification performed best with 73.93%

References

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Thank you!

Do you have any questions?