In [1]:
```
import pandas as pd
import numpy as np
import os
import cv2
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import tensorflow as tf
```

In [2]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

datagen = ImageDataGenerator(rescale=1./255)
batch_size = 20

# All images will be rescaled by 1./255
train_datagen = ImageDataGenerator(rescale=1./255)
test_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
        # This is the target directory
        'C:/Users/Xhensil/Downloads/archive(2)/chest_xray/train',
        batch_size=batch_size,
        # Since we use binary_crossentropy loss, we need binary labels
        class_mode='binary')

validation_generator = test_datagen.flow_from_directory(
        'C:/Users/Xhensil/Downloads/archive(2)/chest_xray/val',
        batch_size=batch_size,
        class_mode='binary')

test_generator = test_datagen.flow_from_directory(
        'C:/Users/Xhensil/Downloads/archive(2)/chest_xray/chest_xray/tes
```

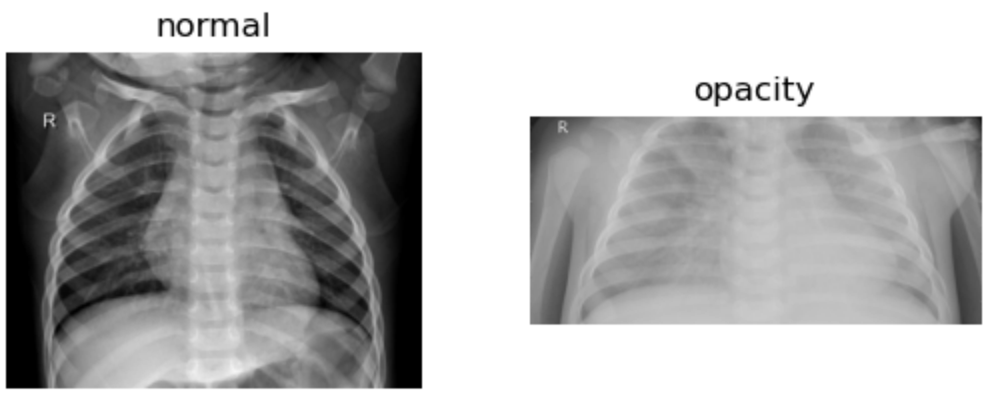
```
Found 4192 images belonging to 2 classes.
Found 1040 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

In [51]:
```
xx_test=np.concatenate([test.next()[0] for i in range(test.__len__())])
xx_test.shape
yy_test=np.concatenate([test.next()[1] for i in range(test.__len__())])
```

Out[51]:
```
(array([0., 1.], dtype=float32), array([234, 390]))
```

In [3]:
```
img = cv2.imread("C:/Users/Xhensil/Downloads/archive(2)/chest_xray/trair
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
plt.subplot(2, 2, 1)
plt.title('normal')
plt.imshow(img)
plt.axis("off")

img = cv2.imread("C:/Users/Xhensil/Downloads/archive(2)/chest_xray/trair
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
plt.subplot(2, 2, 2)
plt.title('opacity')
plt.imshow(img)
```

Out[3]: (-0.5, 1127.5, 519.5, -0.5)



Convolutional Neural Network

Baseline Model

In [4]:
```
model_CNN = models.Sequential()
model_CNN.add(layers.Conv2D(32, (3, 3), activation='relu',
                            input_shape=(256, 256, 3)))
model_CNN.add(layers.MaxPooling2D((2, 2)))
model_CNN.add(layers.Conv2D(64, (3, 3), activation='relu'))
model_CNN.add(layers.MaxPooling2D((2, 2)))
model_CNN.add(layers.Conv2D(128, (3, 3), activation='relu'))
model_CNN.add(layers.MaxPooling2D((2, 2)))
model_CNN.add(layers.Conv2D(128, (3, 3), activation='relu'))
model_CNN.add(layers.MaxPooling2D((2, 2)))
model_CNN.add(layers.Flatten())
model_CNN.add(layers.Dropout(0.35))
model_CNN.add(layers.Dense(512, activation='relu'))
model_CNN.add(layers.Dropout(0.25))
```

In [5]:

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896       
                                                                 
 max_pooling2d (MaxPooling2D  (None, 127, 127, 32)     0         
 )                                                               
                                                                 
 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496     
                                                                 
 max_pooling2d_1 (MaxPooling  (None, 62, 62, 64)       0         
 2D)                                                             
                                                                 
 conv2d_2 (Conv2D)           (None, 60, 60, 128)       73856     
                                                                 
 max_pooling2d_2 (MaxPooling  (None, 30, 30, 128)      0         
 2D)                                                             
                                                                 
 conv2d_3 (Conv2D)           (None, 28, 28, 128)       147584    
                                                                 
 max_pooling2d_3 (MaxPooling  (None, 14, 14, 128)      0         
 2D)                                                             
                                                                 
 flatten (Flatten)           (None, 25088)             0         
                                                                 
 dropout (Dropout)           (None, 25088)             0         
                                                                 
 dense (Dense)               (None, 512)               12845568  
                                                                 
 dropout_1 (Dropout)         (None, 512)               0         
                                                                 
 dense_1 (Dense)             (None, 1)                 513       
                                                                 
=================================================================
Total params: 13,086,913
Trainable params: 13,086,913
Non-trainable params: 0
_________________________________________________________________
```

In [6]:

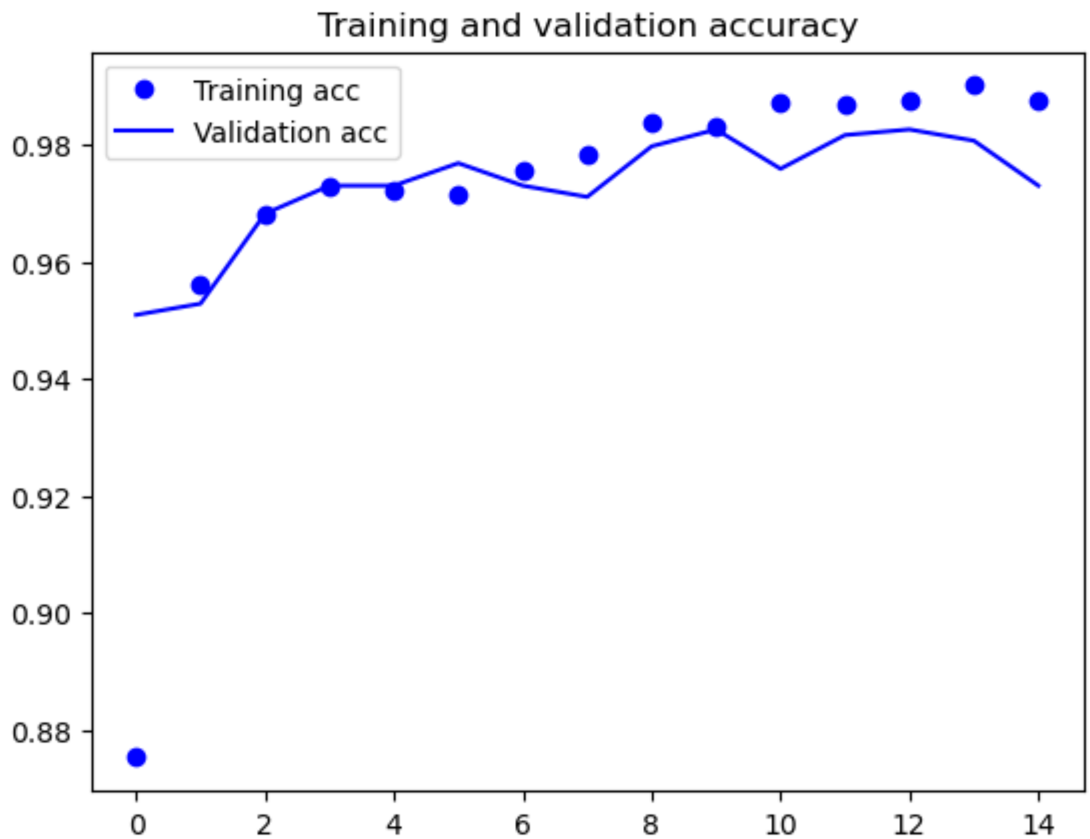
```
from tensorflow.keras import optimizers

model_CNN.compile(loss='binary_crossentropy',
              optimizer=optimizers.Adam(learning_rate=1e-4),
```

In [7]:

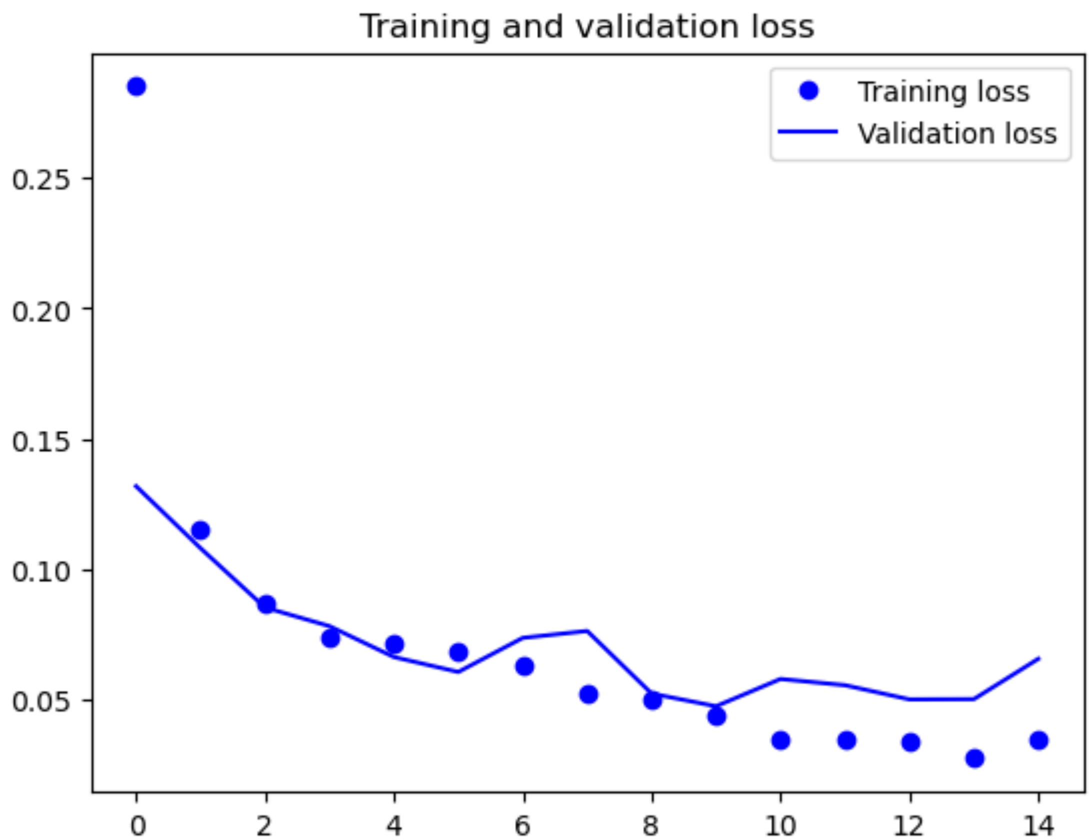
```
Epoch 1/15
210/210 [==============================] - 118s 519ms/step - loss: 0.2
852 - acc: 0.8752 - val_loss: 0.1318 - val_acc: 0.9510
Epoch 2/15
210/210 [==============================] - 69s 329ms/step - loss: 0.11
51 - acc: 0.9561 - val_loss: 0.1080 - val_acc: 0.9529
Epoch 3/15
210/210 [==============================] - 69s 328ms/step - loss: 0.08
72 - acc: 0.9680 - val_loss: 0.0853 - val_acc: 0.9683
Epoch 4/15
210/210 [==============================] - 71s 336ms/step - loss: 0.07
41 - acc: 0.9728 - val_loss: 0.0781 - val_acc: 0.9731
Epoch 5/15
210/210 [==============================] - 69s 331ms/step - loss: 0.07
17 - acc: 0.9723 - val_loss: 0.0663 - val_acc: 0.9731
Epoch 6/15
210/210 [==============================] - 71s 338ms/step - loss: 0.06
84 - acc: 0.9716 - val_loss: 0.0606 - val_acc: 0.9769
Epoch 7/15
210/210 [==============================] - 72s 340ms/step - loss: 0.06
29 - acc: 0.9757 - val_loss: 0.0736 - val_acc: 0.9731
Epoch 8/15
210/210 [==============================] - 71s 339ms/step - loss: 0.05
23 - acc: 0.9783 - val_loss: 0.0763 - val_acc: 0.9712
Epoch 9/15
210/210 [==============================] - 71s 335ms/step - loss: 0.05
00 - acc: 0.9838 - val_loss: 0.0523 - val_acc: 0.9798
Epoch 10/15
210/210 [==============================] - 69s 329ms/step - loss: 0.04
39 - acc: 0.9833 - val_loss: 0.0474 - val_acc: 0.9827
Epoch 11/15
210/210 [==============================] - 76s 364ms/step - loss: 0.03
50 - acc: 0.9874 - val_loss: 0.0579 - val_acc: 0.9760
Epoch 12/15
210/210 [==============================] - 77s 365ms/step - loss: 0.03
49 - acc: 0.9869 - val_loss: 0.0555 - val_acc: 0.9817
Epoch 13/15
210/210 [==============================] - 69s 328ms/step - loss: 0.03
38 - acc: 0.9876 - val_loss: 0.0500 - val_acc: 0.9827
Epoch 14/15
210/210 [==============================] - 68s 326ms/step - loss: 0.02
74 - acc: 0.9902 - val_loss: 0.0501 - val_acc: 0.9808
Epoch 15/15
210/210 [==============================] - 69s 328ms/step - loss: 0.03
50 - acc: 0.9876 - val_loss: 0.0656 - val_acc: 0.9731
```

In [8]:
```
import matplotlib.pyplot as plt

acc = history_CNN.history['acc']
val_acc = history_CNN.history['val_acc']

epochs = range(len(acc))

plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
```

Out[8]:
```
<matplotlib.legend.Legend at 0x7f55e561d8d0>
```



In [9]:
```
loss = history_CNN.history['loss']
val_loss = history_CNN.history['val_loss']

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
```



In [10]:

```
32/32 [==============================] - 11s 335ms/step - loss: 1.4924
- acc: 0.7564
```

Data Augmentation

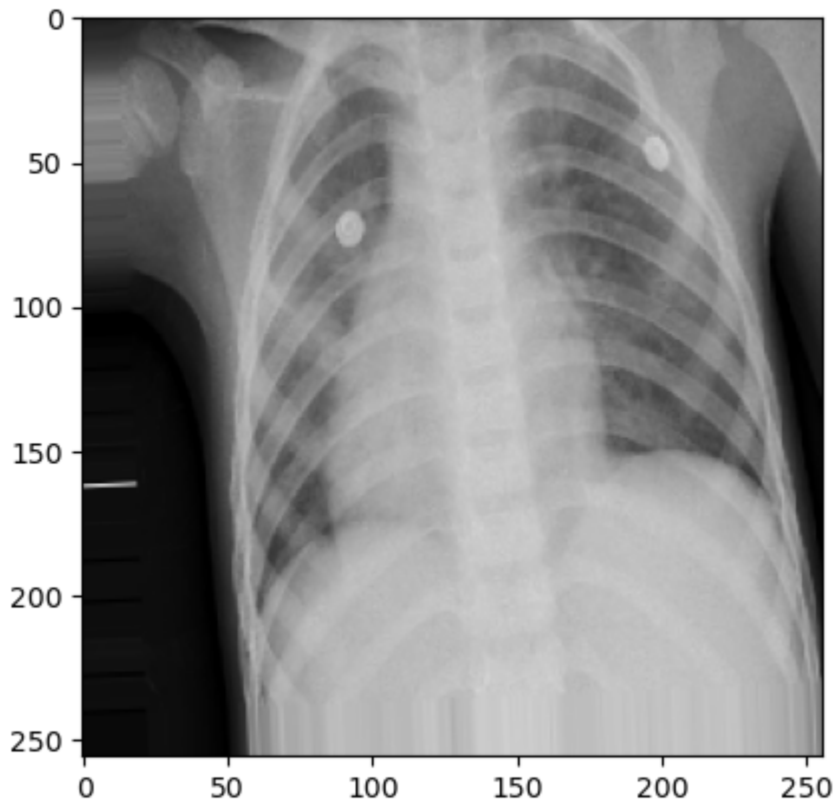
In [11]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications.imagenet_utils import preprocess_inpu

batch_size = 32
datagen = ImageDataGenerator(rescale = 1/255,
                             rotation_range=15,
                             width_shift_range=0.1,
                             height_shift_range=0.1,
                             shear_range=0.05,
                             zoom_range=0.2,
                             horizontal_flip=True,
                             fill_mode='nearest')


train = datagen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(
val_gen = ImageDataGenerator(rescale = 1/255)
val = val_gen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(2)
test_gen = ImageDataGenerator(rescale = 1/255)
test = test_gen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(
```

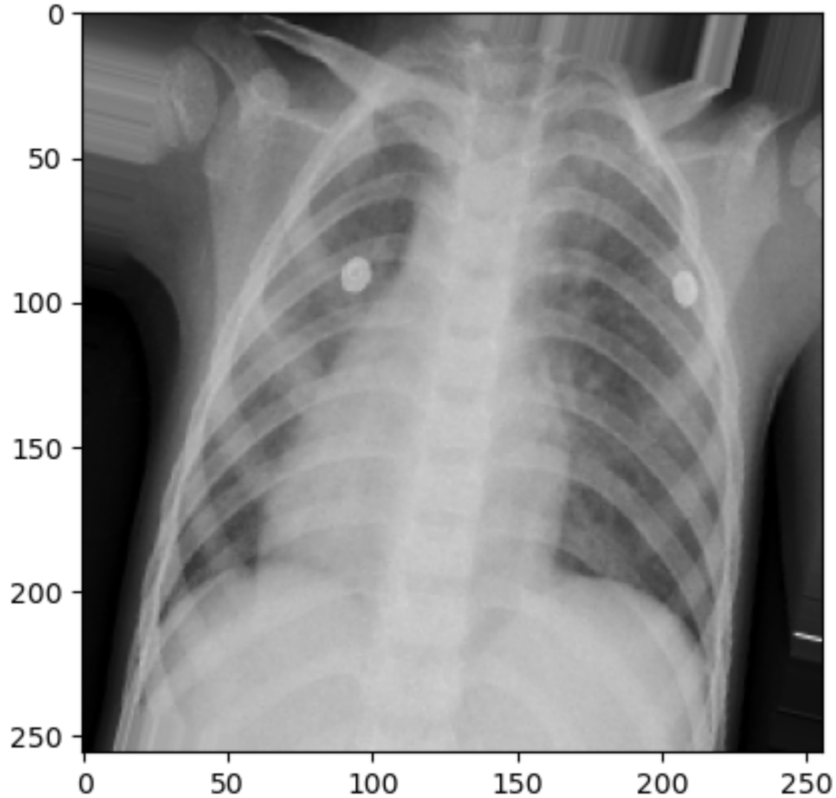
```
Found 4192 images belonging to 2 classes.
Found 1040 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

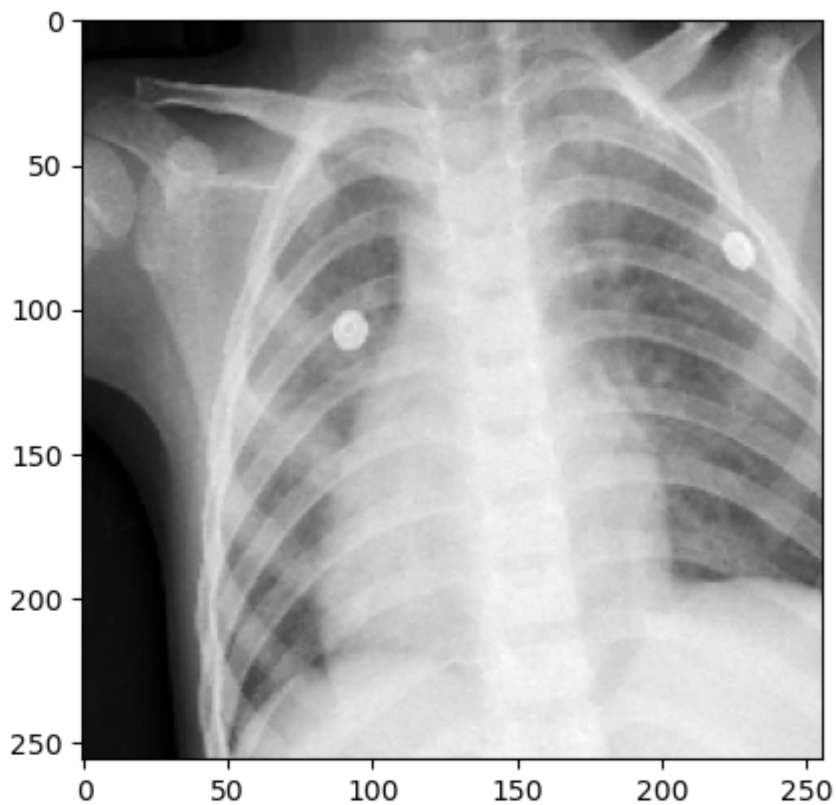
In [12]:
```
xx_test=np.concatenate([test.next()[0] for i in range(test.__len__())])
xx_test.shape
yy_test=np.concatenate([test.next()[1] for i in range(test.__len__())])
yy_test.shape
```

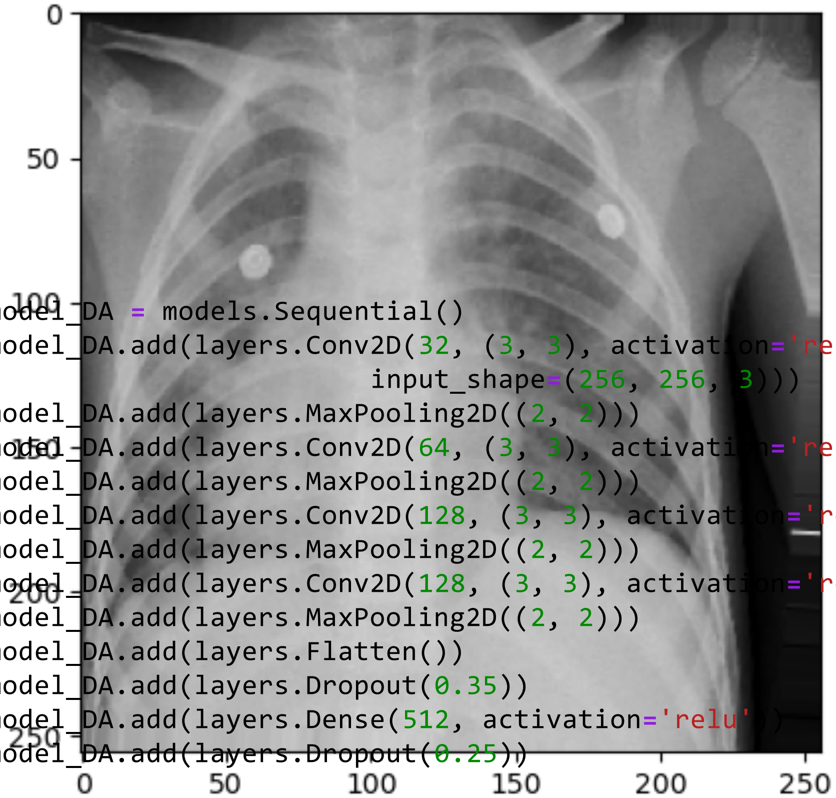
Out[12]:
```
(624, 256, 256, 3)
```

In [13]:
```
from tensorflow.keras.preprocessing import image

img = xx_test[0]

x = np.reshape(img,(256,256,3))

x = x.reshape((1,) + x.shape)

i = 0
for batch in datagen.flow(x, batch_size=1):
    plt.figure(i)
    imgplot = plt.imshow(image.array_to_img(batch[0]))
    i += 1
    if i % 4 == 0:
        break
```




0
50
100
150
200
250
0
50
100
150
200
250


0
50
100
150
200
250
0
50
100
150
200
250



Ba

In [14]:

```
model_DA = models.Sequential()
model_DA.add(layers.Conv2D(32, (3, 3), activation='relu',
                        input_shape=(256, 256, 3)))
model_DA.add(layers.MaxPooling2D((2, 2)))
model_DA.add(layers.Conv2D(64, (3, 3), activation='relu'))
model_DA.add(layers.MaxPooling2D((2, 2)))
model_DA.add(layers.Conv2D(128, (3, 3), activation='relu'))
model_DA.add(layers.MaxPooling2D((2, 2)))
model_DA.add(layers.Conv2D(128, (3, 3), activation='relu'))
model_DA.add(layers.MaxPooling2D((2, 2)))
model_DA.add(layers.Flatten())
model_DA.add(layers.Dropout(0.35))
model_DA.add(layers.Dense(512, activation='relu'))
model_DA.add(layers.Dropout(0.25))
```

In [15]:

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_4 (Conv2D)           (None, 254, 254, 32)      896       
                                                                 
 max_pooling2d_4 (MaxPooling  (None, 127, 127, 32)     0         
 2D)                                                             
                                                                 
 conv2d_5 (Conv2D)           (None, 125, 125, 64)      18496     
                                                                 
 max_pooling2d_5 (MaxPooling  (None, 62, 62, 64)       0         
 2D)                                                             
                                                                 
 conv2d_6 (Conv2D)           (None, 60, 60, 128)       73856     
                                                                 
 max_pooling2d_6 (MaxPooling  (None, 30, 30, 128)      0         
 2D)                                                             
                                                                 
 conv2d_7 (Conv2D)           (None, 28, 28, 128)       147584    
                                                                 
 max_pooling2d_7 (MaxPooling  (None, 14, 14, 128)      0         
 2D)                                                             
                                                                 
 flatten_1 (Flatten)         (None, 25088)             0         
                                                                 
 dropout_2 (Dropout)         (None, 25088)             0         
                                                                 
 dense_2 (Dense)             (None, 512)               12845568  
                                                                 
 dropout_3 (Dropout)         (None, 512)               0         
                                                                 
 dense_3 (Dense)             (None, 1)                 513       
                                                                 
=================================================================
Total params: 13,086,913
Trainable params: 13,086,913
Non-trainable params: 0
_________________________________________________________________
```

In [16]:

```
model_DA.compile(loss='binary_crossentropy',
              optimizer='adam',
```

In [17]:

```
history_DA = model_DA.fit(train,
          epochs=10,
          #steps_per_epoch=4192/batch_size,
```

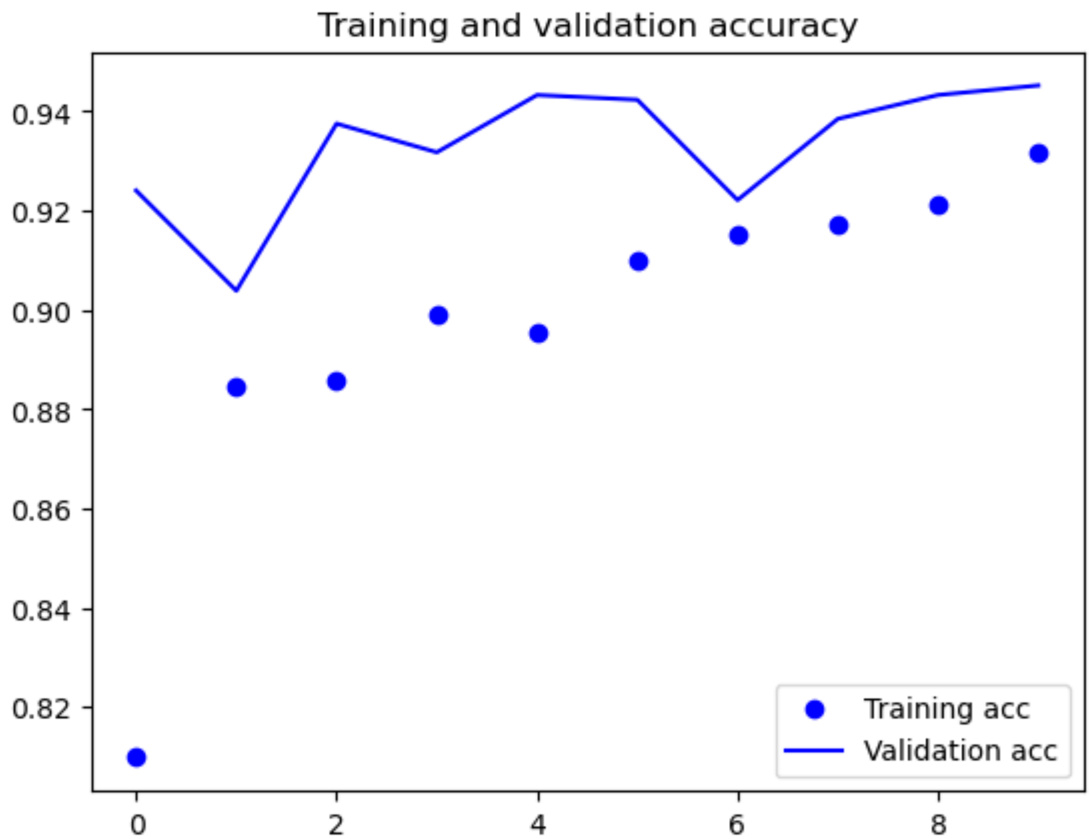
```
Epoch 1/10
131/131 [==============================] - 120s 898ms/step - loss: 0.4
225 - acc: 0.8099 - val_loss: 0.2160 - val_acc: 0.9240
Epoch 2/10
131/131 [==============================] - 120s 917ms/step - loss: 0.2
824 - acc: 0.8845 - val_loss: 0.2452 - val_acc: 0.9038
Epoch 3/10
131/131 [==============================] - 119s 907ms/step - loss: 0.2
647 - acc: 0.8857 - val_loss: 0.2573 - val_acc: 0.9375
Epoch 4/10
131/131 [==============================] - 118s 903ms/step - loss: 0.2
363 - acc: 0.8991 - val_loss: 0.1980 - val_acc: 0.9317
Epoch 5/10
131/131 [==============================] - 118s 903ms/step - loss: 0.2
468 - acc: 0.8955 - val_loss: 0.1627 - val_acc: 0.9433
Epoch 6/10
131/131 [==============================] - 118s 901ms/step - loss: 0.2
148 - acc: 0.9098 - val_loss: 0.1757 - val_acc: 0.9423
Epoch 7/10
131/131 [==============================] - 118s 902ms/step - loss: 0.2
002 - acc: 0.9151 - val_loss: 0.2088 - val_acc: 0.9221
Epoch 8/10
131/131 [==============================] - 117s 897ms/step - loss: 0.2
051 - acc: 0.9172 - val_loss: 0.1705 - val_acc: 0.9385
Epoch 9/10
131/131 [==============================] - 118s 904ms/step - loss: 0.1
846 - acc: 0.9210 - val_loss: 0.1493 - val_acc: 0.9433
Epoch 10/10
131/131 [==============================] - 118s 901ms/step - loss: 0.1
778 - acc: 0.9315 - val_loss: 0.1510 - val_acc: 0.9452
```

In [18]:

```
import matplotlib.pyplot as plt

acc = history_DA.history['acc']
val_acc = history_DA.history['val_acc']

epochs = range(len(acc))

plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
```

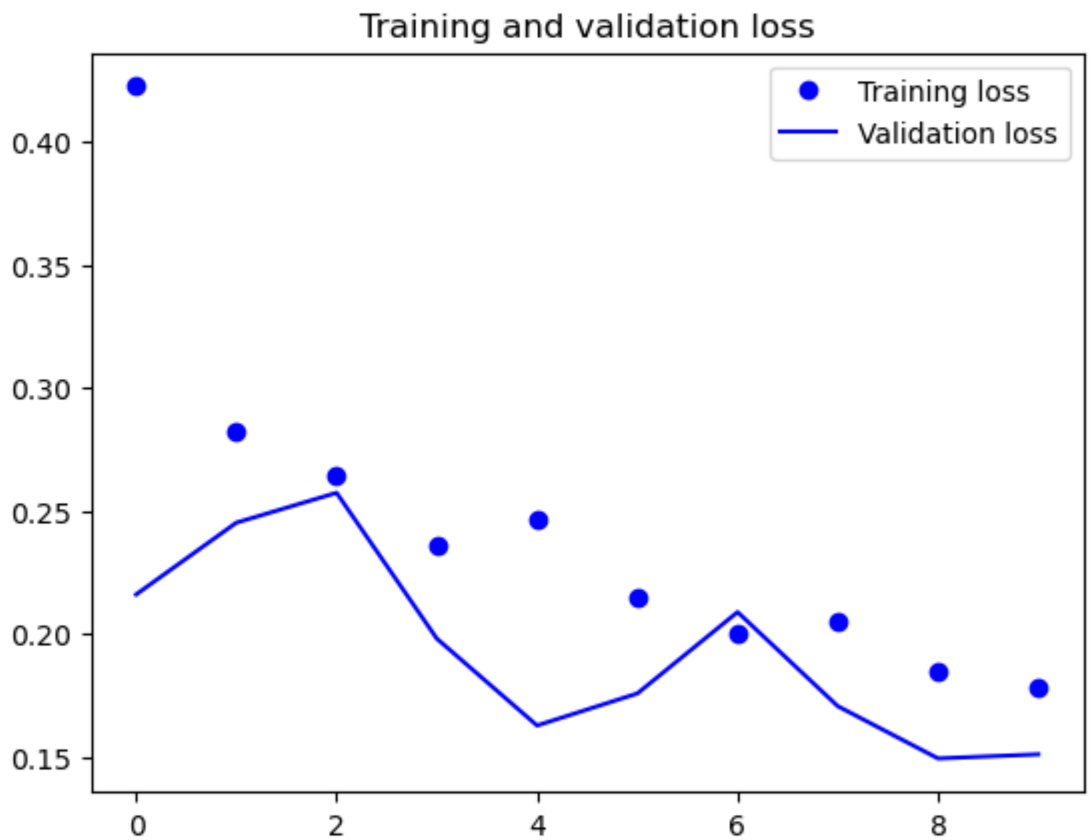
Out[18]:

```
<matplotlib.legend.Legend at 0x7f55e463ed50>
```



In [19]:

```
loss = history_DA.history['loss']
val_loss = history_DA.history['val_loss']

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
```



In [20]:

```
20/20 [==============================] - 8s 377ms/step - loss: 0.3199
- acc: 0.8734
```

Transfer Learning

In [21]:

```
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications.imagenet_utils import preprocess_inpu

batch_size = 32
datagen = ImageDataGenerator(rescale = 1/255,
                             rotation_range=15,
                             width_shift_range=0.1,
                             height_shift_range=0.1,
                             shear_range=0.05,
                             zoom_range=0.2,
                             horizontal_flip=True,
                             fill_mode='nearest')


train = datagen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(
val_gen = ImageDataGenerator(rescale = 1/255)
val = val_gen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(2)
test_gen = ImageDataGenerator(rescale = 1/255)
test = test_gen.flow_from_directory('C:/Users/Xhensil/Downloads/archive(
```

```
Found 4192 images belonging to 2 classes.
Found 1040 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

In [22]:
```
from tensorflow.keras.applications import VGG16

conv_base = VGG16(weights='imagenet',
                  include_top=False,
                  input_shape=(256, 256, 3))
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5 (https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5)
58889256/58889256 [==============================] - 0s 0us/step
Model: "vgg16"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 256, 256, 3)]     0

 block1_conv1 (Conv2D)       (None, 256, 256, 64)      1792

 block1_conv2 (Conv2D)       (None, 256, 256, 64)      36928

 block1_pool (MaxPooling2D)  (None, 128, 128, 64)      0

 block2_conv1 (Conv2D)       (None, 128, 128, 128)     73856

 block2_conv2 (Conv2D)       (None, 128, 128, 128)     147584

 block2_pool (MaxPooling2D)  (None, 64, 64, 128)       0

 block3_conv1 (Conv2D)       (None, 64, 64, 256)       295168

 block3_conv2 (Conv2D)       (None, 64, 64, 256)       590080

 block3_conv3 (Conv2D)       (None, 64, 64, 256)       590080

 block3_pool (MaxPooling2D)  (None, 32, 32, 256)       0

 block4_conv1 (Conv2D)       (None, 32, 32, 512)       1180160

 block4_conv2 (Conv2D)       (None, 32, 32, 512)       2359808

 block4_conv3 (Conv2D)       (None, 32, 32, 512)       2359808

 block4_pool (MaxPooling2D)  (None, 16, 16, 512)       0

 block5_conv1 (Conv2D)       (None, 16, 16, 512)       2359808

 block5_conv2 (Conv2D)       (None, 16, 16, 512)       2359808

 block5_conv3 (Conv2D)       (None, 16, 16, 512)       2359808

 block5_pool (MaxPooling2D)  (None, 8, 8, 512)         0

=================================================================
Total params: 14,714,688
```

```
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
```

In [23]:

```
model_TL = models.Sequential()
model_TL.add(conv_base)
model_TL.add(layers.Flatten())
model_TL.add(layers.Dense(512, activation='relu'))
model_TL.add(layers.Dropout(0.4))
model_TL.add(layers.Dense(1, activation='sigmoid'))
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 vgg16 (Functional)          (None, 8, 8, 512)         14714688

 flatten_2 (Flatten)         (None, 32768)             0

 dense_4 (Dense)             (None, 512)               16777728

 dropout_4 (Dropout)         (None, 512)               0

 dense_5 (Dense)             (None, 1)                 513

=================================================================
Total params: 31,492,929
Trainable params: 31,492,929
Non-trainable params: 0
_________________________________________________________________
```

In [24]:

```
print('This is the number of trainable weights '
```

```
This is the number of trainable weights before freezing the conv base:
30
```

In [25]:

In [26]:

```
print('This is the number of trainable weights '
```

```
This is the number of trainable weights before freezing the conv base:
4
```

In [27]:

```
model_TL.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

history_TL = model_TL.fit(train,
          epochs=10,
```

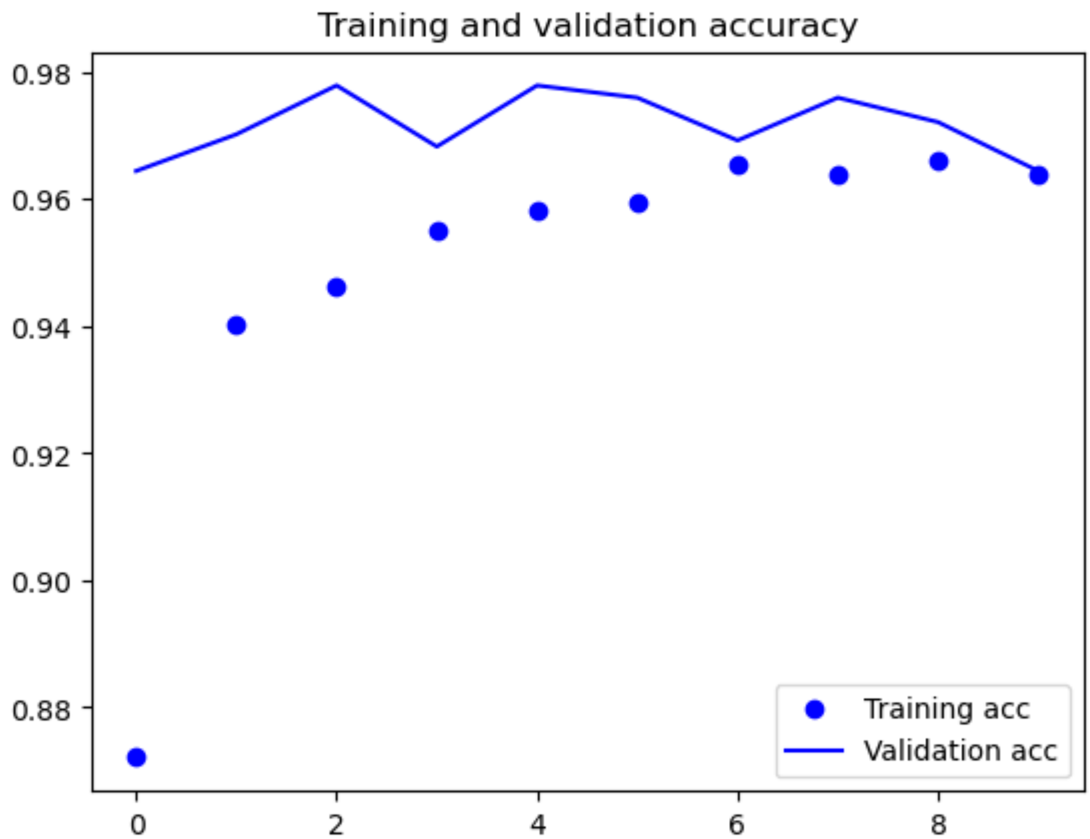
```
Epoch 1/10
66/66 [==============================] - 137s 2s/step - loss: 5.7719 -
accuracy: 0.8721 - val_loss: 0.1235 - val_accuracy: 0.9644
Epoch 2/10
66/66 [==============================] - 126s 2s/step - loss: 0.1441 -
accuracy: 0.9401 - val_loss: 0.0964 - val_accuracy: 0.9702
Epoch 3/10
66/66 [==============================] - 126s 2s/step - loss: 0.1399 -
accuracy: 0.9463 - val_loss: 0.0765 - val_accuracy: 0.9779
Epoch 4/10
66/66 [==============================] - 126s 2s/step - loss: 0.1158 -
accuracy: 0.9549 - val_loss: 0.1040 - val_accuracy: 0.9683
Epoch 5/10
66/66 [==============================] - 126s 2s/step - loss: 0.1061 -
accuracy: 0.9583 - val_loss: 0.0875 - val_accuracy: 0.9779
Epoch 6/10
66/66 [==============================] - 126s 2s/step - loss: 0.1091 -
accuracy: 0.9594 - val_loss: 0.0702 - val_accuracy: 0.9760
Epoch 7/10
66/66 [==============================] - 126s 2s/step - loss: 0.0873 -
accuracy: 0.9654 - val_loss: 0.0865 - val_accuracy: 0.9692
Epoch 8/10
66/66 [==============================] - 126s 2s/step - loss: 0.0921 -
accuracy: 0.9640 - val_loss: 0.0706 - val_accuracy: 0.9760
Epoch 9/10
66/66 [==============================] - 127s 2s/step - loss: 0.0870 -
accuracy: 0.9661 - val_loss: 0.1157 - val_accuracy: 0.9721
Epoch 10/10
66/66 [==============================] - 126s 2s/step - loss: 0.0953 -
accuracy: 0.9637 - val_loss: 0.0910 - val_accuracy: 0.9644
```

In [28]:

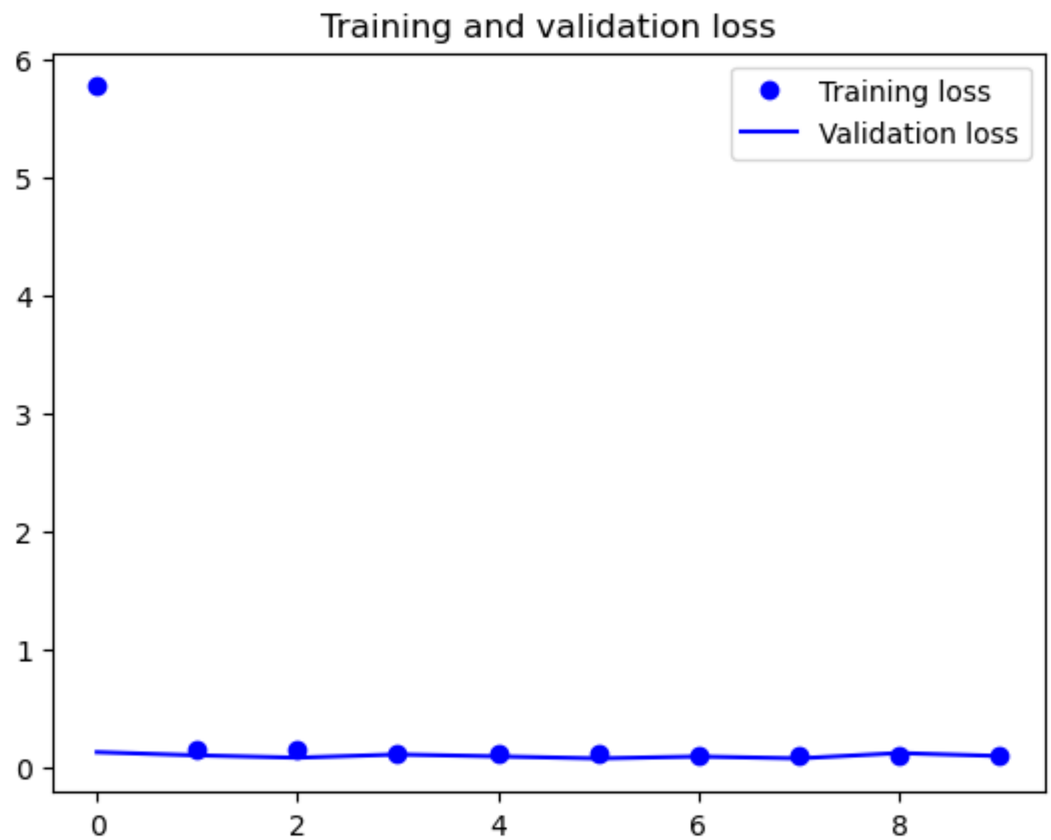
```
import matplotlib.pyplot as plt

acc = history_TL.history['accuracy']
val_acc = history_TL.history['val_accuracy']

epochs = range(len(acc))

plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
```

Out[28]:

```
<matplotlib.legend.Legend at 0x7f55e40d0e50>
```



In [29]:
```
loss = history_TL.history['loss']
val_loss = history_TL.history['val_loss']

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
```



In [30]:

```
10/10 [==============================] - 14s 1s/step - loss: 0.3148 -
accuracy: 0.9199
```

In [32]:
```
conv_base.trainable = True

set_trainable = False
for layer in conv_base.layers:
    if layer.name == 'block5_conv1':
        set_trainable = True
    if set_trainable:
        layer.trainable = True
    else:
        layer.trainable = False
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 vgg16 (Functional)          (None, 8, 8, 512)         14714688

 flatten_2 (Flatten)         (None, 32768)             0

 dense_4 (Dense)             (None, 512)               16777728

 dropout_4 (Dropout)         (None, 512)               0

 dense_5 (Dense)             (None, 1)                 513

=================================================================
Total params: 31,492,929
Trainable params: 23,857,665
Non-trainable params: 7,635,264
_________________________________________________________________
```

In [33]:

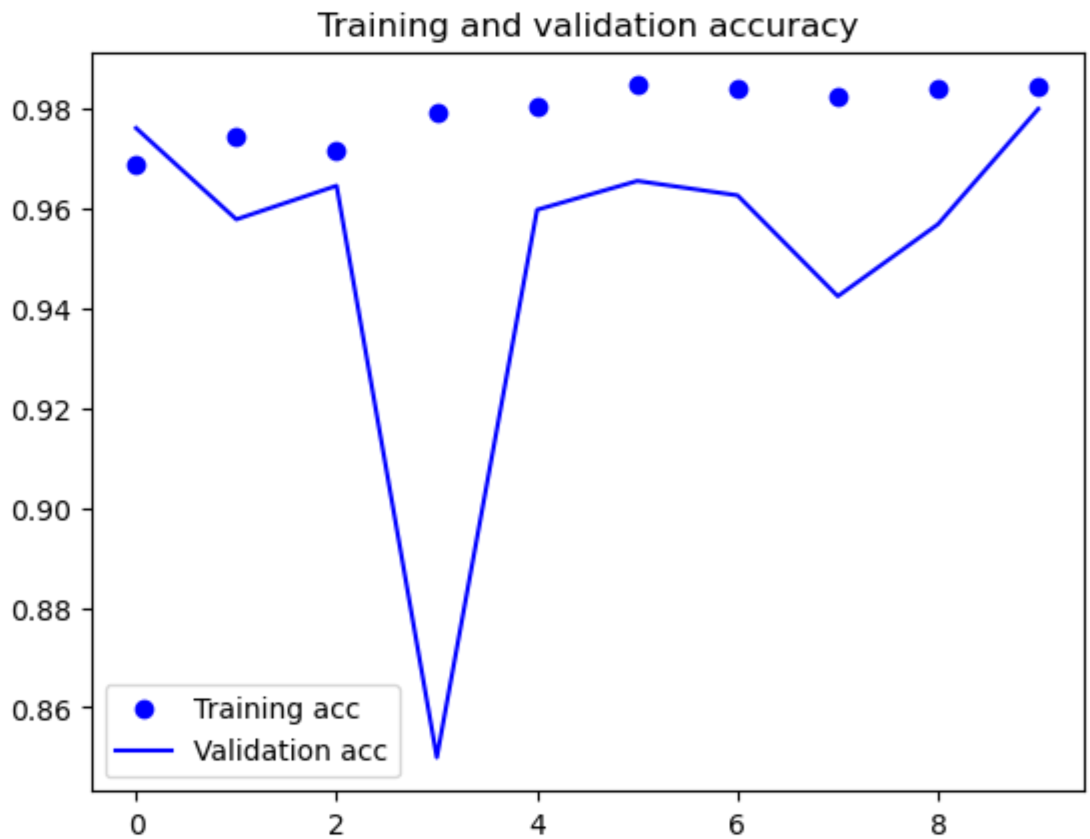
```
model_TL.compile(optimizer=optimizers.Adam(learning_rate=1e-5),
              loss='binary_crossentropy',
              metrics=['accuracy'])

history_FT = model_TL.fit(train,
          epochs=10,
          # steps_per_epoch=100, # Run same number of steps we would if
```

```
Epoch 1/10
66/66 [==============================] - 129s 2s/step - loss: 0.0919 -
accuracy: 0.9688 - val_loss: 0.0645 - val_accuracy: 0.9760
Epoch 2/10
66/66 [==============================] - 125s 2s/step - loss: 0.0742 -
accuracy: 0.9742 - val_loss: 0.1274 - val_accuracy: 0.9577
Epoch 3/10
66/66 [==============================] - 125s 2s/step - loss: 0.0729 -
accuracy: 0.9716 - val_loss: 0.1069 - val_accuracy: 0.9644
Epoch 4/10
66/66 [==============================] - 127s 2s/step - loss: 0.0637 -
accuracy: 0.9790 - val_loss: 0.4936 - val_accuracy: 0.8500
Epoch 5/10
66/66 [==============================] - 125s 2s/step - loss: 0.0628 -
accuracy: 0.9802 - val_loss: 0.1228 - val_accuracy: 0.9596
Epoch 6/10
66/66 [==============================] - 125s 2s/step - loss: 0.0451 -
accuracy: 0.9845 - val_loss: 0.1269 - val_accuracy: 0.9654
Epoch 7/10
66/66 [==============================] - 126s 2s/step - loss: 0.0464 -
accuracy: 0.9840 - val_loss: 0.1258 - val_accuracy: 0.9625
Epoch 8/10
66/66 [==============================] - 126s 2s/step - loss: 0.0470 -
accuracy: 0.9823 - val_loss: 0.2018 - val_accuracy: 0.9423
Epoch 9/10
66/66 [==============================] - 125s 2s/step - loss: 0.0438 -
accuracy: 0.9838 - val_loss: 0.1478 - val_accuracy: 0.9567
Epoch 10/10
66/66 [==============================] - 127s 2s/step - loss: 0.0501 -
accuracy: 0.9843 - val_loss: 0.0746 - val_accuracy: 0.9798
```

In [34]:

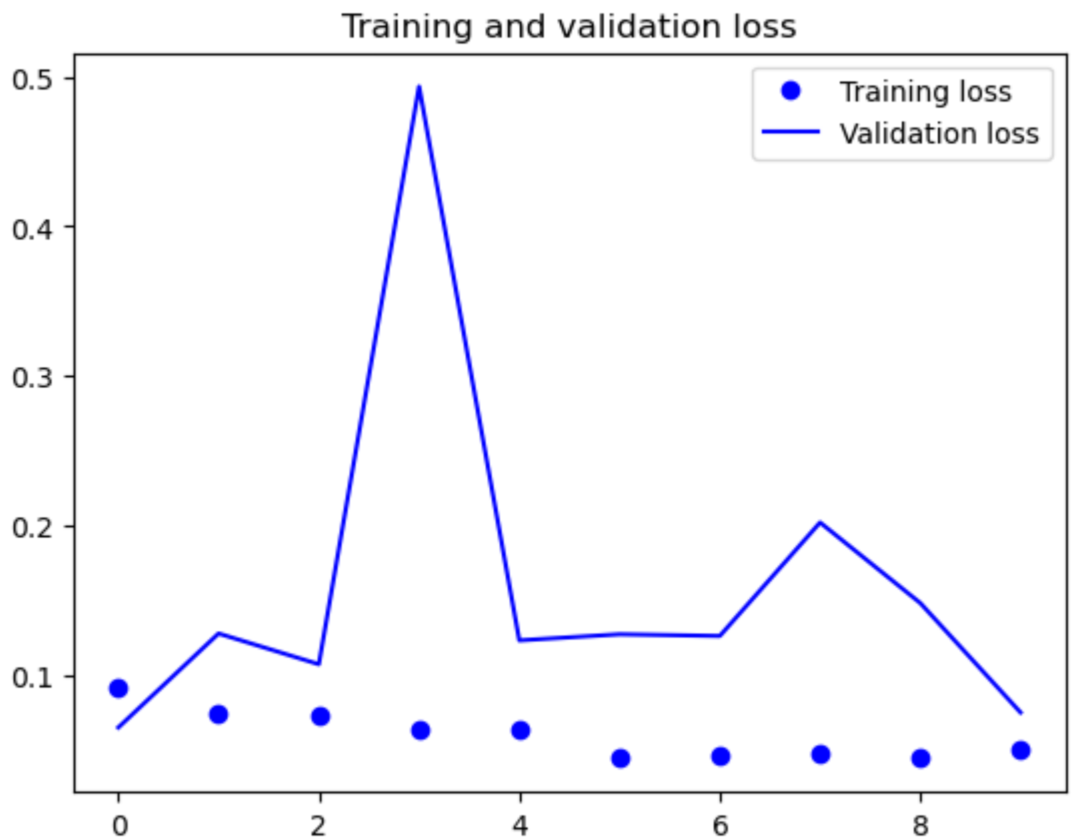
```
import matplotlib.pyplot as plt

acc = history_FT.history['accuracy']
val_acc = history_FT.history['val_accuracy']

epochs = range(len(acc))

plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
```

Out[34]: <matplotlib.legend.Legend at 0x7f55e45c6890>



In [35]:

```
loss = history_FT.history['loss']
val_loss = history_FT.history['val_loss']

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
```



In [36]:

```
10/10 [==============================] - 9s 925ms/step - loss: 0.3591
- accuracy: 0.9199
```

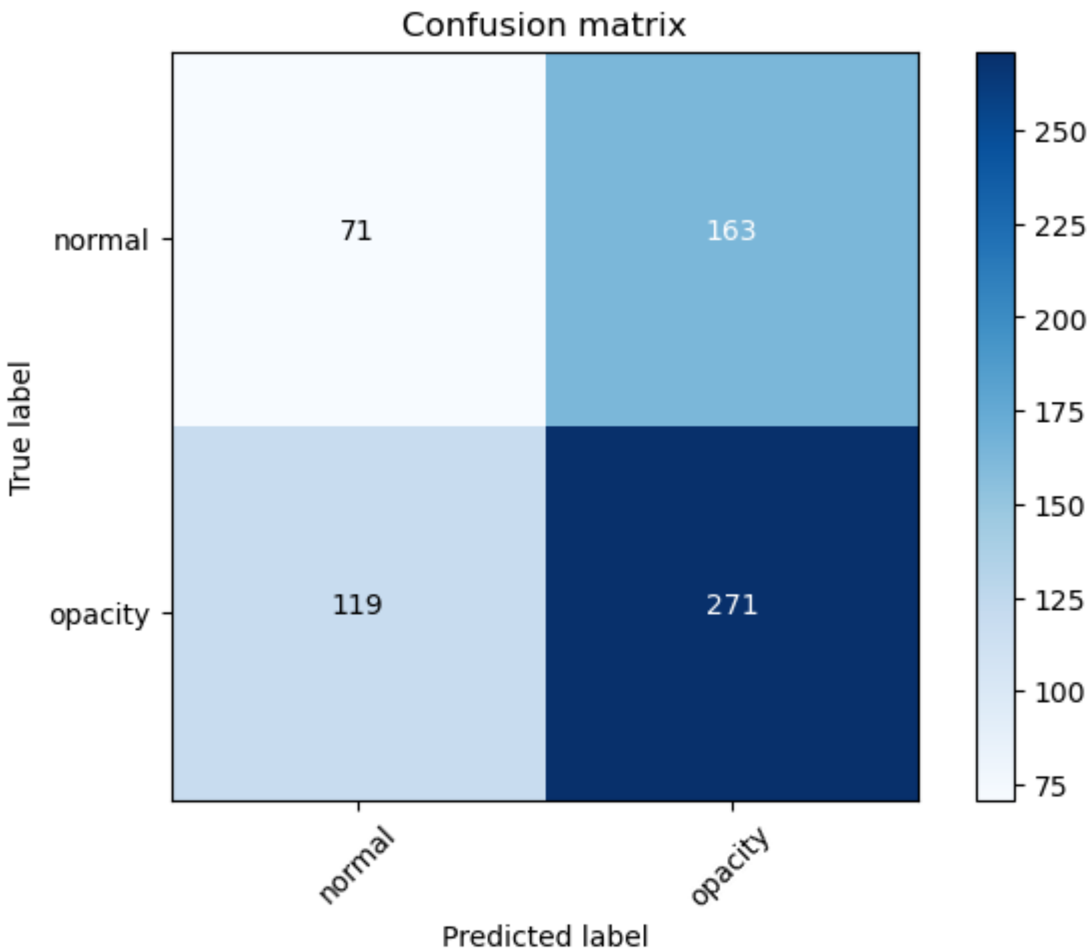
In [48]:

```
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
# Make predictions on the batches of images
y_pred = model_TL.predict_generator(test)

# Convert predicted probabilities to predicted labels
y_pred_labels = np.where(y_pred > 0.5, 1, 0)

# Get true labels
```

```
/opt/conda/lib/python3.7/site-packages/ipykernel_launcher.py:3: UserWa
rning: `Model.predict_generator` is deprecated and will be removed in
a future version. Please use `Model.predict`, which supports generator
s.
  This is separate from the ipykernel package so we can avoid doing im
ports until
```

In [49]:

```
import matplotlib.pyplot as plt
import itertools

# Define the classes
classes = ['normal', 'opacity']

# Calculate the confusion matrix
confusion_mtx = confusion_matrix(y_true_labels, y_pred_labels)

# Define a function to plot the confusion matrix
def plot_confusion_matrix(cm, classes, title='Confusion matrix', cmap=pl
    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)
    fmt = 'd'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])
        plt.text(j, i, format(cm[i, j], fmt), horizontalalignment="cente
    plt.tight_layout()
    plt.ylabel('True label')
    plt.xlabel('Predicted label')

# Plot the confusion matrix
plot_confusion_matrix(confusion_mtx, classes)
plt.show()
```



In [38]:

```
# CNN model
acc2=history_CNN.history['acc'][-1]
vacc2=history_CNN.history['val_acc'][-1]
loss2=history_CNN.history['loss'][-2]
vloss2=history_CNN.history['val_loss'][-2]

# Data Augmentation
acc3=history_DA.history['acc'][-1]
vacc3=history_DA.history['val_acc'][-1]
loss3=history_DA.history['loss'][-2]
vloss3=history_DA.history['val_loss'][-2]

# ResNet50
acc4=history_TL.history['accuracy'][-1]
vacc4=history_TL.history['val_accuracy'][-1]
loss4=history_TL.history['loss'][-2]
vloss4=history_TL.history['val_loss'][-2]

# ResNet50 Fine Tune
acc5=history_FT.history['accuracy'][-1]
vacc5=history_FT.history['val_accuracy'][-1]
loss5=history_FT.history['loss'][-2]
```

In [39]:

```
results = pd.DataFrame([["CNN",acc2*100,vacc2*100,loss2,vloss2],
                       ["CNN_data_augmentation",acc3*100,vacc3*100,loss3
                       ["Transfer Learning model",acc4*100,vacc4*100,los
                       ["Transfer Learning model_FT",acc5*100,vacc5*100,
                       columns = ["Model","Training Accuracy %","Validat
```

Out[39]:

	Model	Training Accuracy %	Validation Accuracy %	Loss	Validation Loss
0	CNN	98.759544	97.307694	0.027386	0.050128
1	CNN_data_augmentation	93.153626	94.519234	0.184610	0.149308
2	Transfer Learning model	96.374047	96.442306	0.087022	0.115681
3	Transfer Learning model_FT	98.425573	97.980767	0.043833	0.147835

In [ ]: