ARUNet-3D-NRS-VFold-Test

November 25, 2021

[5]:
```
from monai.utils import first, set_determinism
from monai.transforms import (
    AddChanneld,
    AsChannelFirstd,
    AsDiscrete,
    AsDiscreted,
    Compose,
    EnsureChannelFirstd,
    EnsureTyped,
    EnsureType,
    Invertd,
    Lambdad,
    LoadImaged,
    RandFlipd,
    RandSpatialCropd,
    RandZoomd,
    Resized,
    ScaleIntensityRanged,
    SpatialCrop,
    SpatialCropd,
    ToTensord,
)
from monai.handlers.utils import from_engine
from monai.networks.nets import UNet
from monai.networks.layers import Norm
from monai.metrics import DiceMetric
from monai.losses import DiceLoss
from monai.inferers import sliding_window_inference
from monai.data import CacheDataset, DataLoader, Dataset, decollate_batch
from monai.config import print_config
from monai.apps import download_and_extract
import monai.utils as utils

import torch
import matplotlib.pyplot as plt
import tempfile
import shutil
```

```
import os
from glob import glob

import itk
from itk import TubeTK as ttk

import numpy as np

import site
site.addsitedir('../../ARGUS')
from ARGUSUtils_Transforms import *
```

[6]:
```
img1_dir = "../../Data/VFoldData/BAMC-PTX*Sliding-Annotations-Linear/"

all_images = sorted(glob(os.path.join(img1_dir, '*_?????.nii.gz')))
all_labels = sorted(glob(os.path.join(img1_dir, '*.interpolated-overlay.nii.
↪gz')))

gpu_device = 1

num_classes = 4
class_sliding = 3
class_not_sliding = 1

net_dims = 3
net_in_channels = 1
net_channels=(16, 32, 64, 128, 32)
net_strides=(2, 2, 2, 2)

num_folds = 15

num_slices = 48
size_x = 320
size_y = 320
roi_size = (size_x,size_y,num_slices)

num_workers_te = 0
batch_size_te = 1

model_filename_base = "./results/BAMC_PTX_ARUNet-3D-NRS"

model_type = "best"  #"best" or "last"
```

[7]:
```
num_images = len(all_images)
print(num_images, len(all_labels))

ns_prefix = ['025ns','026ns','027ns','035ns','048ns','055ns','117ns',
```

```
            '135ns','193ns','210ns','215ns','218ns','219ns','221ns','247ns']
s_prefix = ['004s','019s','030s','034s','037s','043s','065s','081s',
            '206s','208s','211s','212s','224s','228s','236s','237s']

fold_prefix_list = []
ns_count = 0
s_count = 0
for i in range(num_folds):
    if i%2 == 0:
        num_ns = 1
        num_s = 1
        if i > num_folds-3:
            num_s = 2
    else:
        num_ns = 1
        num_s = 1
    f = []
    for ns in range(num_ns):
        f.append([ns_prefix[ns_count+ns]])
    ns_count += num_ns
    for s in range(num_s):
        f.append([s_prefix[s_count+s]])
    s_count += num_s
    fold_prefix_list.append(f)

train_files = []
val_files = []
test_files = []
for i in range(num_folds):
    tr_folds = []
    for f in range(i,i+num_folds-2):
        tr_folds.append(fold_prefix_list[f%num_folds])
    tr_folds = list(np.concatenate(tr_folds).flat)
    va_folds = list(np.concatenate(fold_prefix_list[(i+num_folds-2) %␣
 ↪num_folds]).flat)
    te_folds = list(np.concatenate(fold_prefix_list[(i+num_folds-1) %␣
 ↪num_folds]).flat)
    train_files.append(
            [
                {"image": img, "label": seg}
                for img, seg in zip(
                    [im for im in all_images if any(pref in im for pref in␣
 ↪tr_folds)],
                    [se for se in all_labels if any(pref in se for pref in␣
 ↪tr_folds)])
            ]
        )
```

```
    val_files.append(
            [
                {"image": img, "label": seg}
                for img, seg in zip(
                    [im for im in all_images if any(pref in im for pref in va_folds)],
                    [se for se in all_labels if any(pref in se for pref in va_folds)])
            ]
        )
    test_files.append(
            [
                {"image": img, "label": seg}
                for img, seg in zip(
                    [im for im in all_images if any(pref in im for pref in te_folds)],
                    [se for se in all_labels if any(pref in se for pref in te_folds)])
            ]
        )
    print(len(train_files[i]),len(val_files[i]),len(test_files[i]))
```

```
62 62
53 4 5
53 5 4
54 4 4
54 4 4
54 4 4
55 4 3
55 3 4
54 4 4
54 4 4
54 4 4
53 4 5
53 5 4
53 4 5
53 5 4
54 4 4
```

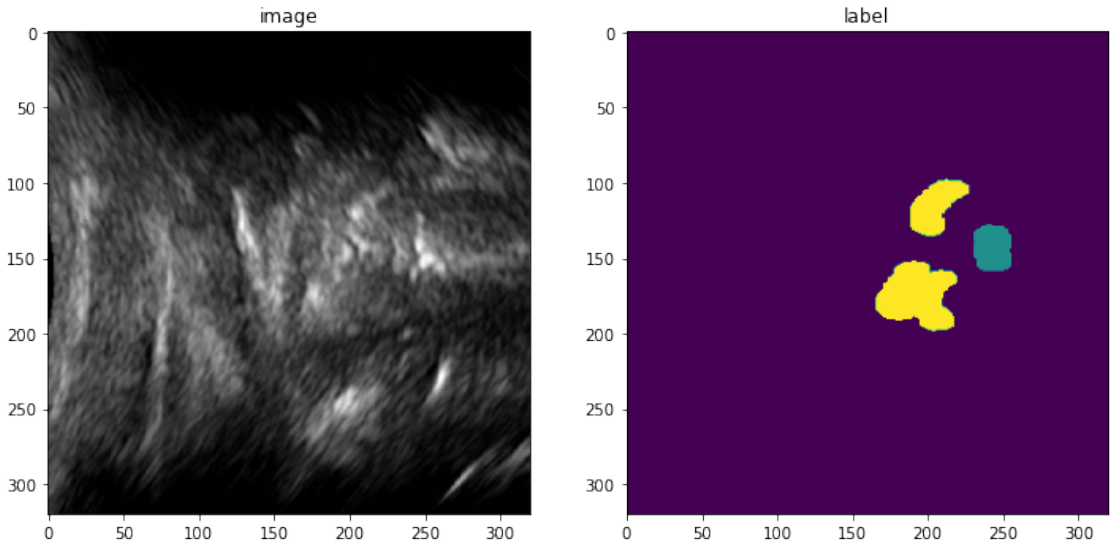
[8]:
```
train_shape = itk.GetArrayFromImage(itk.imread(train_files[0][0]["image"])).shape

test_transforms = Compose(
    [
        LoadImaged(keys=["image", "label"]),
        AddChanneld(keys=['image','label']),
        ScaleIntensityRanged(
```

```
            a_min=0, a_max=255,
            b_min=0.0, b_max=1.0,
            keys=["image"]),
        #Lambdad(
            #func=lambda x: np.where(x==3,1,x),
            #keys=['label']),
        ARGUS_RandSpatialCropSlicesd(
            num_slices=num_slices,
            axis=3,
            keys=['image', 'label']),
        ToTensord(keys=["image", "label"]),
    ]
)
```

[9]:
```
test_ds = [Dataset(data=test_files[i], transform=test_transforms)
           for i in range(num_folds)]
test_loader = [DataLoader(test_ds[i], batch_size=batch_size_te,␣
 ↪num_workers=num_workers_te)
               for i in range(num_folds)]
```

[12]:
```
imgnum = 0
batchnum = 0
channelnum = 0
slicenum = 24

img = utils.first(test_loader[batchnum])["image"]
print("Image shape =", img.shape)
print("Image range =", img[imgnum,channelnum,:,:,slicenum].min(),␣
 ↪img[imgnum,channelnum,:,:,slicenum].max())
lbl = utils.first(test_loader[batchnum])["label"]
print("Label shape =", lbl.shape)
print("Label range =", lbl[imgnum,channelnum,:,:,slicenum].min(), lbl[imgnum,0,:
 ↪,:,slicenum].max())

plt.figure("Testing", (12, 6))
plt.subplot(1, 2, 1)
plt.title("image")
plt.imshow(img[imgnum, channelnum, :, :, slicenum], cmap="gray")
plt.subplot(1, 2, 2)
plt.title("label")
plt.imshow(lbl[imgnum, channelnum, :, :, slicenum])
plt.show()
```

```
Image shape = torch.Size([1, 1, 320, 320, 48])
Image range = tensor(0.) tensor(0.7412)
Label shape = torch.Size([1, 1, 320, 320, 48])
Label range = tensor(0.) tensor(2.)
```



[13]:
```
# standard PyTorch program style: create UNet, DiceLoss and Adam optimizer
device = torch.device("cuda:"+str(gpu_device))
```

[25]:
```
def plot_vfold_training_curves(vfold_num, test_loader, min_size_comp,␣
 ↪min_portion_comp, p_prior, graph):
    if graph:
        print("   VFOLD =", vfold_num, "of", num_folds)

    patient_correct = 0
    patient_incorrect = 0
    patient_false_negatives = 0

    frame_correct = 0
    frame_incorrect = 0
    frame_false_negatives = 0

    roi_correct = 0
    roi_incorrect = 0
    roi_false_negatives = 0

    loss_file = model_filename_base+"_loss_"+str(vfold_num)+".npy"
    if os.path.exists(loss_file):
        epoch_loss_values = np.load(loss_file)

        metric_file = model_filename_base+"_val_dice_"+str(vfold_num)+".npy"
        metric_values = np.load(metric_file)

        if graph:
```

```
            plt.figure("train", (12, 6))
            plt.subplot(1, 2, 1)
            plt.title("Epoch Average Loss")
            x = [i + 1 for i in range(len(epoch_loss_values))]
            y = epoch_loss_values
            plt.xlabel("epoch")
            plt.plot(x, y)
            plt.ylim([0.2,0.8])
            plt.subplot(1, 2, 2)
            plt.title("Val Mean Dice")
            x = [2 * (i + 1) for i in range(len(metric_values))]
            y = metric_values
            plt.xlabel("epoch")
            plt.plot(x, y)
            plt.ylim([0.2,0.8])
            plt.show()

    model_file = model_filename_base+'.'+model_type+'_model.
↪vfold_'+str(vfold_num)+'.pth'
    if os.path.exists(model_file):
        model = UNet(
            dimensions=net_in_dims,
            in_channels=net_in_channels,
            out_channels=num_classes,
            channels=net_channels,
            strides=net_strides,
            num_res_units=2,
            norm=Norm.BATCH,
        ).to(device)
        model.load_state_dict(torch.load(model_file))
        model.eval()
        with torch.no_grad():
            fold_imgnum = 0
            fname = os.path.
↪basename(test_files[vfold_num][fold_imgnum]["image"])
            prevfname = fname
            frame_roi_count = 0
            frame_roi_count_not_sliding = 0
            patient_frame_count = 0
            patient_frame_count_not_sliding = 0
            for batchnum,test_data in enumerate(test_loader):
                test_outputs = sliding_window_inference(
                    test_data["image"].to(device), roi_size, batch_size_te,␣
↪model
                )
                for batch_imgnum in range(test_outputs.shape[0]):
                    prevfname = fname
```

```
                    fname = os.path.
↪basename(test_files[vfold_num][fold_imgnum]["image"])

                    if fname[:22]!=prevfname[:22]:
                        patient_frame_count += 1
                        if frame_roi_count_not_sliding == 0: # frame_roi_count
                            if graph:
                                print(" ** Frame Winner = Sliding ( NS␣
↪=",frame_roi_count_not_sliding,"of",frame_roi_count,")")
                            if prevfname[3] == 's':
                                frame_correct += 1
                                if graph:
                                    print("    Correct")
                            else:
                                frame_incorrect += 1
                                frame_false_negatives += 1
                                print("    Frame False Negative =", prevfname)
                        else:
                            patient_frame_count_not_sliding += 1
                            if graph:
                                print(" ** Frame Winner = Not Sliding ( NS␣
↪=",frame_roi_count_not_sliding,"of",frame_roi_count,")")
                            if prevfname[3] == 'n':
                                frame_correct += 1
                                if graph:
                                    print("    Correct")
                            else:
                                frame_incorrect += 1
                                print("    Frame False Positive =", prevfname)
                        if graph:
                            print()
                            print()
                        frame_roi_count = 0
                        frame_roi_count_not_sliding = 0
                    if fname[:4]!=prevfname[:4]:
                        if patient_frame_count_not_sliding == 0:
                            if graph:
                                print("*** Patient Winner = Sliding ( NS␣
↪=",patient_frame_count_not_sliding,"of",patient_frame_count,")")
                            if prevfname[3] == 's':
                                patient_correct += 1
                                if graph:
                                    print("    Correct")
                            else:
                                patient_incorrect += 1
                                patient_false_negatives += 1
                                print("    Patient False Negative =", prevfname)
```

```
                        else:
                            if graph:
                                print("*** Patient Winner = Not Sliding ( NS␣
↪=",patient_frame_count_not_sliding,"of",patient_frame_count,")")
                            if prevfname[3] == 'n':
                                patient_correct += 1
                                if graph:
                                    print("    Correct")
                            else:
                                patient_incorrect += 1
                                print("    Patient False Positive =", prevfname)
                        if graph:
                            print()
                            print()

                    prob_shape = test_outputs[batch_imgnum,:,:,:,:].shape
                    prob = np.empty(prob_shape)
                    for c in range(num_classes):
                        itkProb = itk.
↪GetImageFromArray(test_outputs[batch_imgnum,c,:,:,:].cpu())
                        imMathProb = ttk.ImageMath.New(itkProb)
                        imMathProb.Blur(5)
                        itkProb = imMathProb.GetOutput()
                        prob[c] = itk.GetArrayFromImage(itkProb)
                    arrc1 = np.zeros(prob[0].shape)
                    if False:
                        arrc1 = np.argmax(prob,axis=0)
                    else:
                        pmin = prob[0].min()
                        pmax = prob[0].max()
                        for c in range(1,num_classes):
                            pmin = min(pmin, prob[c].min())
                            pmax = max(pmax, prob[c].max())
                        prange = pmax - pmin
                        prob = (prob - pmin) / prange
                        for c in range(num_classes):
                            prob[c] = prob[c] * p_prior[c]
                        arrc1 = np.argmax(prob,axis=0)

                    roi_max_size = np.
↪count_nonzero(test_data["label"][batch_imgnum,0,:,:,:].cpu()>0)
                    roi_sliding_min_thresh = max(min_size_comp,␣
↪roi_max_size*min_portion_comp)

                    itkc1 = itk.GetImageFromArray(arrc1.astype(np.float32))
                    imMathC1 = ttk.ImageMath.New(itkc1)
                    for c in range(num_classes):
```

```
                        imMathC1.Erode(10,c,0)
                        imMathC1.Dilate(10,c,0)
                    itkc1 = imMathC1.GetOutputUChar()
                    arrc1 = itk.GetArrayFromImage(itkc1)
                    roi_count_sliding = np.count_nonzero(arrc1==class_sliding)
                    roi_count_not_sliding = np.
↪count_nonzero(arrc1==class_not_sliding)
                    roi_decision = "Unknown"
                    roi_message = "Correct"
                    frame_roi_count += 1
                    if roi_count_sliding>roi_count_not_sliding and␣
↪roi_count_not_sliding>roi_sliding_min_thresh:
                        roi_decision = "Sliding"
                        if fname[3] == 's':
                            roi_correct += 1
                        else:
                            roi_incorrect += 1
                            roi_false_negatives += 1
                            roi_message = "False Negative"
                    else:
                        frame_roi_count_not_sliding += 1
                        roi_decision = "Not Sliding"
                        if fname[3] == 'n':
                            roi_correct += 1
                        else:
                            roi_incorrect += 1
                            roi_message = "Fales Positive"


                    if graph:
                        print(fname)

                        plt.figure("check", (18, 6))
                        plt.subplot(1, 3, 1)
                        plt.title(f"image {fold_imgnum}")
                        tmpV = test_data["image"][batch_imgnum, 0, :, :
↪,num_slices//2]
                        plt.imshow(tmpV, cmap="gray")
                        plt.subplot(1, 3, 2)
                        plt.title(f"label {fold_imgnum}")
                        tmpV = test_data["label"][batch_imgnum, 0, :, :
↪,num_slices//2]
                        for c in range(num_classes):
                            tmpV[0,c]=c
                        plt.imshow(tmpV)
                        plt.subplot(1, 3, 3)
                        plt.title(f"output {fold_imgnum}")
```

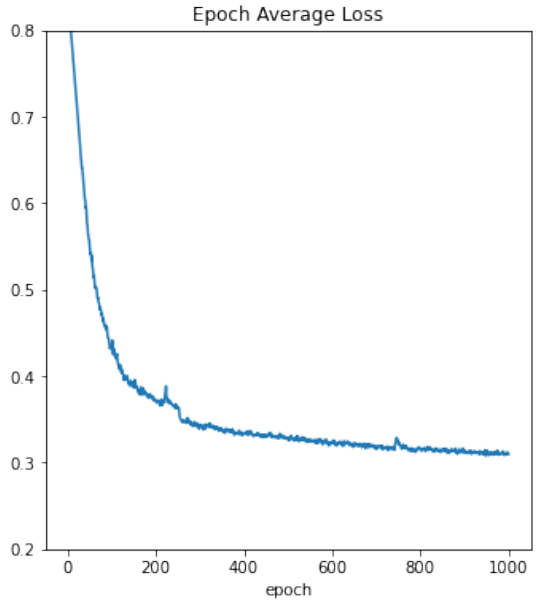
```
                        for c in range(num_classes):
                            arrc1[0,c]=c
                        plt.imshow(arrc1[:,:,num_slices//2])
                        plt.show()

                        print("  * ROI Number of not-sliding / sliding pixel␣
↪=", roi_count_not_sliding, roi_count_sliding)
                        print("    ROI Sldiing Min thresh =",␣
↪roi_sliding_min_thresh)
                        print("    ROI =", roi_decision)
                        print("   ", roi_message)
                        print()
                        print()

                        for c in range(num_classes):
                            arrimg = test_outputs.detach().
↪cpu()[batch_imgnum,c,:,:,:]
                            itkimg = itk.GetImageFromArray(arrimg)
                            filename =␣
↪model_filename_base+"_f"+str(vfold_num)+"_i"+str(i)+"_c"+str(c)+".nii.gz"
                            itk.imwrite(itkimg, filename)

                    fold_imgnum += 1

            prevfname = fname
            patient_frame_count += 1
            if frame_roi_count_not_sliding == 0: # frame_roi_count
                if graph:
                    print(" ** Frame Winner = Sliding ( NS␣
↪=",frame_roi_count_not_sliding,"of",frame_roi_count,")")
                if prevfname[3] == 's':
                    frame_correct += 1
                    if graph:
                        print("    Correct")
                else:
                    frame_incorrect += 1
                    frame_false_negatives += 1
                    print("    Frame False Negative =", prevfname)
            else:
                patient_frame_count_not_sliding += 1
                if graph:
                    print(" ** Frame Winner = Not Sliding ( NS␣
↪=",frame_roi_count_not_sliding,"of",frame_roi_count,")")
                if prevfname[3] == 'n':
                    frame_correct += 1
                    if graph:
```

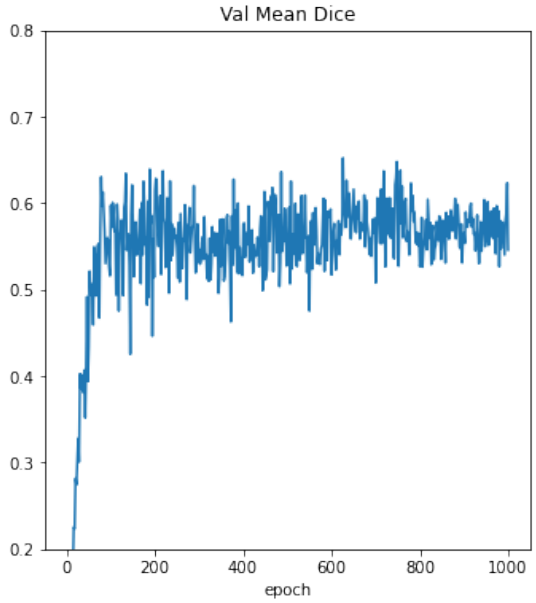
```
                        print("    Correct")
                else:
                    frame_incorrect += 1
                    print("    Frame False Positive =", prevfname)
            if graph:
                print()
                print()
            frame_roi_count = 0
            frame_roi_count_not_sliding = 0
            if patient_frame_count_not_sliding == 0:
                if graph:
                    print("*** Patient Winner = Sliding ( NS␣
↪=",patient_frame_count_not_sliding,"of",patient_frame_count,")")
                if prevfname[3] == 's':
                    patient_correct += 1
                    if graph:
                        print("    Correct")
                else:
                    patient_incorrect += 1
                    patient_false_negatives += 1
                    print("    Patient False Negative =", prevfname)
            else:
                if graph:
                    print("*** Patient Winner = Not Sliding ( NS␣
↪=",patient_frame_count_not_sliding,"of",patient_frame_count,")")
                if prevfname[3] == 'n':
                    patient_correct += 1
                    if graph:
                        print("    Correct")
                else:
                    patient_incorrect += 1
                    print("    Patient False Positive =", prevfname)
            if graph:
                print()
                print()

    return patient_correct, patient_incorrect, patient_false_negatives,␣
↪frame_correct, frame_incorrect, frame_false_negatives, roi_correct,␣
↪roi_incorrect, roi_false_negatives
```

[26]:
```
min_size = 1000
min_portion = 0.0

for prior in [[1.0,1.0,1.0,1.0]]: #[[0.7,1.2,1.2,1.2]]:
    print('*************')
    print("Prior =", prior)
    t_p_correct = 0
```

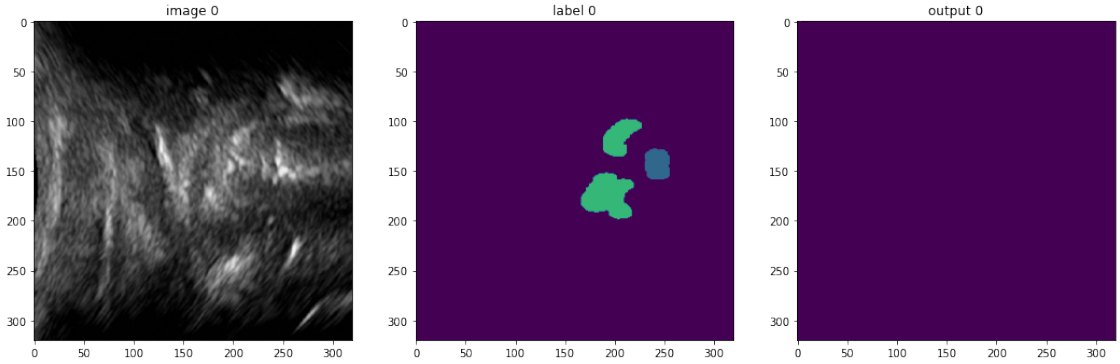
```
    t_p_incorrect = 0
    t_p_false_negatives = 0
    t_f_correct = 0
    t_f_incorrect = 0
    t_f_false_negatives = 0
    t_r_correct = 0
    t_r_incorrect = 0
    t_r_false_negatives = 0
    for i in range(num_folds):
        (p_correct, p_incorrect, p_false_negatives, f_correct, f_incorrect,␣
↪f_false_negatives, r_correct, r_incorrect, r_false_negatives) =␣
↪plot_vfold_training_curves(i, test_loader[i],
            min_size, min_portion, prior, True)
        t_p_correct += p_correct
        t_p_incorrect += p_incorrect
        t_p_false_negatives += p_false_negatives
        t_f_correct += f_correct
        t_f_incorrect += f_incorrect
        t_f_false_negatives += f_false_negatives
        t_r_correct += r_correct
        t_r_incorrect += r_incorrect
        t_r_false_negatives += r_false_negatives
    print()
    print()
    print("Patients: Correct =", t_p_correct, "Incorrect =", t_p_incorrect,␣
↪"Not Sliding as Sliding =", t_p_false_negatives)
    print("Frame: Correct =", t_f_correct, "Incorrect =", t_f_incorrect, "Not␣
↪Sliding as Sliding =", t_f_false_negatives)
    print("ROIs: Correct =", t_r_correct, "Incorrect =", t_r_incorrect, "Not␣
↪Sliding as Sliding =", t_r_false_negatives)
    print('**************')
```

```
**************
Prior = [1.0, 1.0, 1.0, 1.0]
   VFOLD = 0 of 15
```



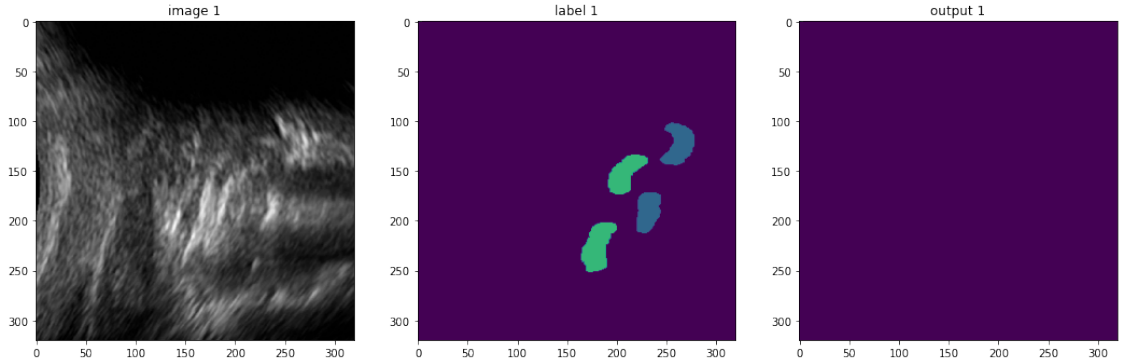


247ns_image_2734882394424_CLEAN.nii.gz



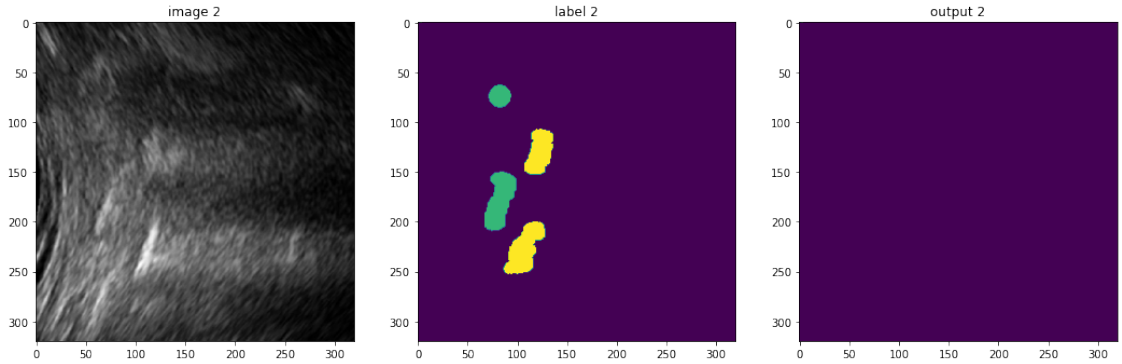

```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct


** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

247ns_image_2743083265515_CLEAN.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

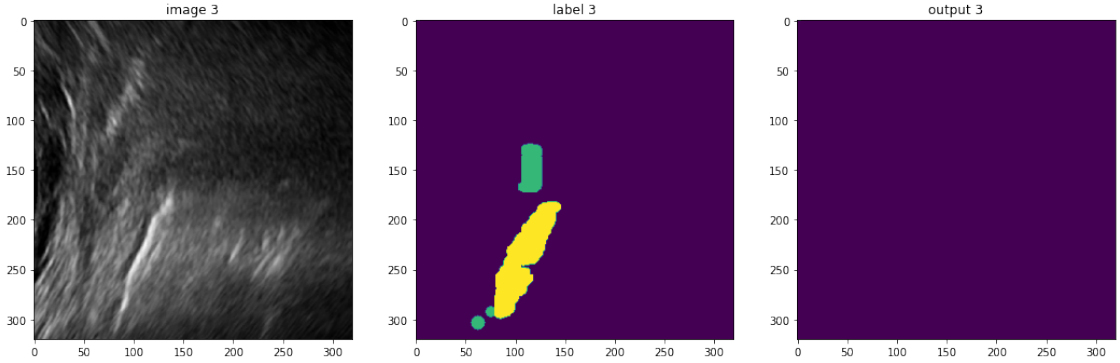
236s_iimage_1139765223418_CLEAN.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 236s_iimage_1139765223418_CLEAN.nii.gz
```

236s_iimage_1327616672148_clean.nii.gz

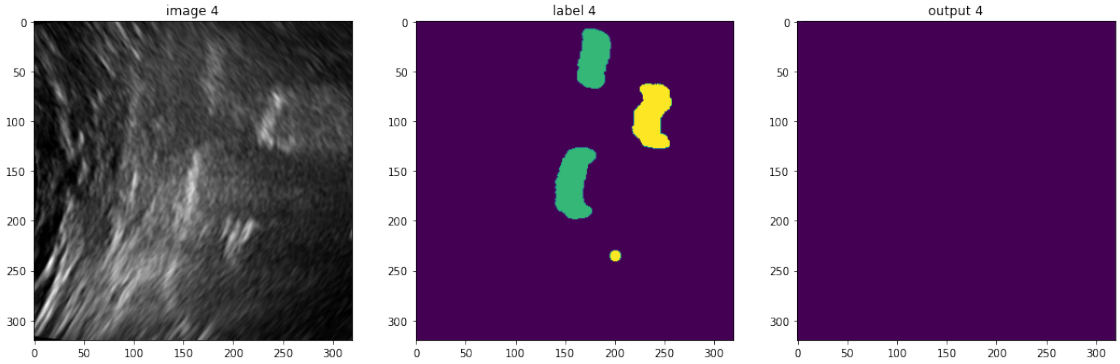



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

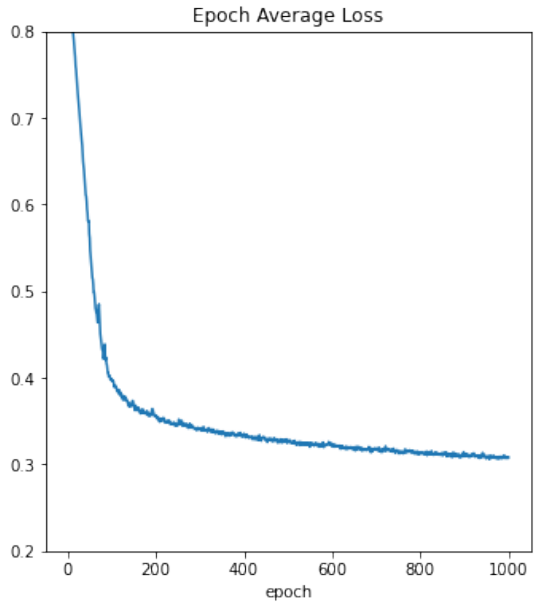
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 236s_iimage_1327616672148_clean.nii.gz
```

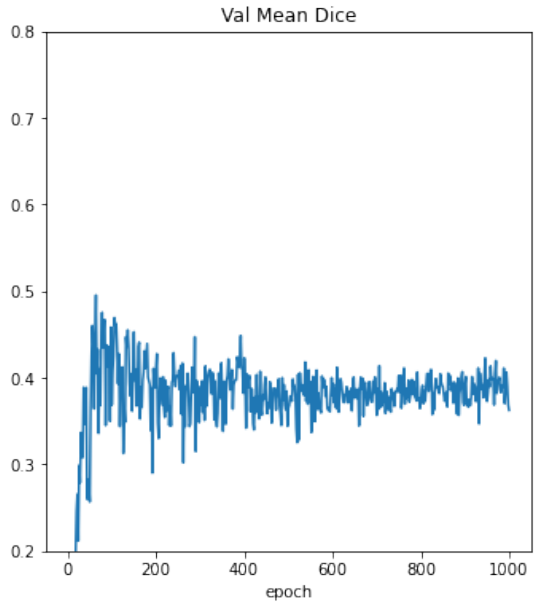
```
*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 236s_iimage_1327616672148_clean.nii.gz
```

237s_iimage_24164968068436_CLEAN.nii.gz

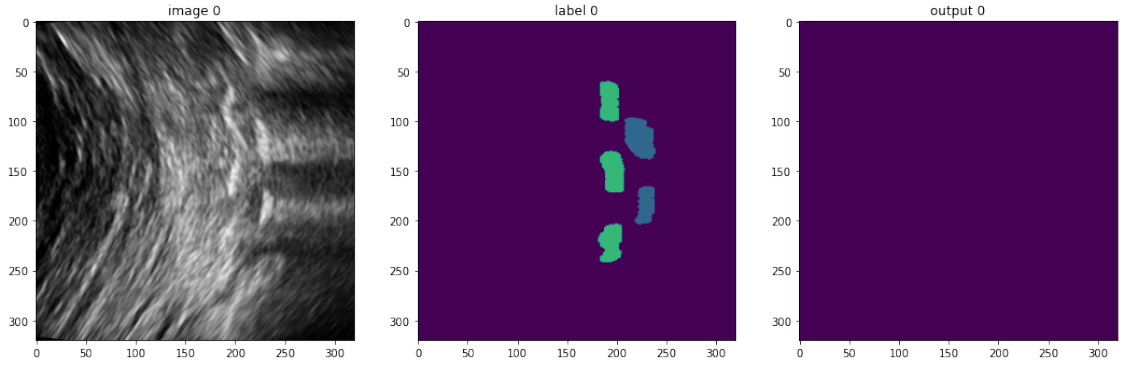


```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 237s_iimage_24164968068436_CLEAN.nii.gz


*** Patient Winner = Not Sliding ( NS = 5 of 5 )
    Patient False Positive = 237s_iimage_24164968068436_CLEAN.nii.gz


   VFOLD = 1 of 15
```



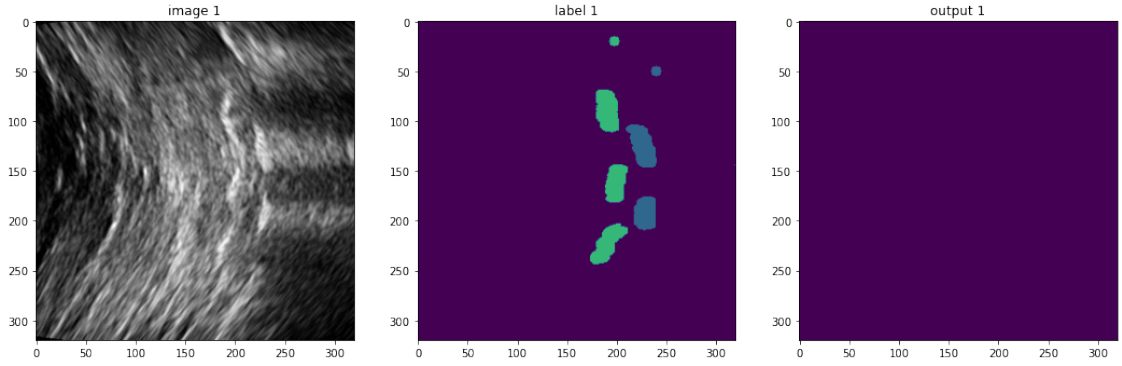



```
025ns_Image_262499828648_clean.nii.gz
```




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

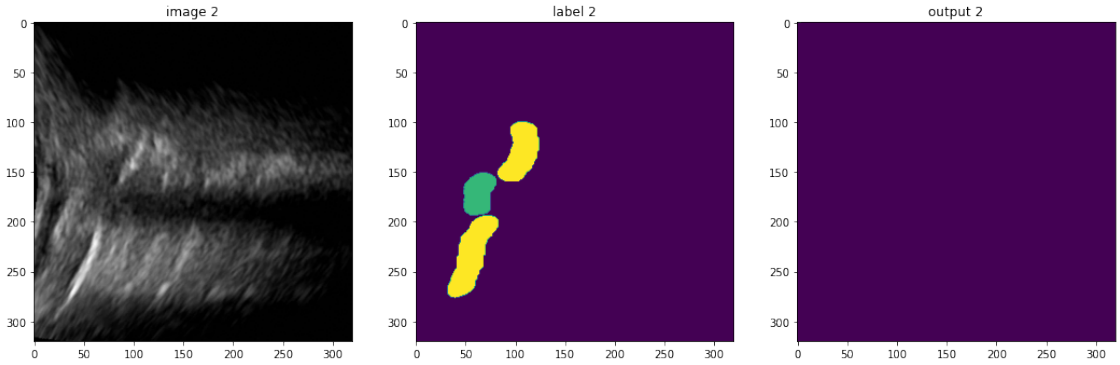
025ns_image_267456908021_clean.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

```
*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

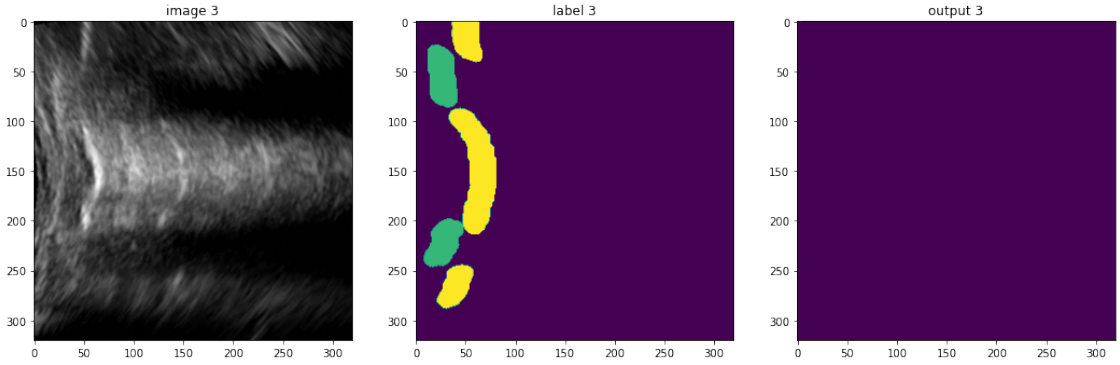
004s_iimage_73815992352100_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

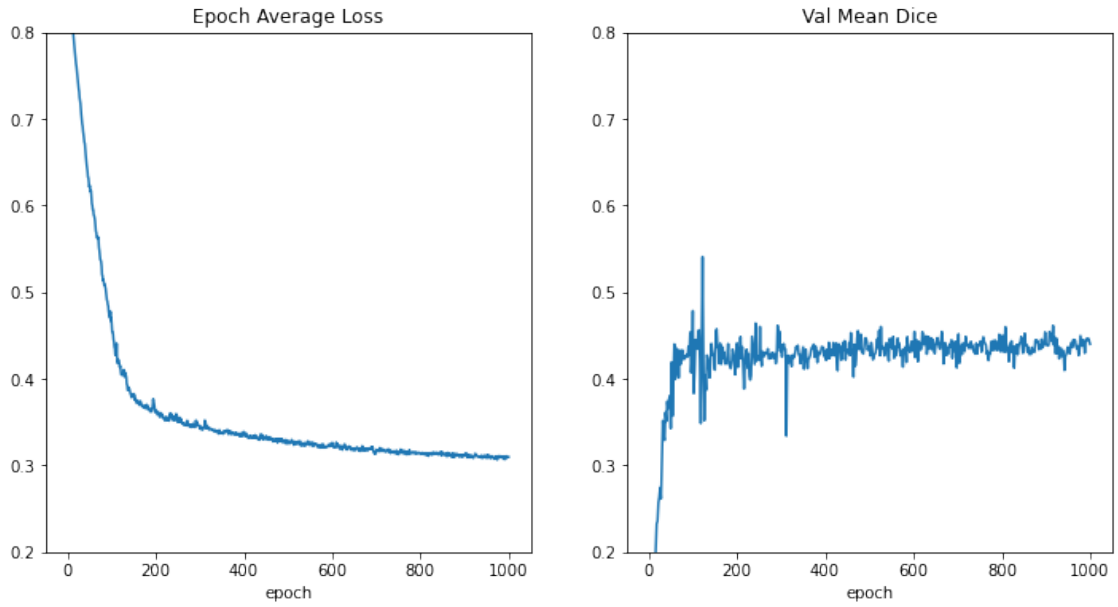
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 004s_iimage_73815992352100_clean.nii.gz
```

004s_iimage_74132233134844_clean.nii.gz

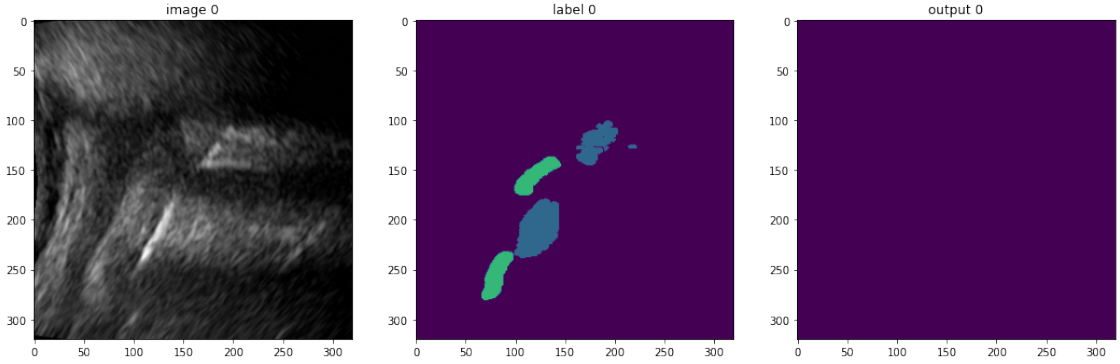



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
```

```
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 004s_iimage_74132233134844_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 004s_iimage_74132233134844_clean.nii.gz


   VFOLD = 2 of 15
```

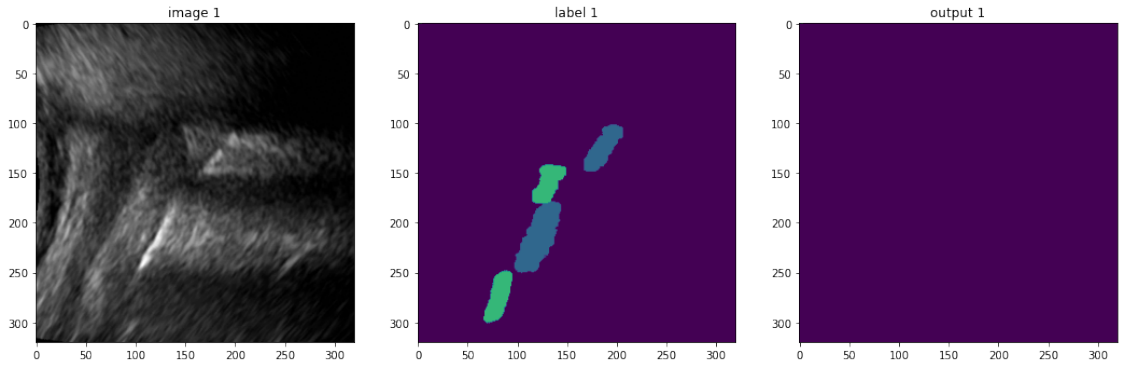


026ns_image_1083297968960_clean.nii.gz



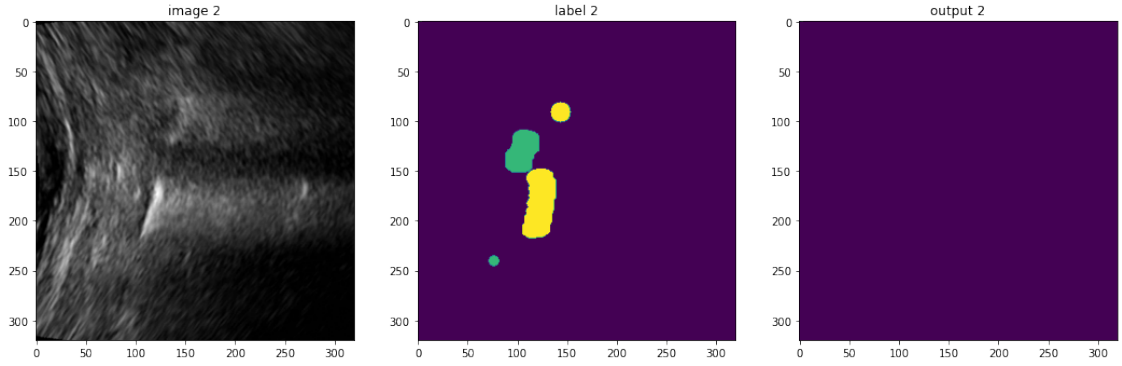
```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

026ns_image_1087766719219_clean.nii.gz



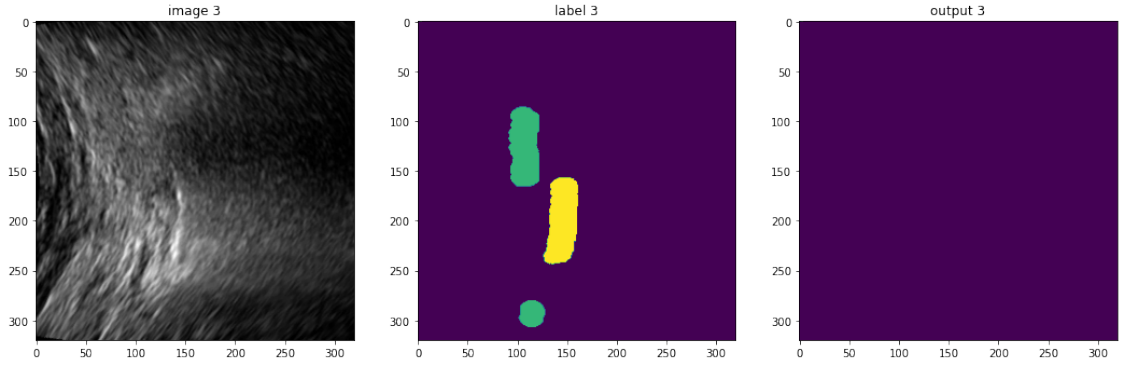

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct


*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

019s_iimage_10705997566592_CLEAN.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 019s_iimage_10705997566592_CLEAN.nii.gz
```

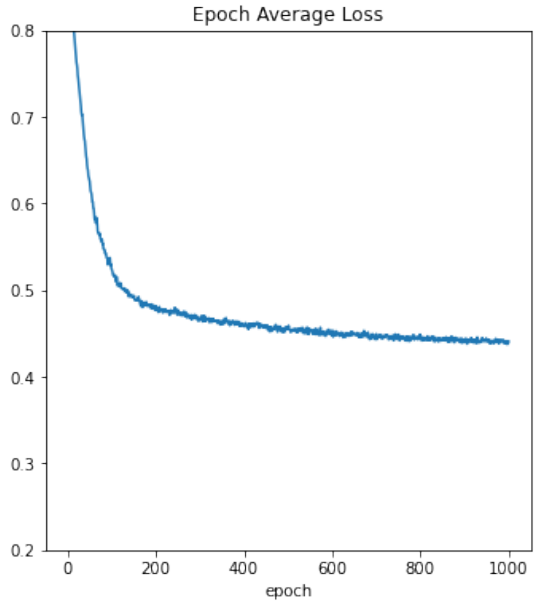
019s_iimage_10891015221417_clean.nii.gz

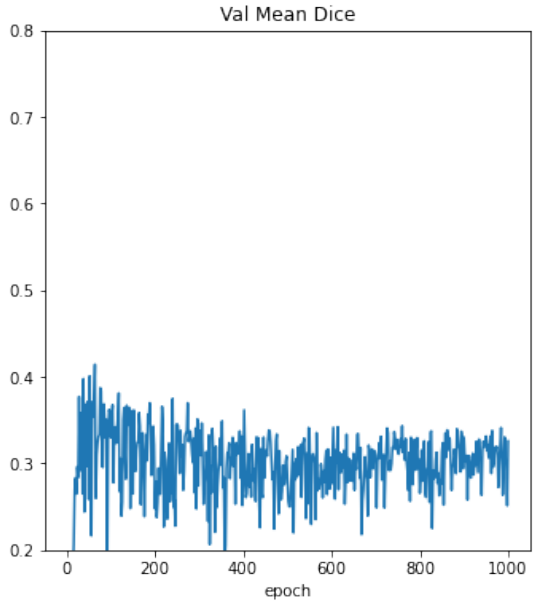



```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 019s_iimage_10891015221417_clean.nii.gz
```

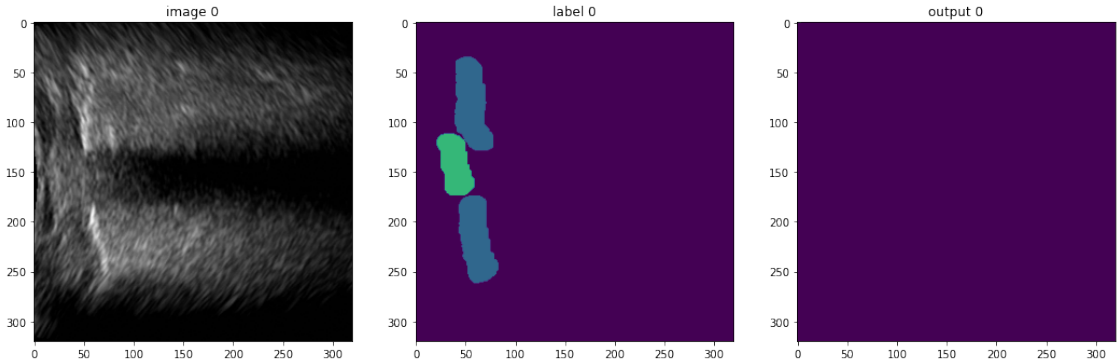
*** Patient Winner = Not Sliding (NS = 4 of 4)
Patient False Positive = 019s_iimage_10891015221417_clean.nii.gz

VFOLD = 3 of 15





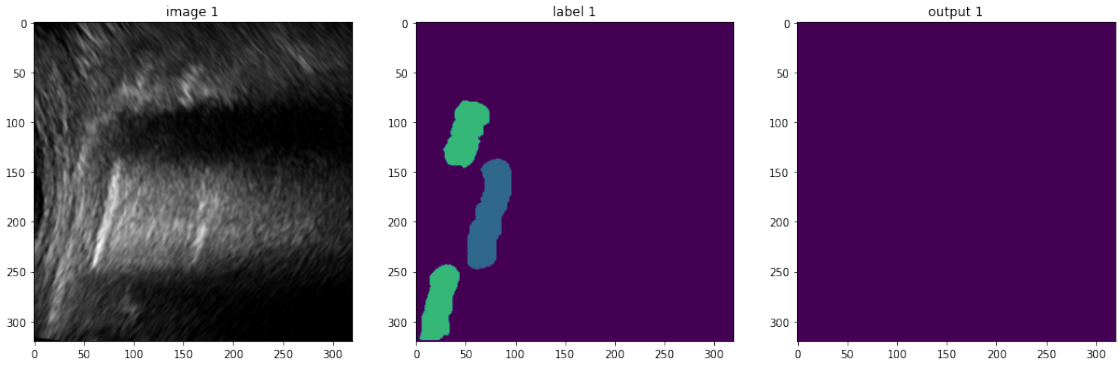
027ns_image_4641643404894_CLEAN.nii.gz



* ROI Number of not-sliding / sliding pixel = 0 0
ROI Sldiing Min thresh = 1000
ROI = Not Sliding
Correct

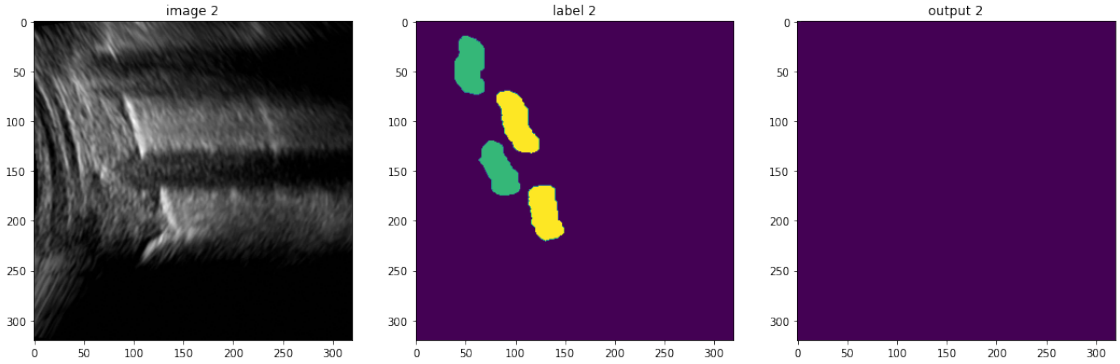
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

027ns_image_4743880599022_clean.nii.gz



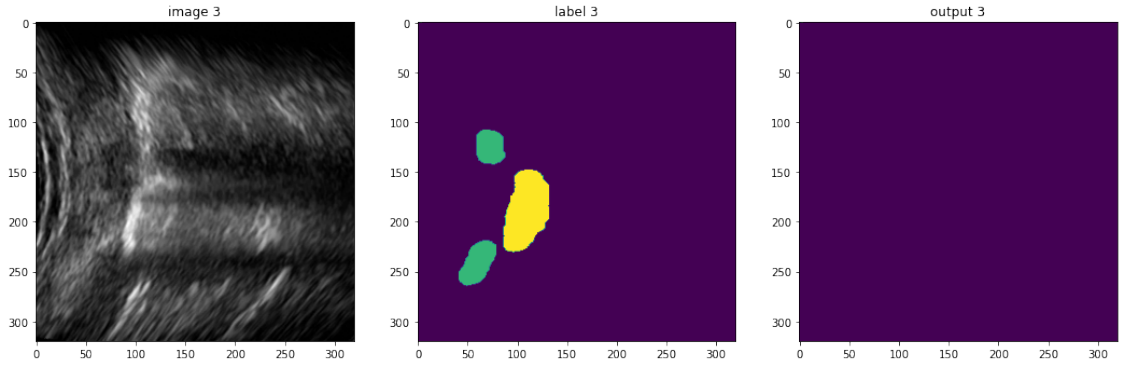

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

030s_iimage_1180496934444_clean.nii.gz

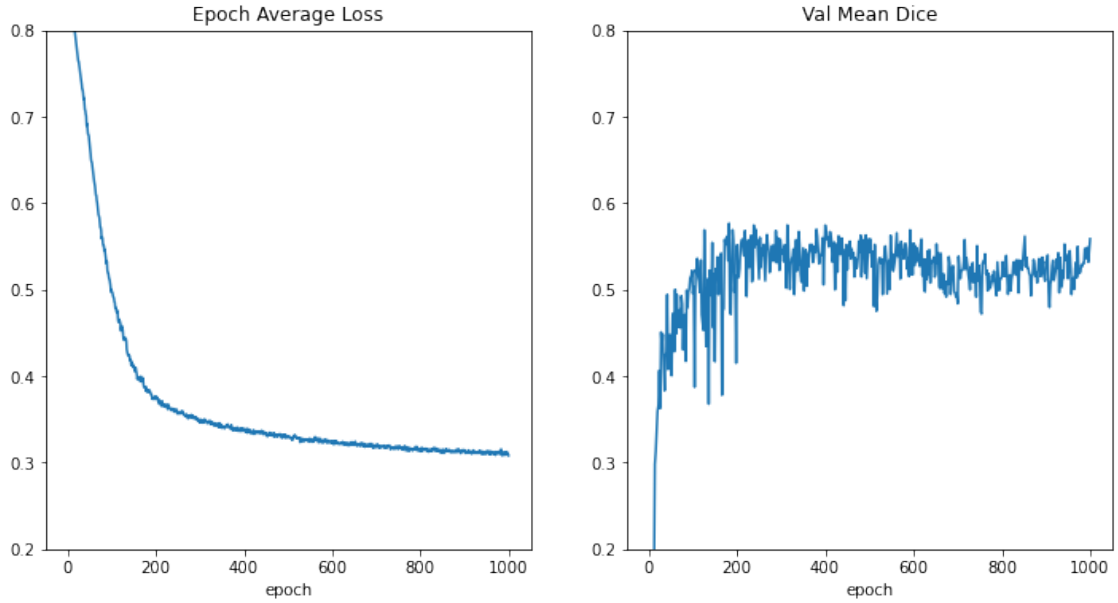


```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 030s_iimage_1180496934444_clean.nii.gz
```

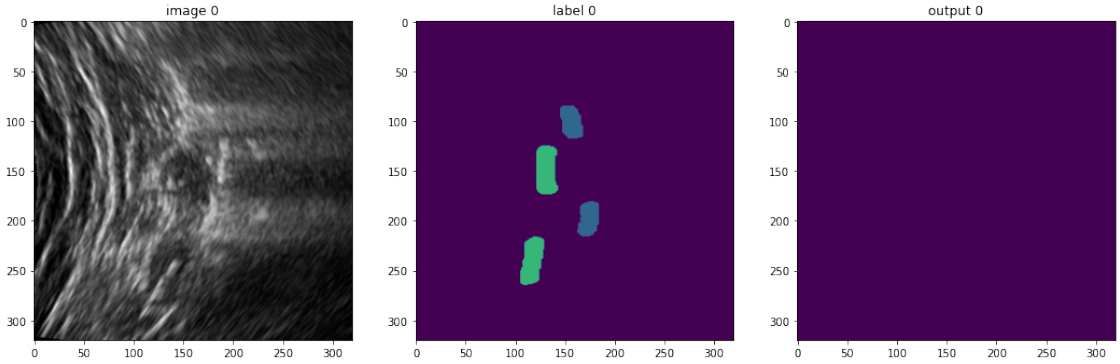
030s_iimage_677741729740_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 030s_iimage_677741729740_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 030s_iimage_677741729740_clean.nii.gz


   VFOLD = 4 of 15
```

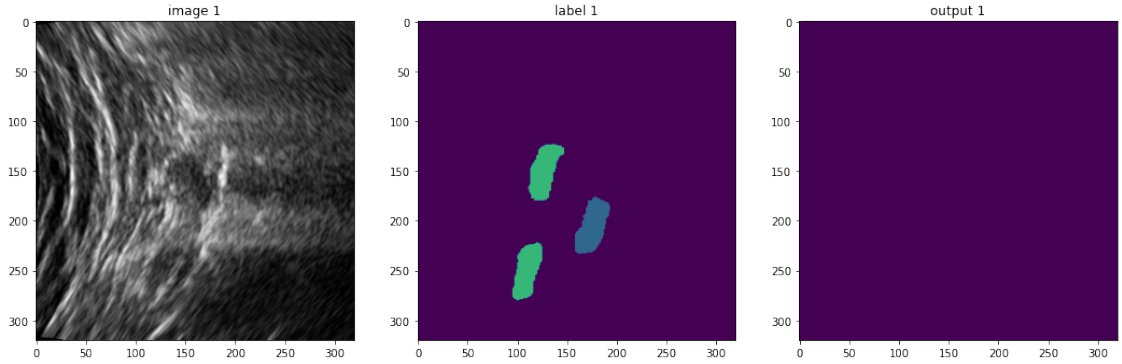


035ns_image_1394469579519_clean.nii.gz



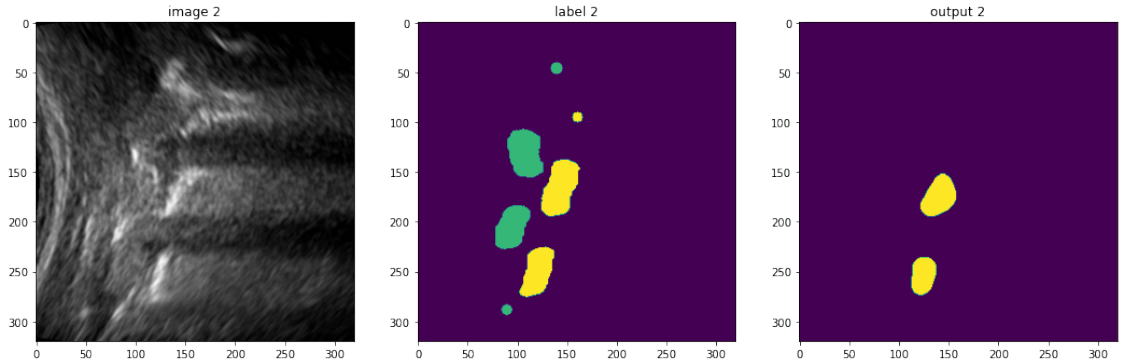

```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct


** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

035ns_image_1404802450036_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

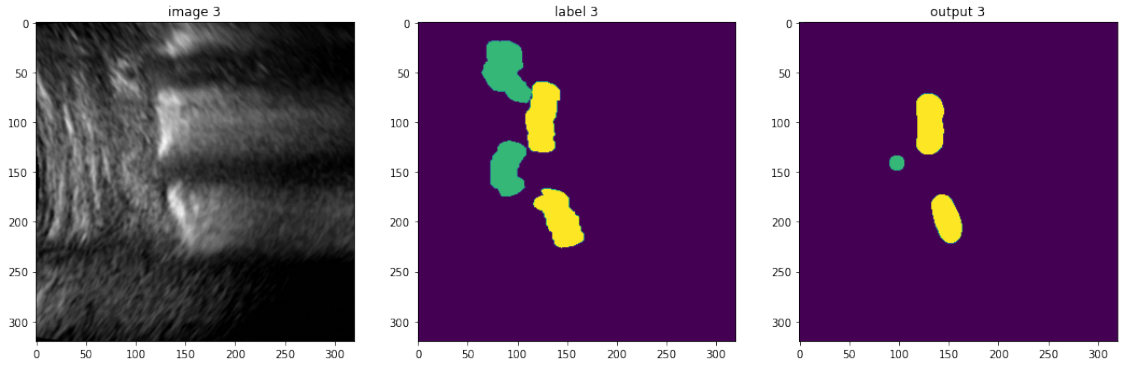
034s_iimage_3368391807672_clean.nii.gz



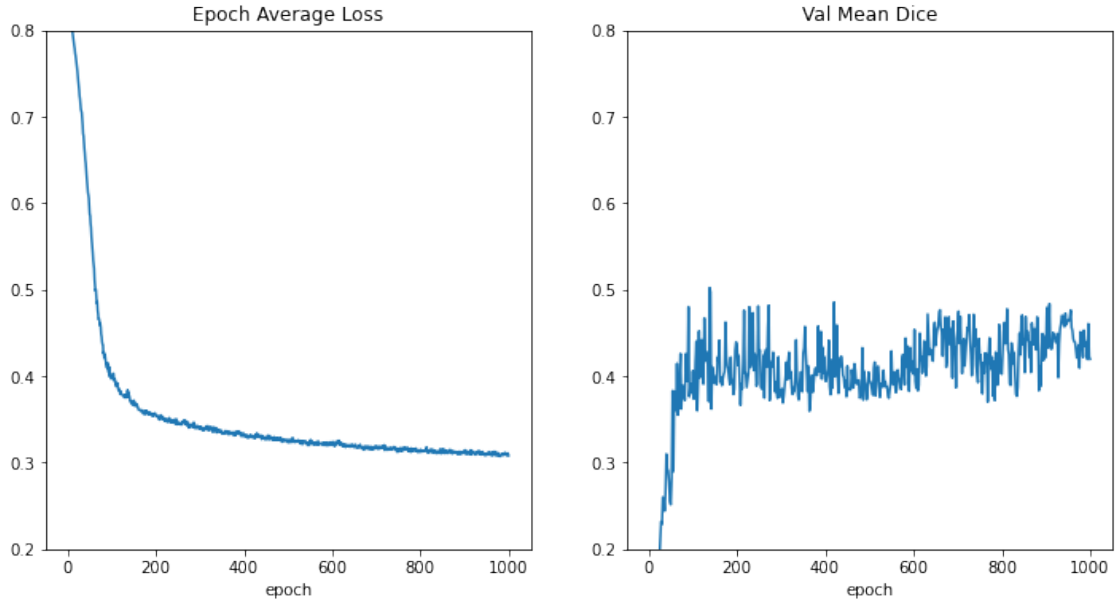

```
  * ROI Number of not-sliding / sliding pixel = 0 93258
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 034s_iimage_3368391807672_clean.nii.gz
```

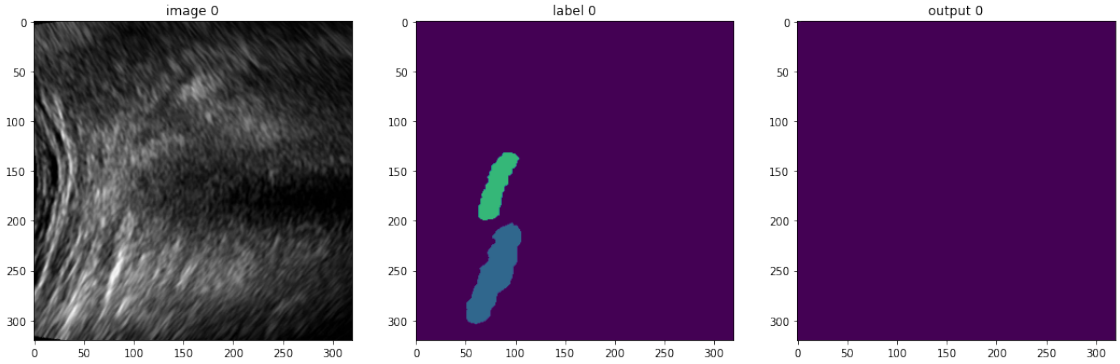
034s_iimage_3401832241774_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 122782
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 034s_iimage_3401832241774_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 034s_iimage_3401832241774_clean.nii.gz


   VFOLD = 5 of 15
```



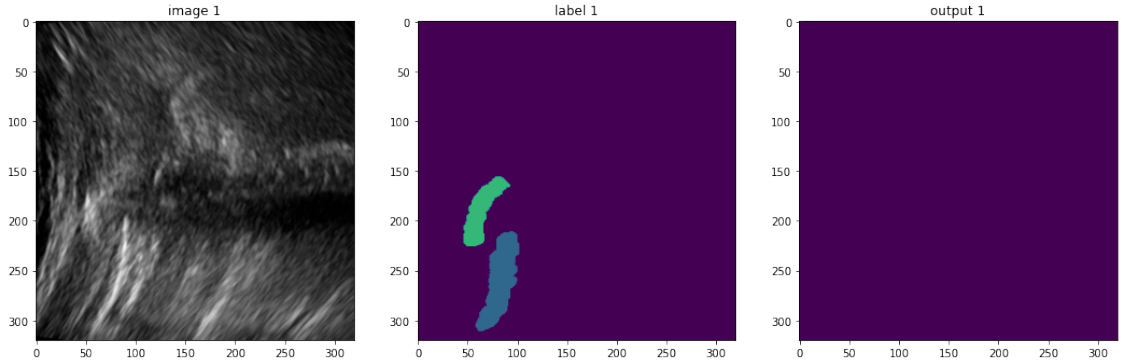
048ns_image_1543571117118_clean.nii.gz



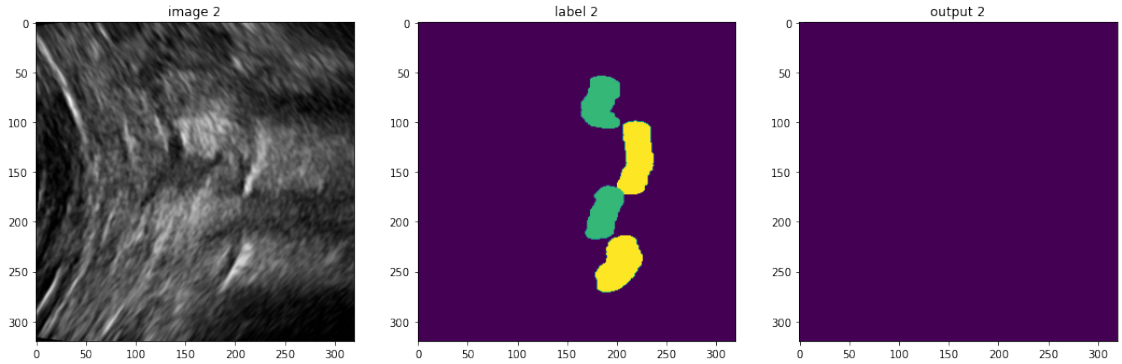
* ROI Number of not-sliding / sliding pixel = 0 0
  ROI Sldiing Min thresh = 1000
  ROI = Not Sliding
  Correct

** Frame Winner = Not Sliding (NS = 1 of 1)
  Correct

048ns_image_1749559540112_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct

037s_iimage_588413346180_CLEAN.nii.gz
```

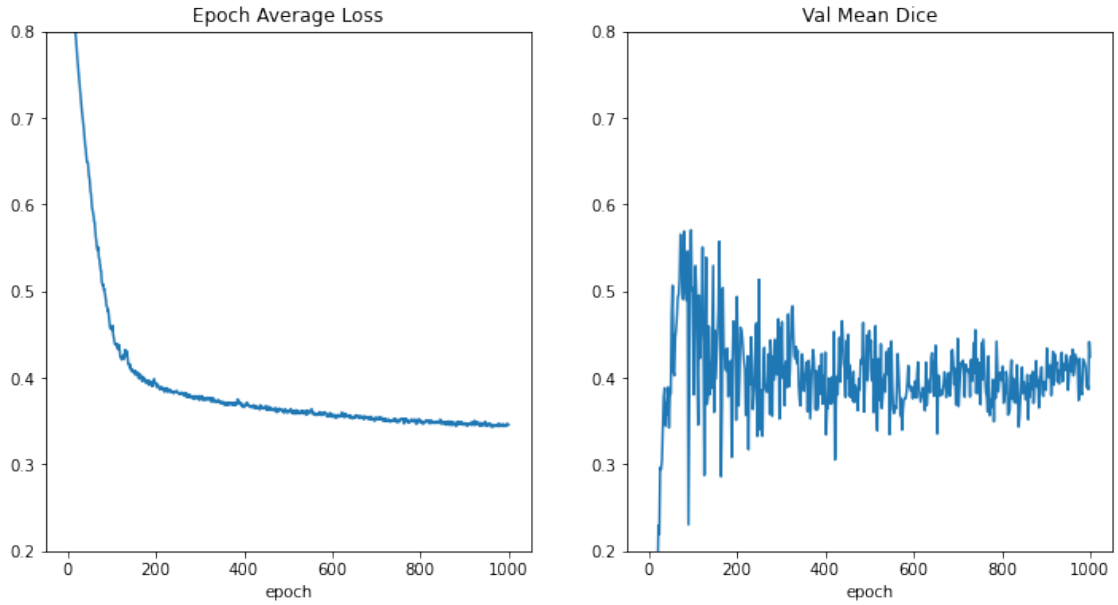



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

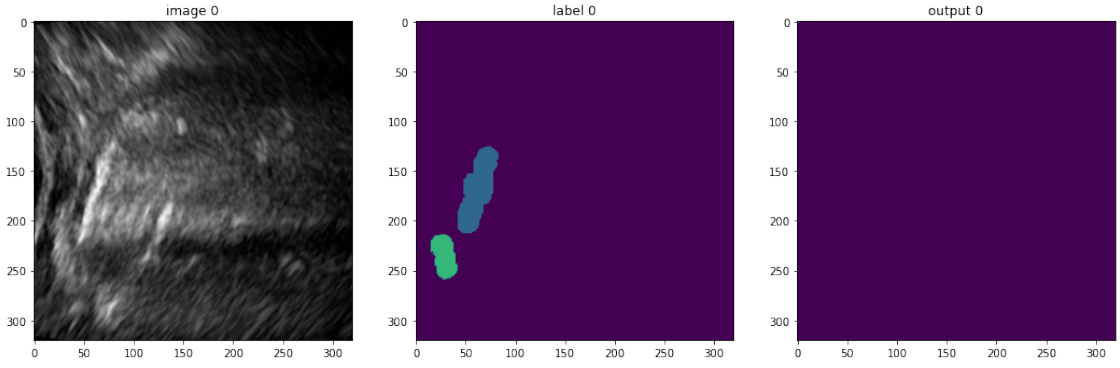
** Frame Winner = Not Sliding (NS = 1 of 1)
Frame False Positive = 037s_iimage_588413346180_CLEAN.nii.gz

*** Patient Winner = Not Sliding (NS = 3 of 3)
Patient False Positive = 037s_iimage_588413346180_CLEAN.nii.gz

VFOLD = 6 of 15

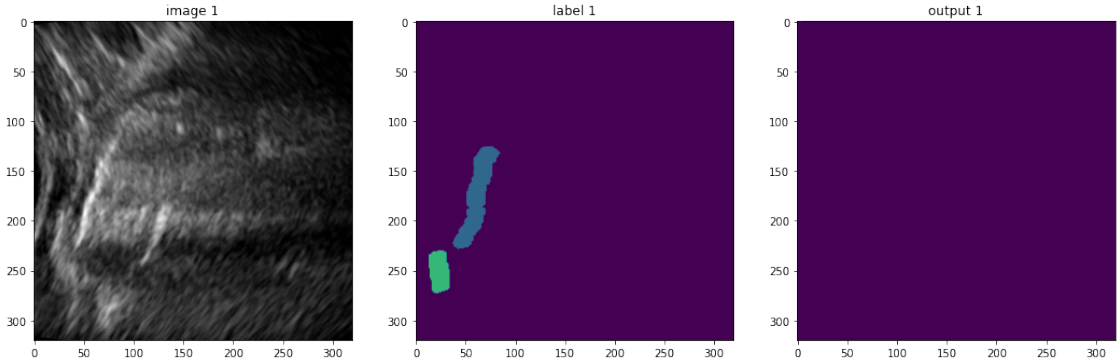


055ns_image_27180764486244_CLEAN.nii.gz

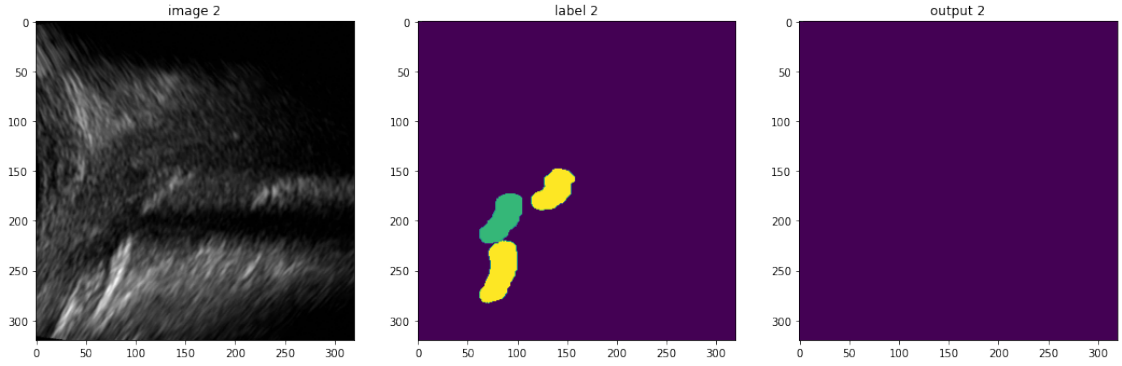


* ROI Number of not-sliding / sliding pixel = 0 0
ROI Sldiing Min thresh = 1000

```
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct


055ns_image_27185428518326_CLEAN.nii.gz
```

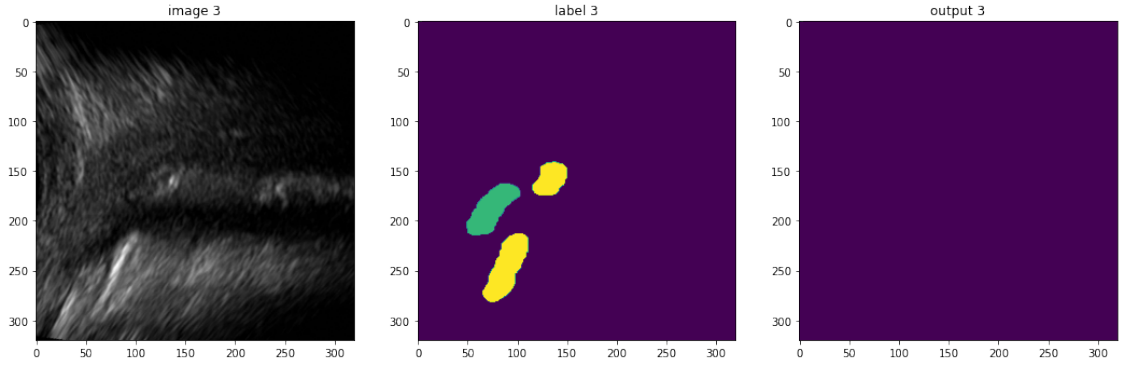



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct


*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct


043s_iimage_10391571128899_CLEAN.nii.gz
```




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 043s_iimage_10391571128899_CLEAN.nii.gz
```

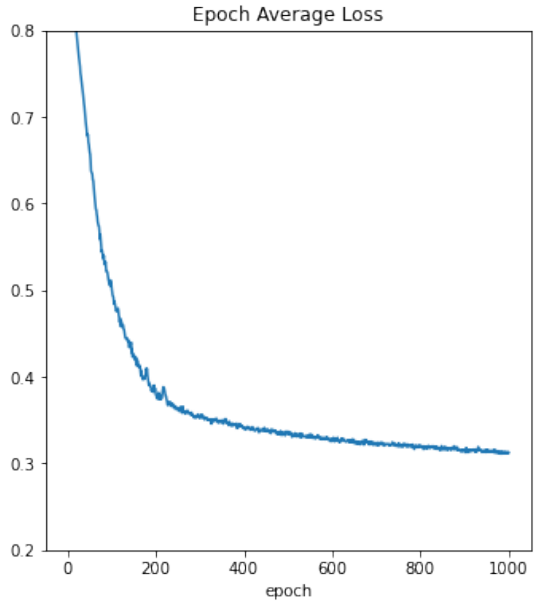
043s_iimage_10395655826502_CLEAN.nii.gz

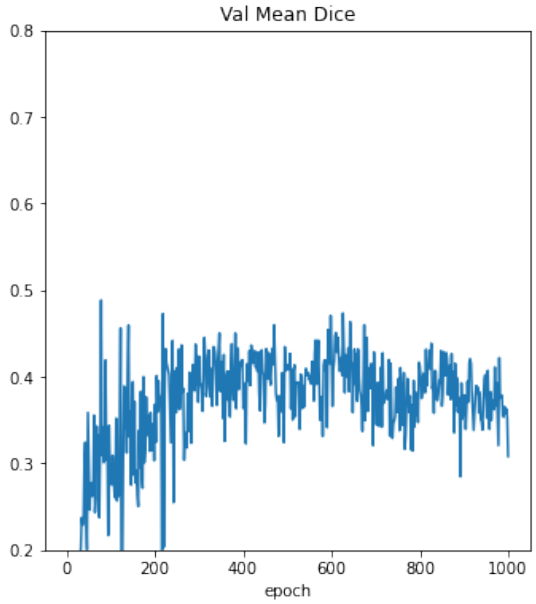



```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 043s_iimage_10395655826502_CLEAN.nii.gz
```

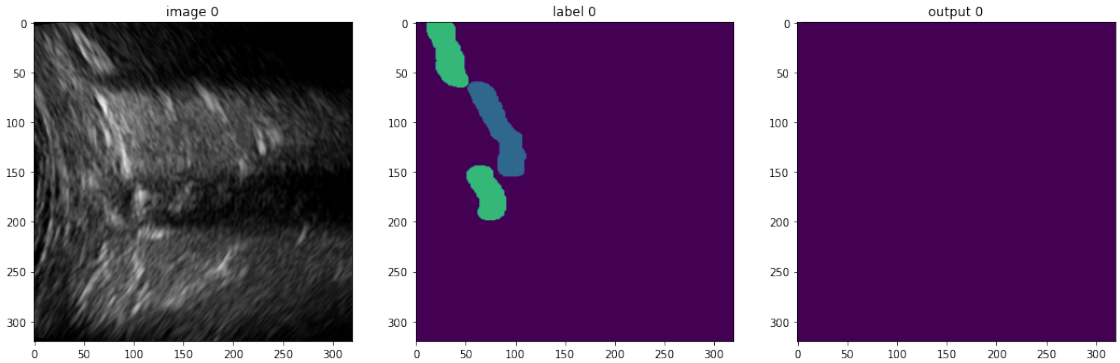
*** Patient Winner = Not Sliding (NS = 4 of 4)
Patient False Positive = 043s_iimage_10395655826502_CLEAN.nii.gz

VFOLD = 7 of 15





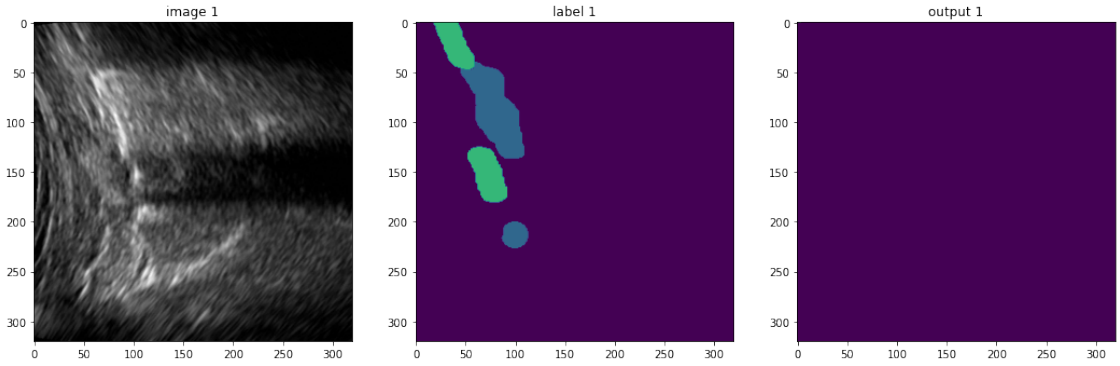
117ns_image_417221672548_CLEAN.nii.gz



* ROI Number of not-sliding / sliding pixel = 0 0
ROI Sldiing Min thresh = 1000
ROI = Not Sliding
Correct

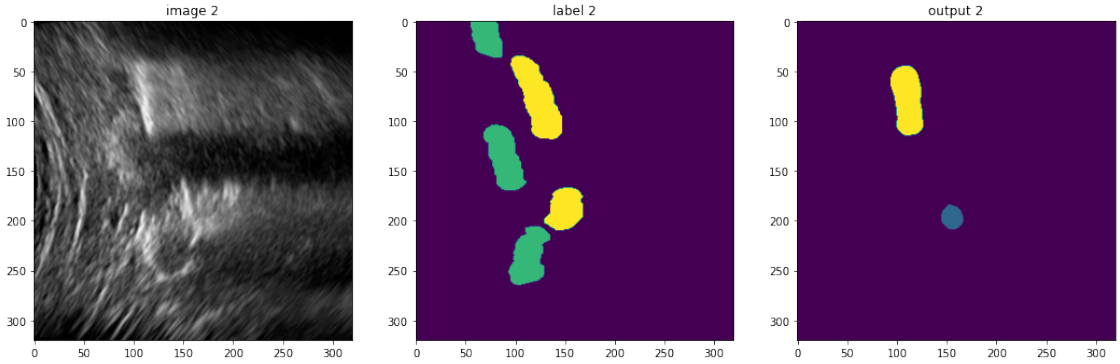
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

117ns_image_426794579576_CLEAN.nii.gz

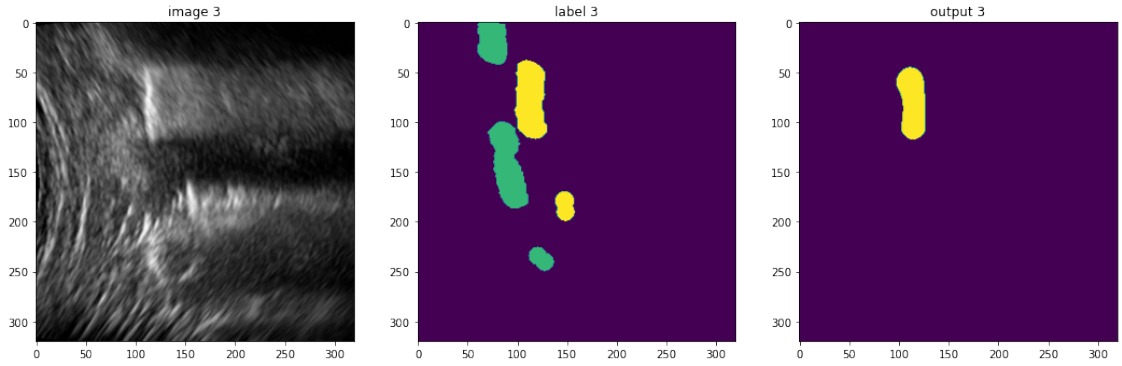



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

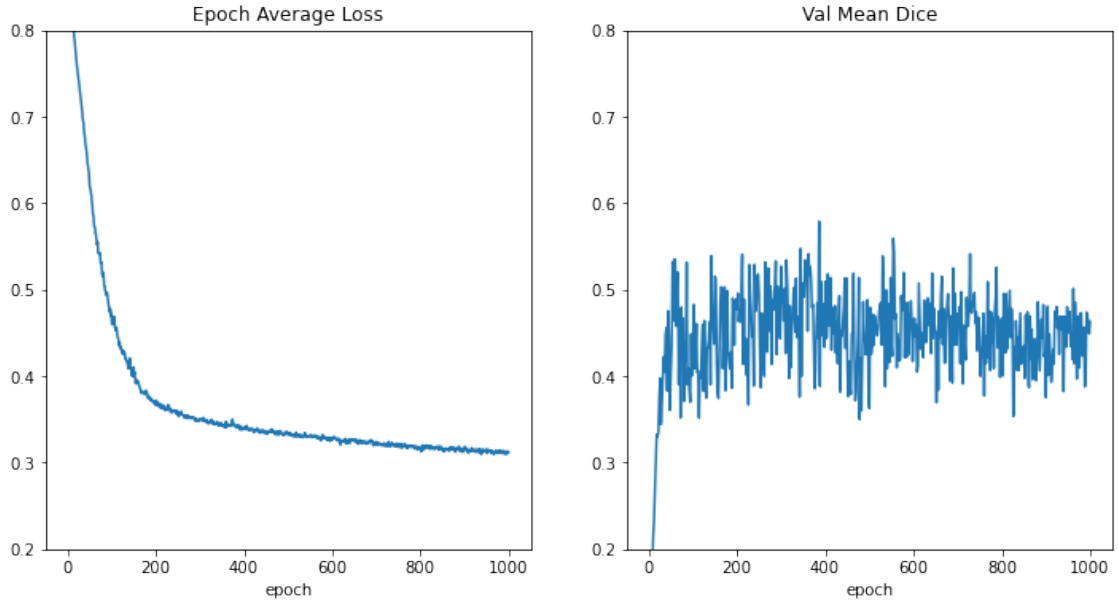
065s_iimage_1896534330004_clean.nii.gz



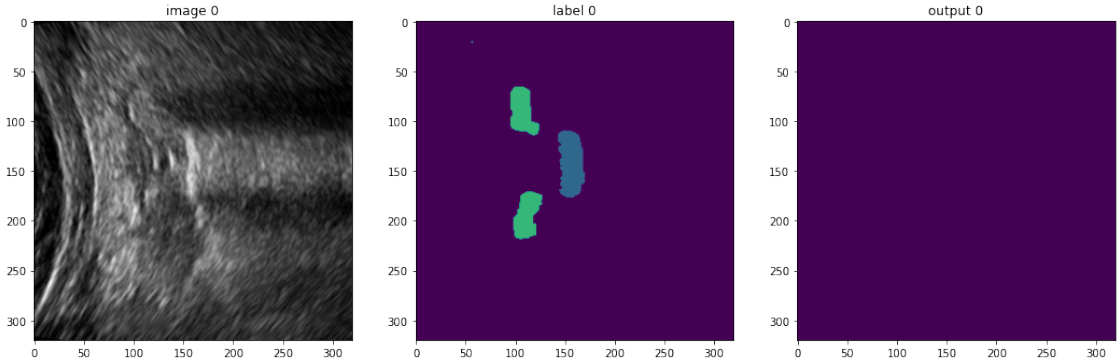
```
  * ROI Number of not-sliding / sliding pixel = 27101 79433
    ROI Sldiing Min thresh = 1000
    ROI = Sliding
    Correct


 ** Frame Winner = Sliding ( NS = 0 of 1 )
    Correct


065s_iimage_1901852337971_clean.nii.gz
```




```
  * ROI Number of not-sliding / sliding pixel = 0 71616
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 065s_iimage_1901852337971_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 3 of 4 )
    Patient False Positive = 065s_iimage_1901852337971_clean.nii.gz


   VFOLD = 8 of 15
```

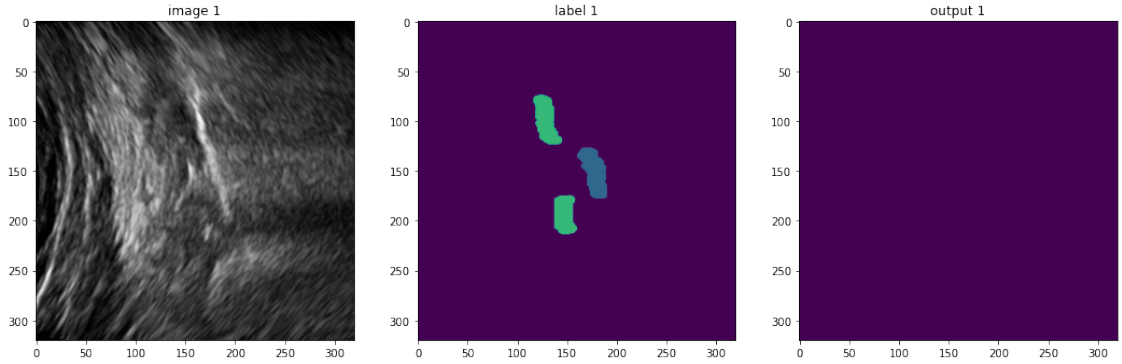


135ns_image_2418161753608_clean.nii.gz



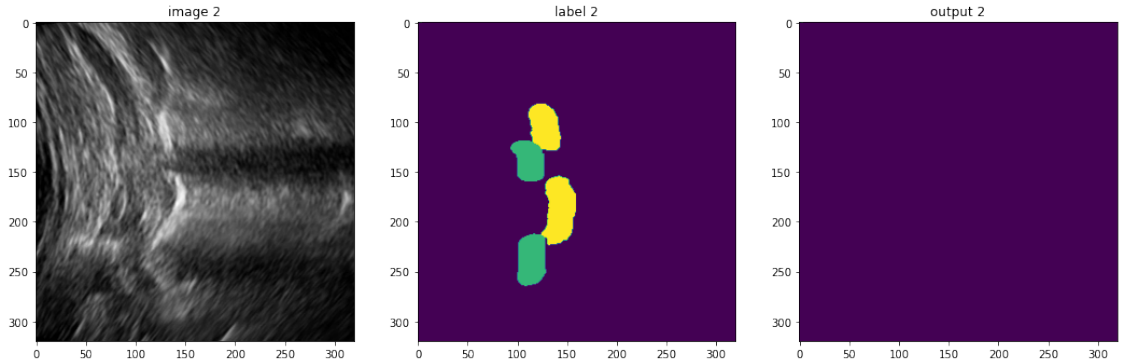

```
  * ROI Number of not-sliding / sliding pixel = 0 8768
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

135ns_image_2454526567135_CLEAN.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

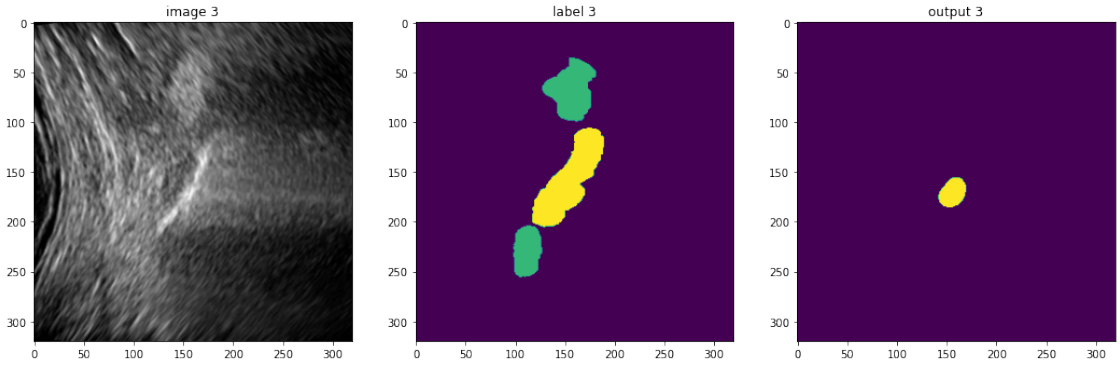
081s_iimage_2959672151786_clean.nii.gz



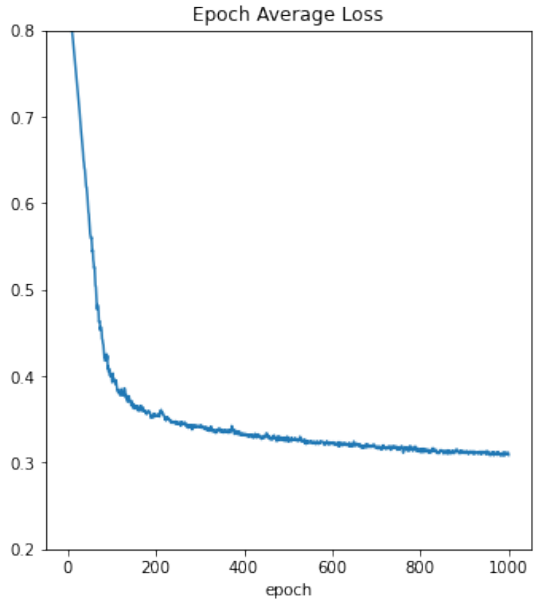

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

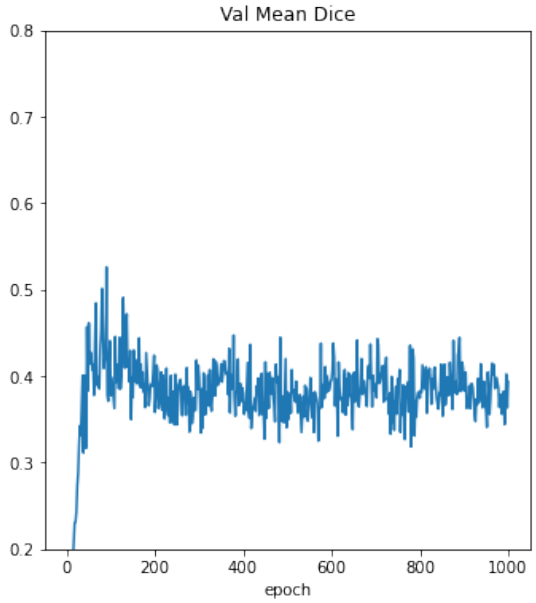
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 081s_iimage_2959672151786_clean.nii.gz
```

081s_iimage_3320344386805_clean.nii.gz

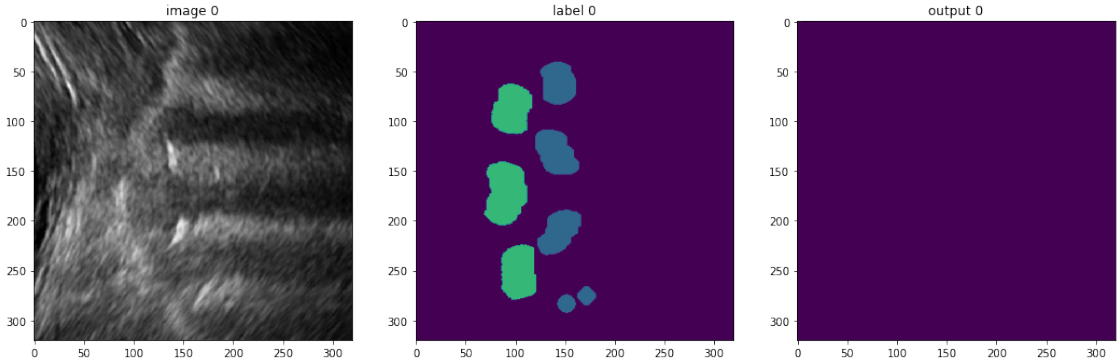



```
  * ROI Number of not-sliding / sliding pixel = 0 31320
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 081s_iimage_3320344386805_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 081s_iimage_3320344386805_clean.nii.gz


   VFOLD = 9 of 15
```



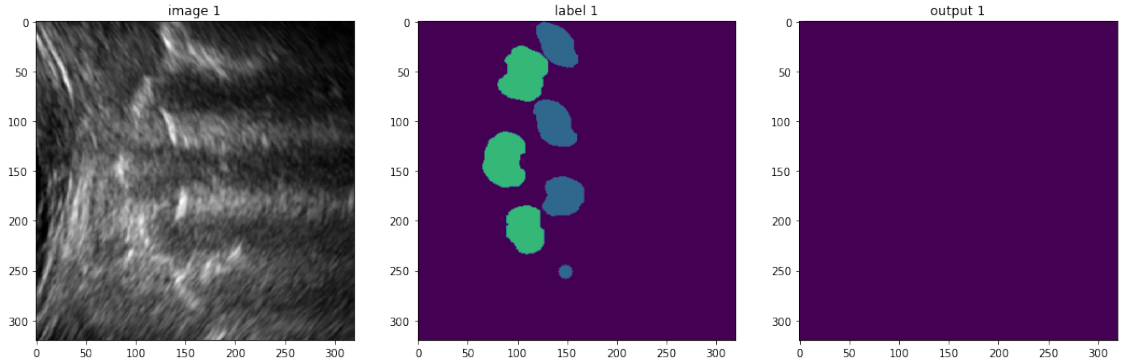


193ns_image_634125159704_CLEAN.nii.gz



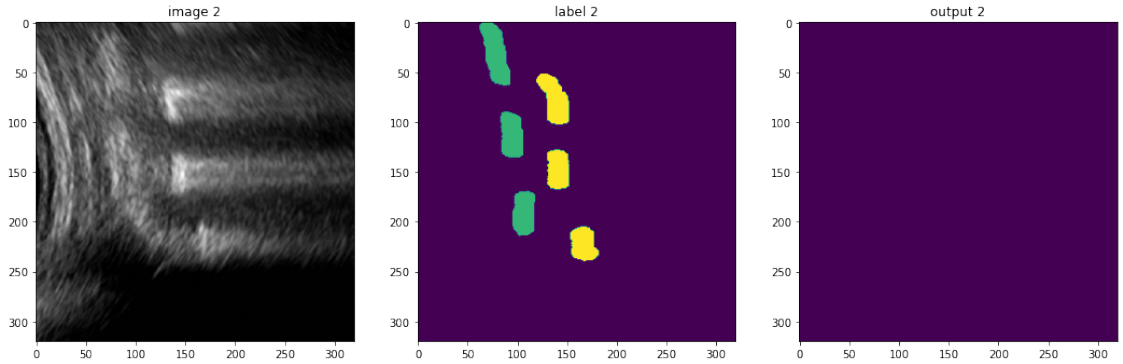

```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct


** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

193ns_image_642169070951_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

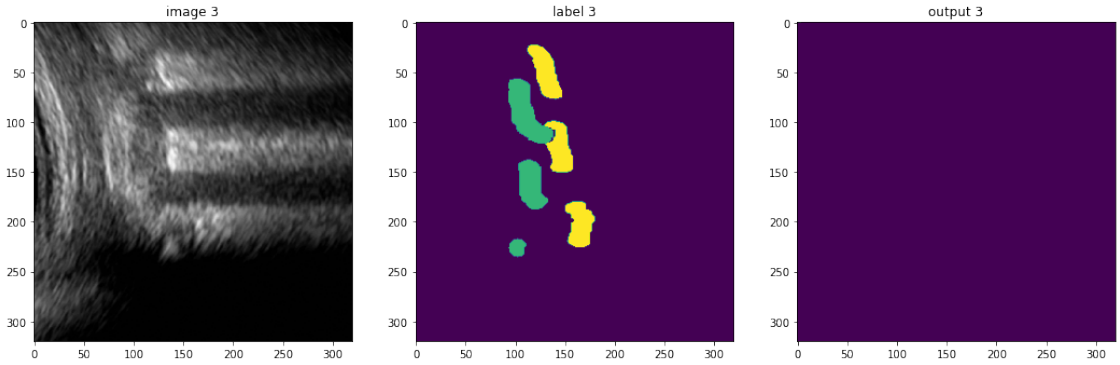
206s_iimage_1499268364374_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 206s_iimage_1499268364374_clean.nii.gz
```

206s_iimage_1511338287338_clean.nii.gz

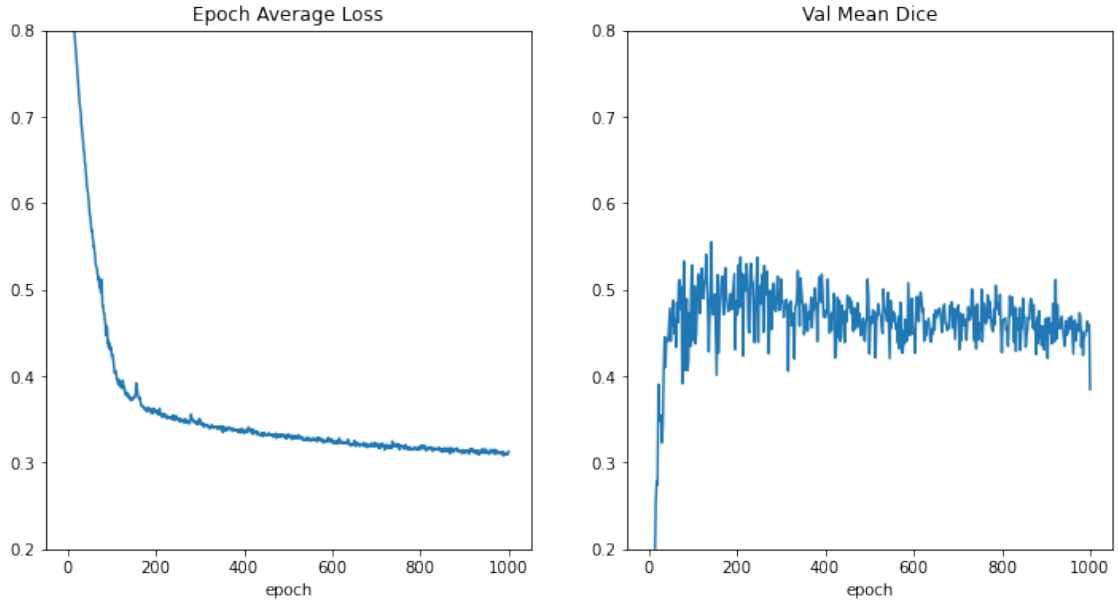



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

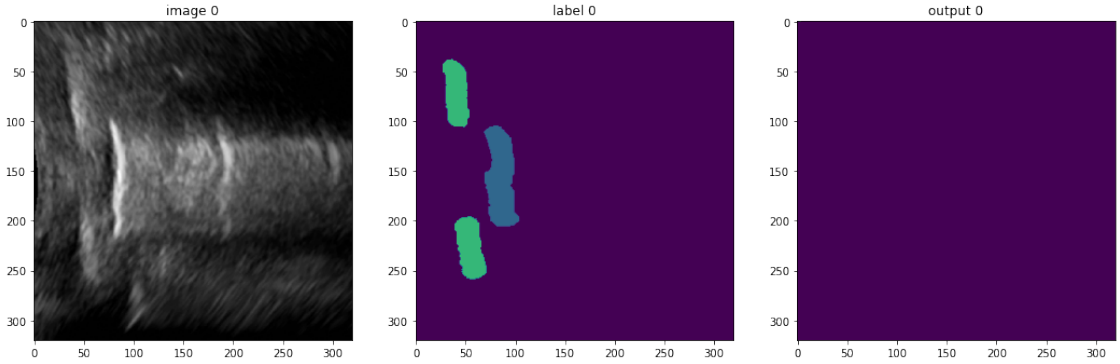
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 206s_iimage_1511338287338_clean.nii.gz
```

```
*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 206s_iimage_1511338287338_clean.nii.gz
```

```
   VFOLD = 10 of 15
```

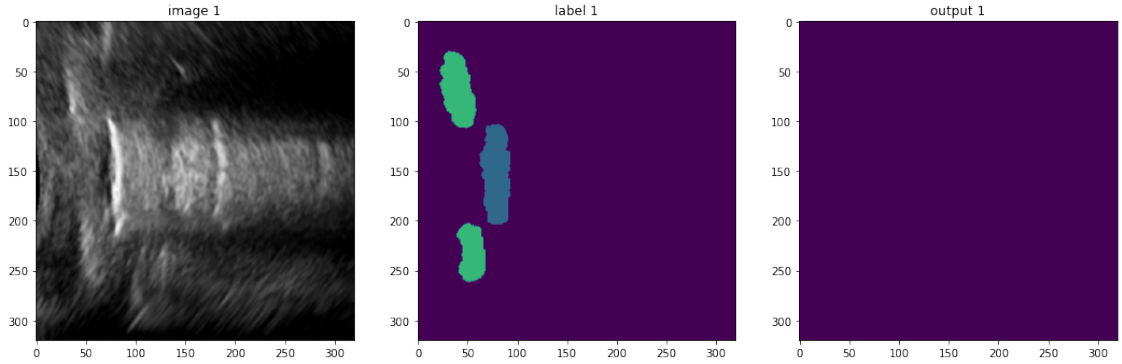


210ns_image_603665940081_clean.nii.gz



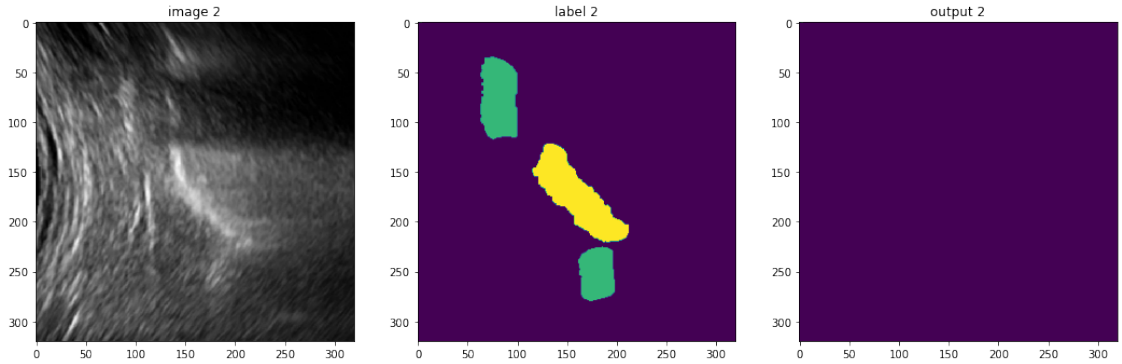

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

210ns_image_614587120545_clean.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

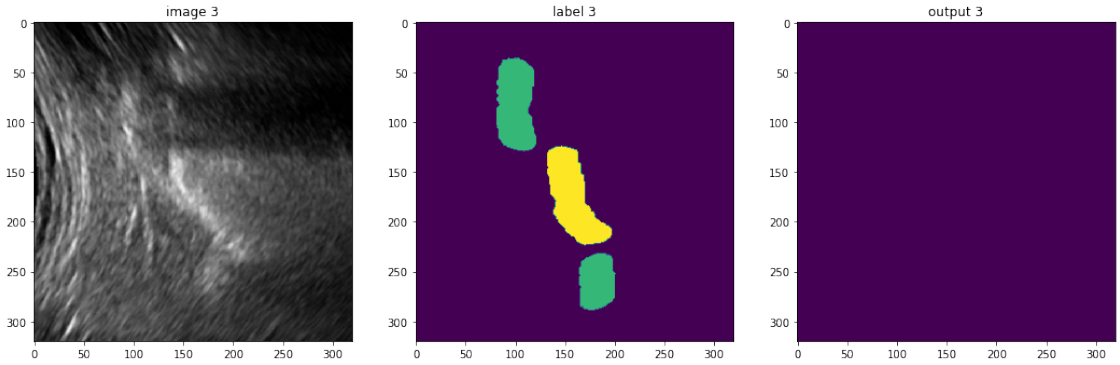
208s_iimage_104543812690743_CLEAN.nii.gz




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive
```

```
** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 208s_iimage_104543812690743_CLEAN.nii.gz
```

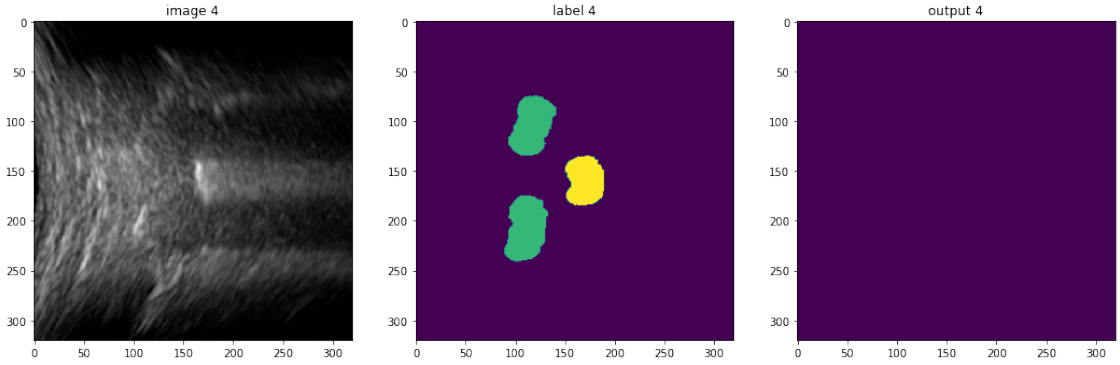
208s_iimage_104548309385533_CLEAN.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive
```

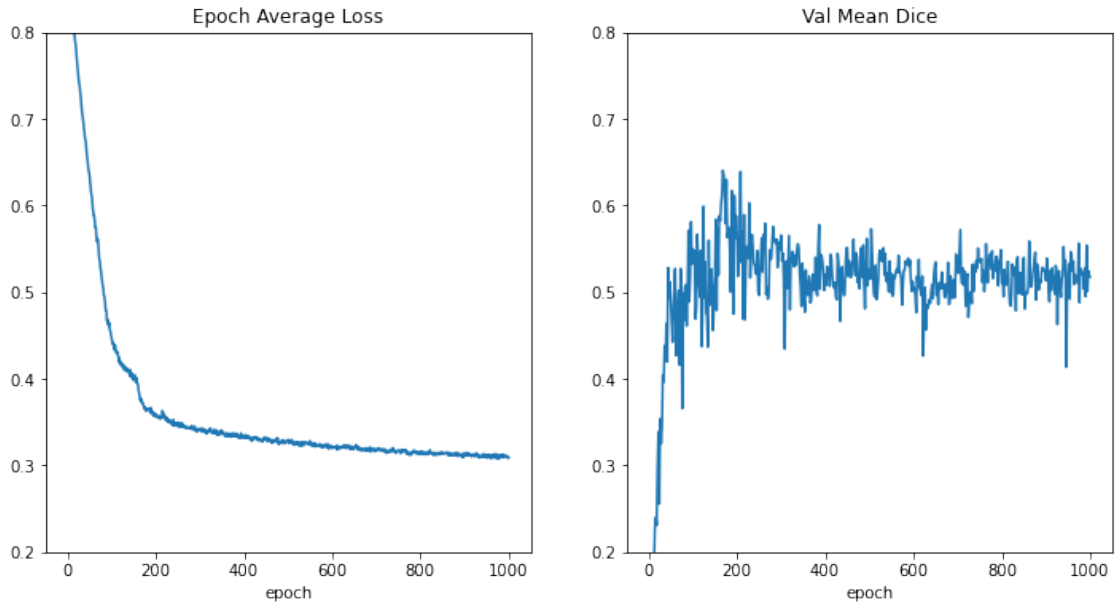
```
** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 208s_iimage_104548309385533_CLEAN.nii.gz
```

208s_iimage_104932526155699_CLEAN.nii.gz

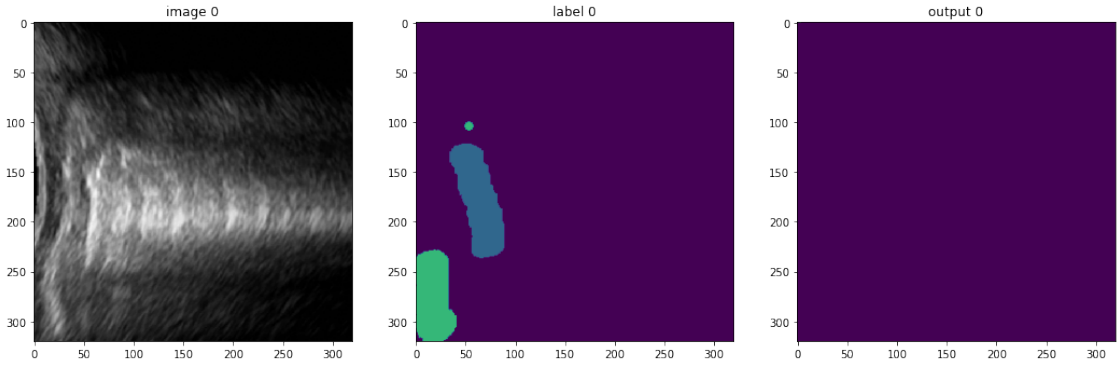



```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
```

```
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 208s_iimage_104932526155699_CLEAN.nii.gz


*** Patient Winner = Not Sliding ( NS = 5 of 5 )
    Patient False Positive = 208s_iimage_104932526155699_CLEAN.nii.gz


   VFOLD = 11 of 15
```

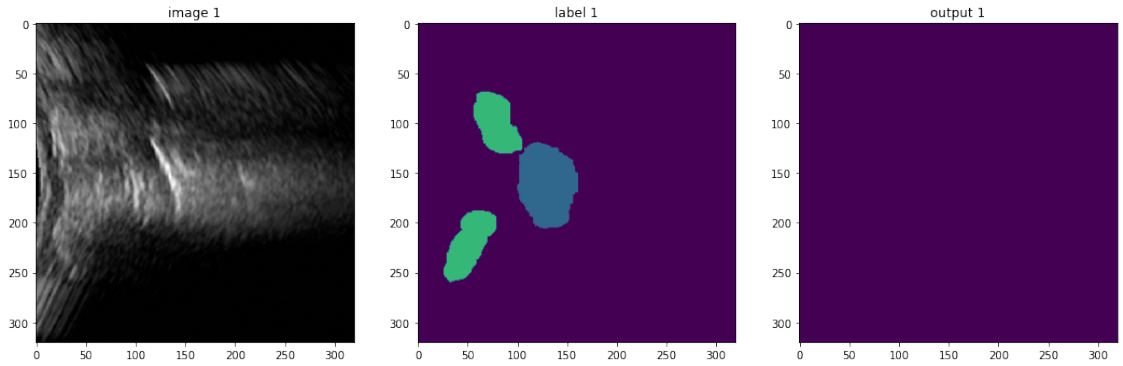


215ns_image_573611404207_CLEAN.nii.gz



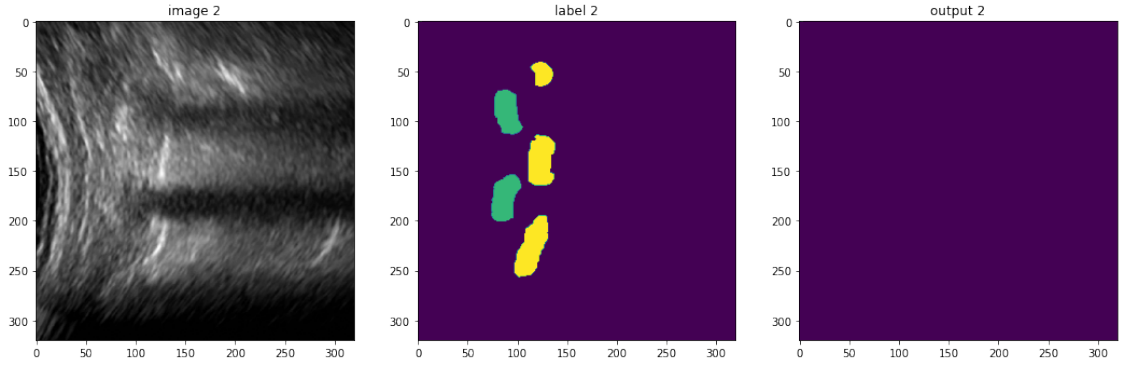
```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

215ns_image_610066411380_CLEAN.nii.gz



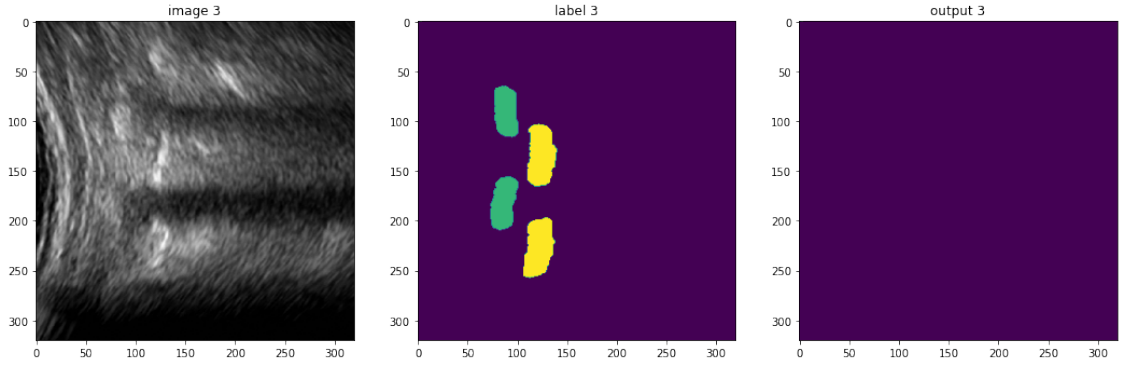

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct


*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

211s_iimage_3925135436261_clean.nii.gz



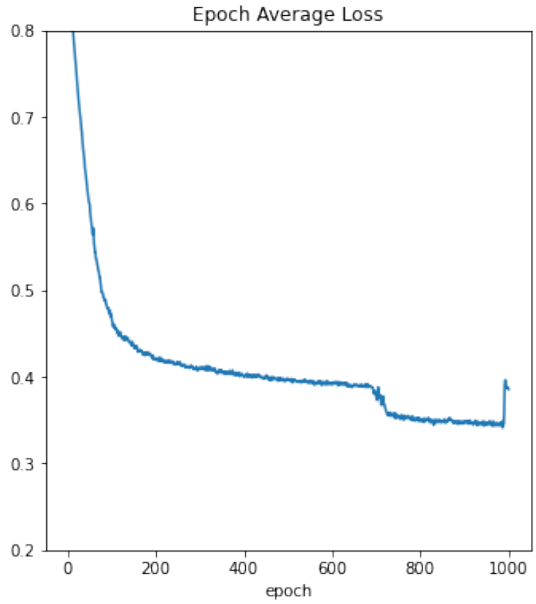

```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 211s_iimage_3925135436261_clean.nii.gz
```

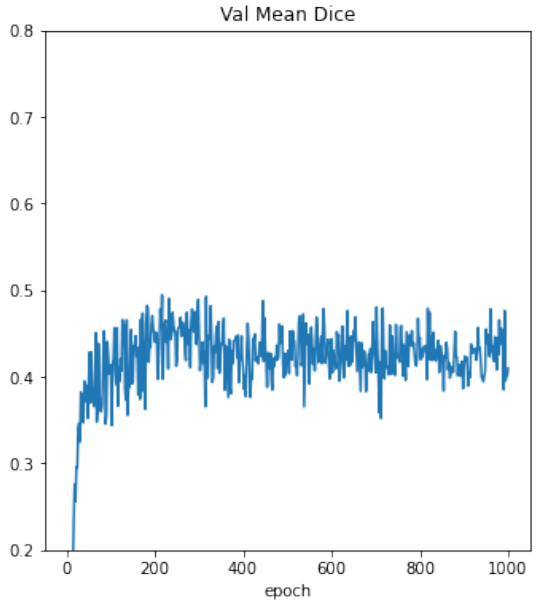
211s_iimage_3929217595322_clean.nii.gz



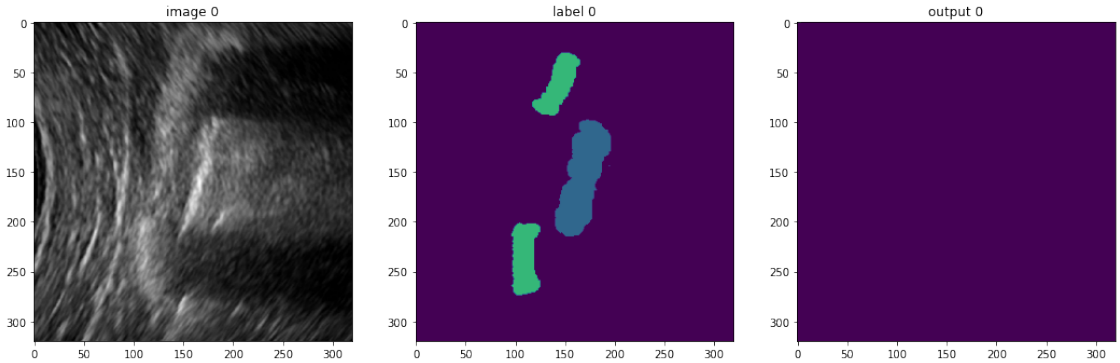

```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 211s_iimage_3929217595322_clean.nii.gz
```

```
*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 211s_iimage_3929217595322_clean.nii.gz

   VFOLD = 12 of 15
```





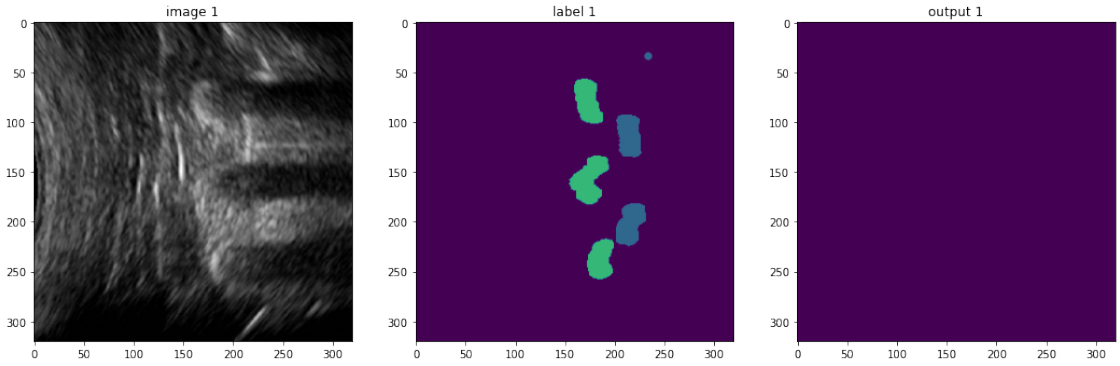

```
218ns_image_6056976176281_CLEAN.nii.gz
```




```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct
```

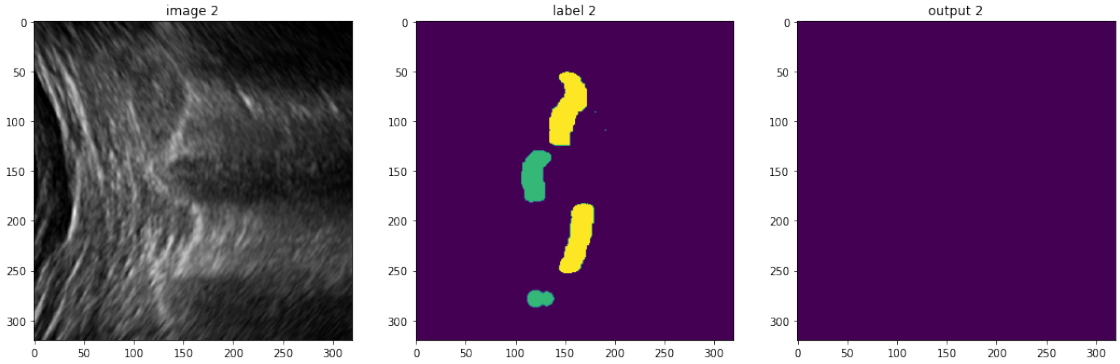
```
 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

218ns_image_6370410622099_CLEAN.nii.gz



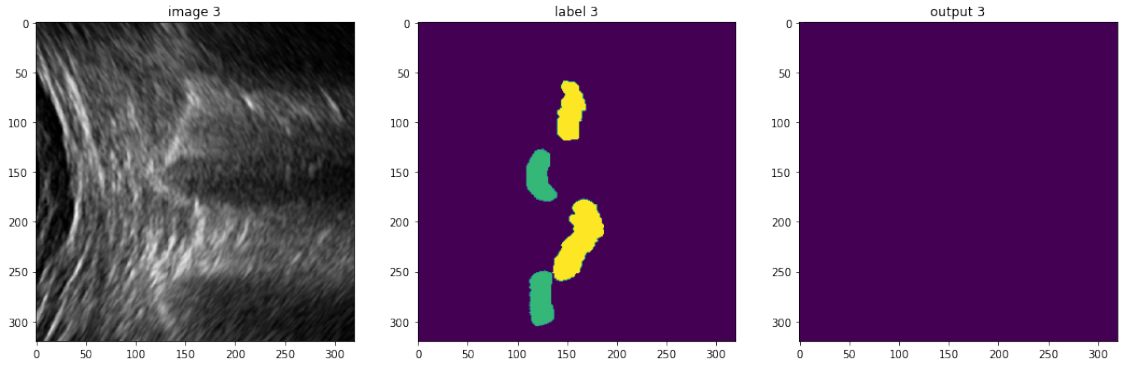

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct

 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct

*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

212s_iimage_128683942015128_CLEAN.nii.gz



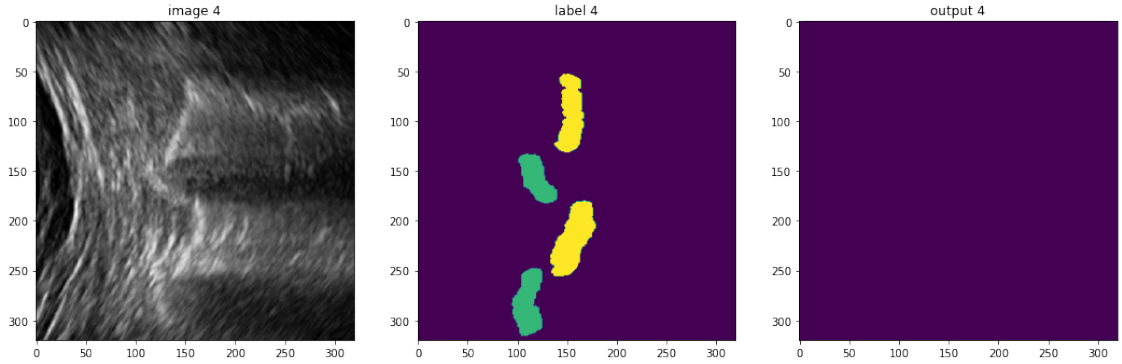
```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 212s_iimage_128683942015128_CLEAN.nii.gz
```

212s_iimage_128688523296793_CLEAN.nii.gz

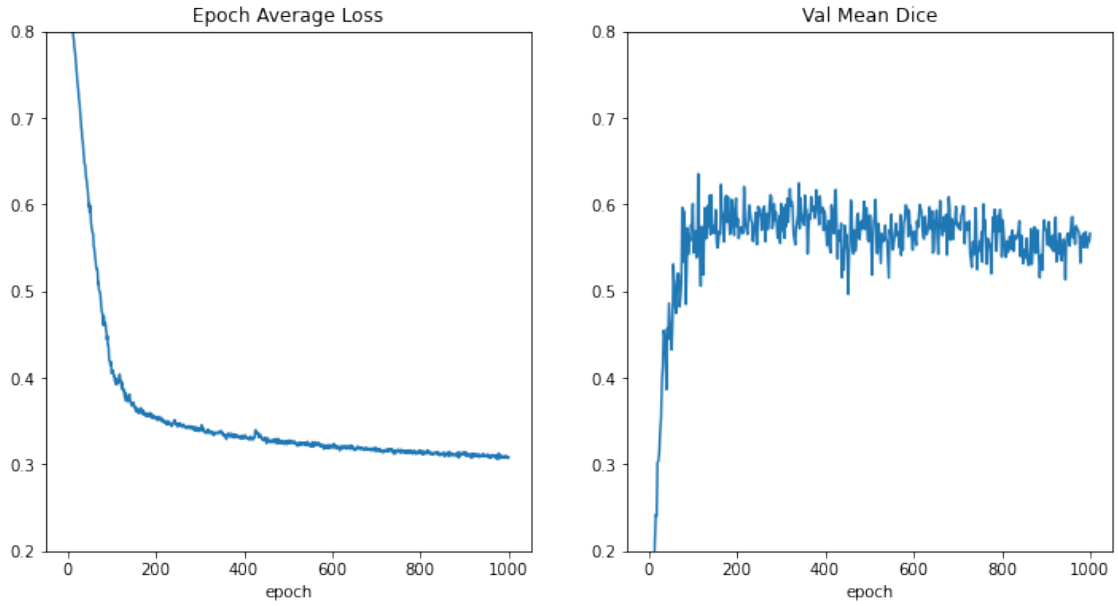



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 212s_iimage_128688523296793_CLEAN.nii.gz
```

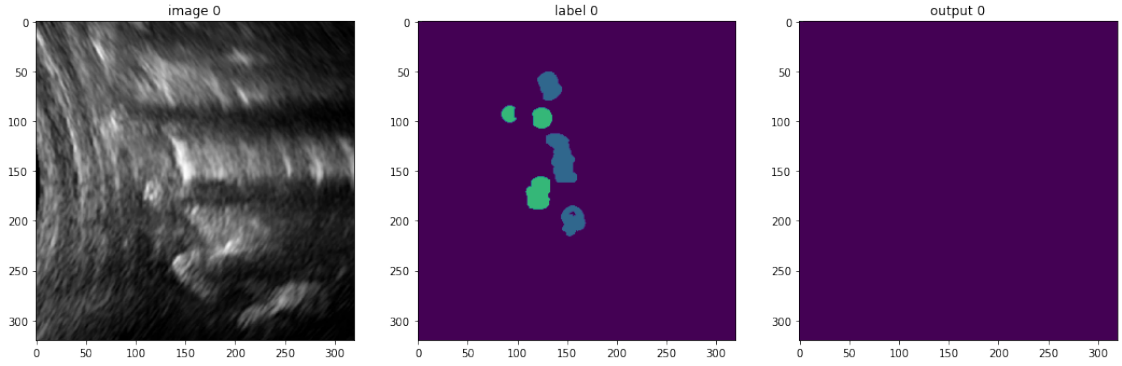
212s_iimage_128692595484031_CLEAN.nii.gz



```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 212s_iimage_128692595484031_CLEAN.nii.gz


*** Patient Winner = Not Sliding ( NS = 5 of 5 )
    Patient False Positive = 212s_iimage_128692595484031_CLEAN.nii.gz


   VFOLD = 13 of 15
```

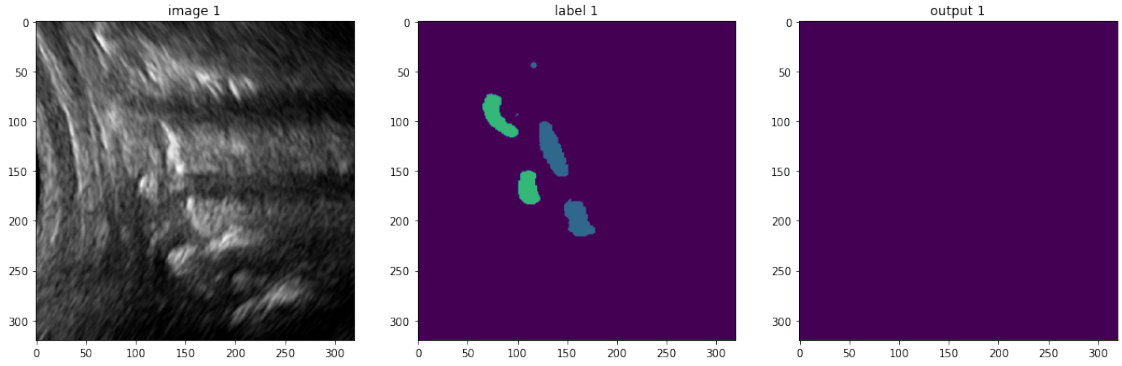



```
219ns_image_1884162273498_clean.nii.gz
```




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

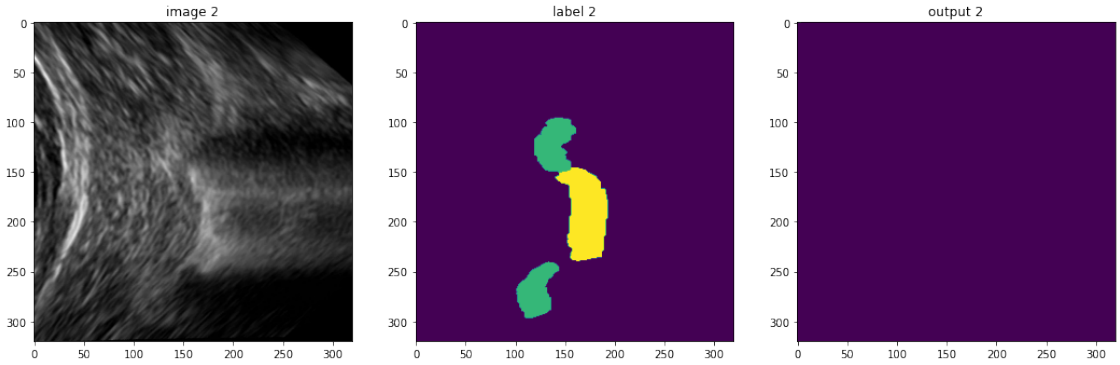
219ns_image_1895283541879_clean.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Correct

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Correct
```

*** Patient Winner = Not Sliding (NS = 2 of 2)
Correct

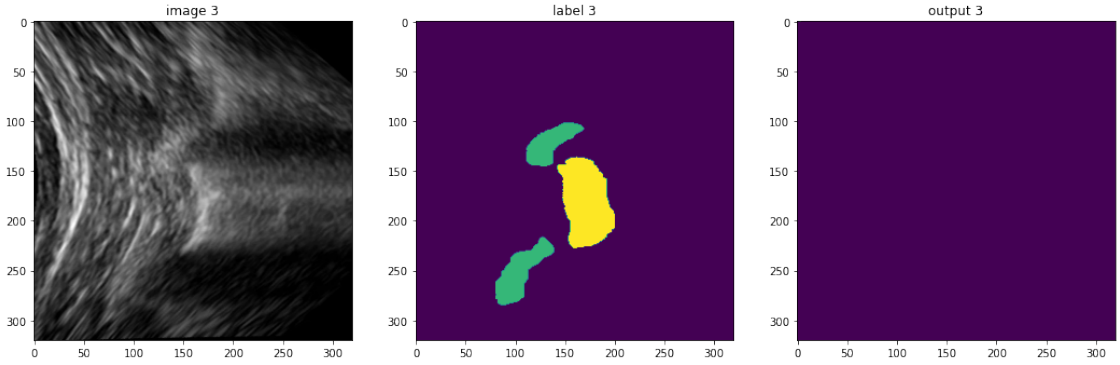
224s_iimage_3308406916756_clean.nii.gz



* ROI Number of not-sliding / sliding pixel = 0 0
ROI Sldiing Min thresh = 1000
ROI = Not Sliding
Fales Positive

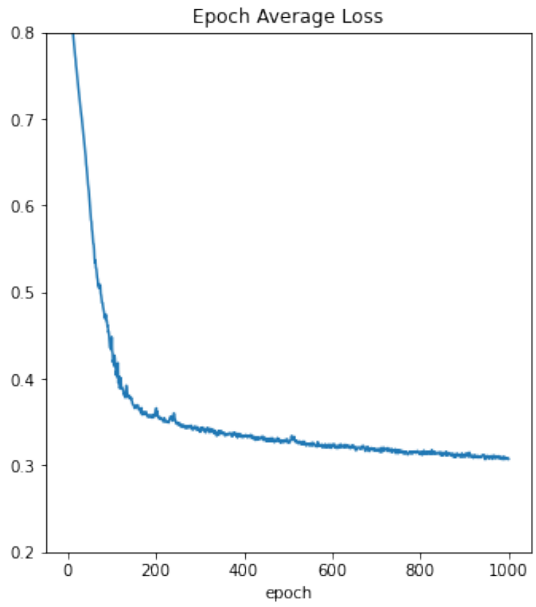
** Frame Winner = Not Sliding (NS = 1 of 1)
Frame False Positive = 224s_iimage_3308406916756_clean.nii.gz

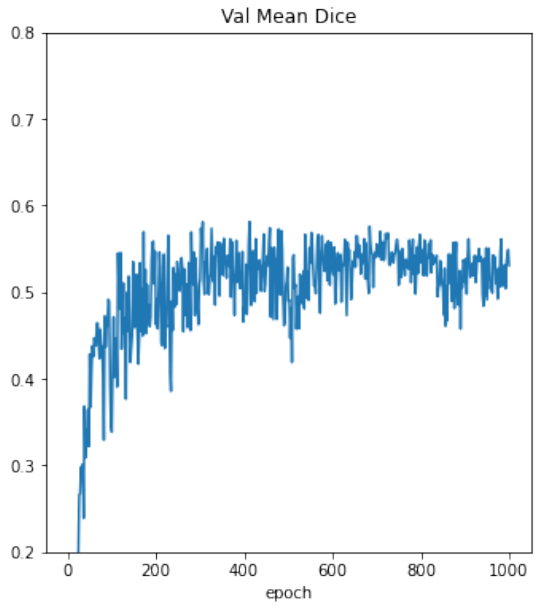
224s_iimage_3315947589826_clean.nii.gz



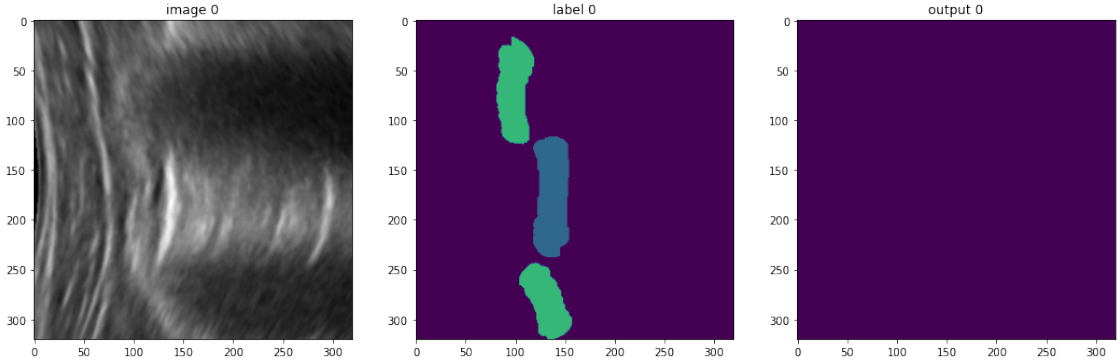
* ROI Number of not-sliding / sliding pixel = 0 0
ROI Sldiing Min thresh = 1000

```
    ROI = Not Sliding
    Fales Positive


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Frame False Positive = 224s_iimage_3315947589826_clean.nii.gz


*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 224s_iimage_3315947589826_clean.nii.gz


   VFOLD = 14 of 15
```



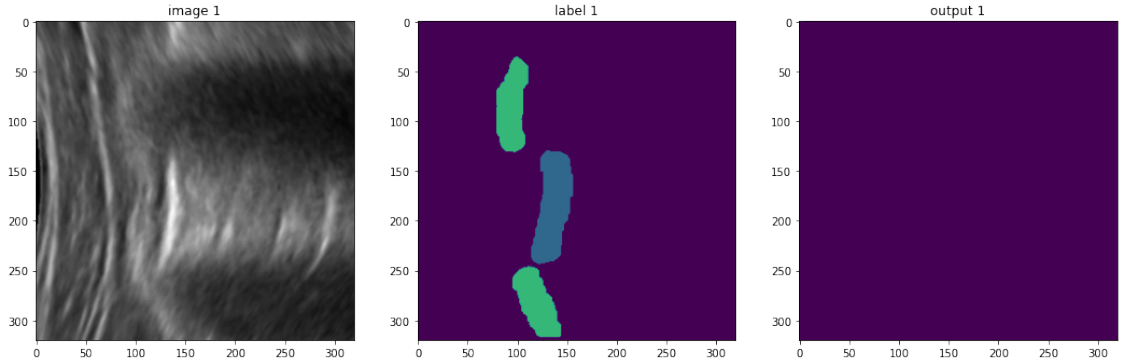


221ns_image_584357289931_clean.nii.gz



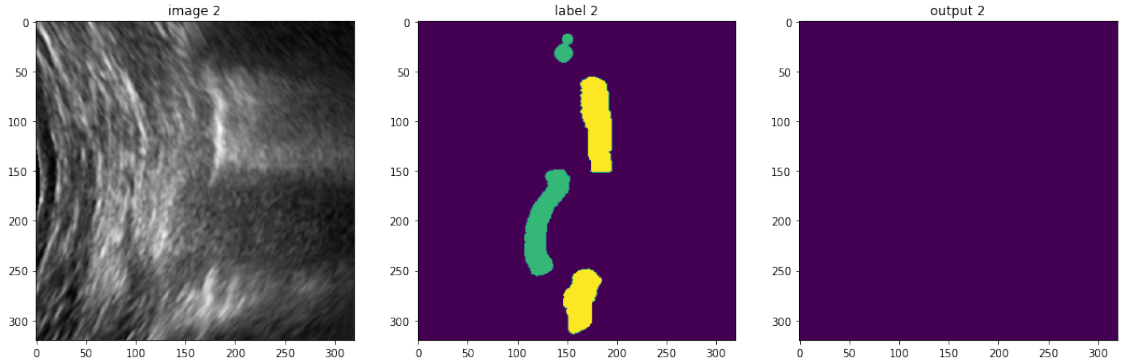
```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct
```

221ns_image_588695055398_clean.nii.gz



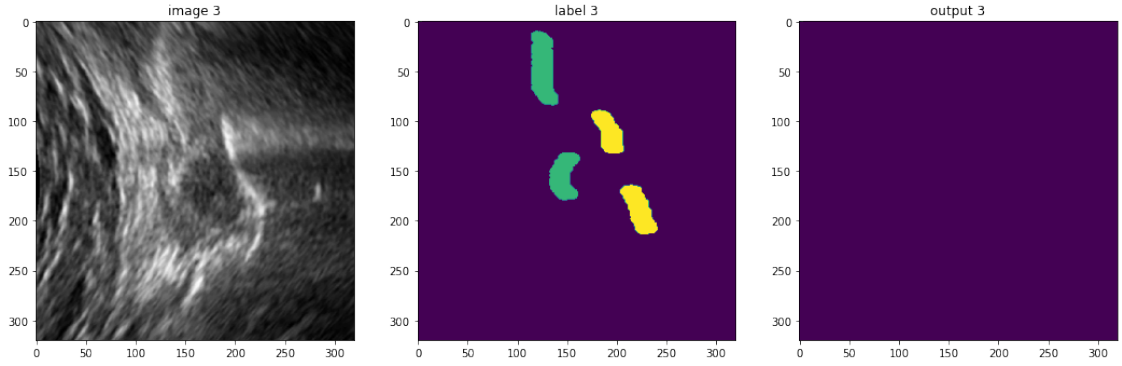

```
  * ROI Number of not-sliding / sliding pixel = 0 0
    ROI Sldiing Min thresh = 1000
    ROI = Not Sliding
    Correct


 ** Frame Winner = Not Sliding ( NS = 1 of 1 )
    Correct


*** Patient Winner = Not Sliding ( NS = 2 of 2 )
    Correct
```

228s_iimage_3321463845606_clean.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 228s_iimage_3321463845606_clean.nii.gz
```

228s_iimage_3384882513134_clean.nii.gz




```
 * ROI Number of not-sliding / sliding pixel = 0 0
   ROI Sldiing Min thresh = 1000
   ROI = Not Sliding
   Fales Positive

** Frame Winner = Not Sliding ( NS = 1 of 1 )
   Frame False Positive = 228s_iimage_3384882513134_clean.nii.gz
```

```
*** Patient Winner = Not Sliding ( NS = 4 of 4 )
    Patient False Positive = 228s_iimage_3384882513134_clean.nii.gz
```

```
Patients: Correct = 15 Incorrect = 16 Not Sliding as Sliding = 0
Frame: Correct = 31 Incorrect = 31 Not Sliding as Sliding = 0
ROIs: Correct = 31 Incorrect = 31 Not Sliding as Sliding = 0
*************
```

[33]:

```
import ipyparams
currentNotebook = ipyparams.notebook_name

from datetime import datetime
now = datetime.now()

experimentName = currentNotebook+now.strftime("-%Y.%m.%d_%H.%M.pdf")

cmd = "jupyter nbconvert "+currentNotebook+" --output "+experimentName+" --to␣
↪pdf"
import subprocess
subprocess.call(cmd, shell=True)
```

```
[NbConvertApp] Converting notebook ARUNet-3D-NRS-VFold-Test.ipynb to pdf
[NbConvertApp] Support files will be in ARUNet-3D-NRS-VFold-
Test.ipynb-2021.11.25_10.50_files/
[NbConvertApp] Making directory ./ARUNet-3D-NRS-VFold-
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[NbConvertApp] Writing 124814 bytes to notebook.tex
[NbConvertApp] Building PDF
Traceback (most recent call last):
  File "/home/local/KHQ/stephen.aylward/anaconda3/bin/jupyter-nbconvert", line
11, in <module>
    sys.exit(main())
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/jupyter_core/application.py", line 264, in launch_instance
```

```
    return super(JupyterApp, cls).launch_instance(argv=argv, **kwargs)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/traitlets/config/application.py", line 846, in launch_instance
    app.start()
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/nbconvertapp.py", line 346, in start
    self.convert_notebooks()
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/nbconvertapp.py", line 518, in convert_notebooks
    self.convert_single_notebook(notebook_filename)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/nbconvertapp.py", line 483, in convert_single_notebook
    output, resources = self.export_single_notebook(notebook_filename,
resources, input_buffer=input_buffer)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/nbconvertapp.py", line 412, in export_single_notebook
    output, resources = self.exporter.from_filename(notebook_filename,
resources=resources)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/exporters/exporter.py", line 181, in from_filename
    return self.from_file(f, resources=resources, **kw)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/exporters/exporter.py", line 199, in from_file
    return self.from_notebook_node(nbformat.read(file_stream, as_version=4),
resources=resources, **kw)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/exporters/pdf.py", line 183, in from_notebook_node
    self.run_latex(tex_file)
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/exporters/pdf.py", line 153, in run_latex
    return self.run_command(self.latex_command, filename,
  File "/home/local/KHQ/stephen.aylward/anaconda3/lib/python3.8/site-
packages/nbconvert/exporters/pdf.py", line 110, in run_command
    raise OSError("{formatter} not found on PATH, if you have not installed "
OSError: xelatex not found on PATH, if you have not installed xelatex you may
need to do so. Find further instructions at
https://nbconvert.readthedocs.io/en/latest/install.html#installing-tex.
```

[33]: 1

[ ]: