CS516 Medical Imaging

Assignment 1

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Set up :

Import Packages and Data Processing

In [1]:
```python
import numpy as np
import matplotlib.pyplot as plt
import nibabel as nib
import numpy.fft as f
```

In [2]:
```python
# Import and Decompressiong the NII Files
img_car_axial = nib.load("E:/medical imaging/assignment 1/modalities/cardiac_axial.nii.gz")
img_car_realt = nib.load("E:/medical imaging/assignment 1/modalities/cardiac_realtime.nii.gz")
img_ct = nib.load("E:/medical imaging/assignment 1/modalities/ct.nii.gz")
img_fmti = nib.load("E:/medical imaging/assignment 1/modalities/fmri.nii.gz")
img_meanp = nib.load("E:/medical imaging/assignment 1/modalities/meanpet.nii.gz")
img_swi = nib.load("E:/medical imaging/assignment 1/modalities/swi.nii.gz")
img_T1_t = nib.load("E:/medical imaging/assignment 1/modalities/T1_with_tumor.nii.gz")
img_tof = nib.load("E:/medical imaging/assignment 1/modalities/tof.nii.gz")
```

In [3]:
```python
# Get the Data
img_car_axial = img_car_axial.get_data()
img_car_realt = img_car_realt.get_data()
img_ct = img_ct.get_data()
img_fmti = img_fmti.get_data()
img_meanp = img_meanp.get_data()
img_swi = img_swi.get_data()
img_T1_t = img_T1_t.get_data()
img_tof = img_tof.get_data()
```

```
<ipython-input-3-279a32428647>:2: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_car_axial = img_car_axial.get_data()
<ipython-input-3-279a32428647>:3: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_car_realt = img_car_realt.get_data()
<ipython-input-3-279a32428647>:4: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_ct = img_ct.get_data()
<ipython-input-3-279a32428647>:5: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_fmti = img_fmti.get_data()
<ipython-input-3-279a32428647>:6: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_meanp = img_meanp.get_data()
<ipython-input-3-279a32428647>:7: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_swi = img_swi.get_data()
<ipython-input-3-279a32428647>:8: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_T1_t = img_T1_t.get_data()
<ipython-input-3-279a32428647>:9: DeprecationWarning: get_data() is deprecated in favor of get_fdata(), which h
as a more predictable return type. To obtain get_data() behavior going forward, use numpy.asanyarray(img.datao
bj).

* deprecated from version: 3.0
* Will raise <class 'nibabel.deprecator.ExpiredDeprecationError'> as of version: 5.0
  img_tof = img_tof.get_data()
```

In [4]:
```python
# Classify the 3D and 4D Images by the shape respectively
img_car_axial.shape,img_car_realt.shape,img_ct.shape,img_fmti.shape,img_meanp.shape,\
img_swi.shape,img_T1_t.shape,img_tof.shape
```

Out[4]:
```
((288, 288, 4, 30),
 (160, 160, 1, 500),
 (512, 512, 239),
 (160, 160, 36, 153),
 (256, 256, 207),
 (512, 512, 500),
 (160, 256, 256),
 (480, 640, 150))
```

Note: From the shape data above, we figured out the cardiac_axial, the cardiac_realtime and the fmti images are 4D, otherwise are 3D images. Baced on the concept of slicing image, we decided to pick up the first volumn to display the 4D images.

In [5]:
```python
# Slice the 4-D images by the first volumn
img_car_axial_vol0 = img_car_axial[:,:,:,0]
img_car_realt_vol0 = img_car_realt[:,:,:,0]
img_fmti_vol0 = img_fmti[:,:,:,0]
```

In [6]:
```python
# Define the lists of images and titles for furthur use
imglist = [img_car_axial_vol0,img_car_realt_vol0,img_ct,img_fmti_vol0,
           img_meanp,img_swi,img_T1_t,img_tof]
imglist_t = [img_car_axial,img_car_realt,img_ct,img_fmti,
           img_meanp,img_swi,img_T1_t,img_tof]
imgtitle = ["cardiac_axial","cardiac_realtime","ct","fmri","meanpet","swi",
            "T1_with_tumor","tof"]
```

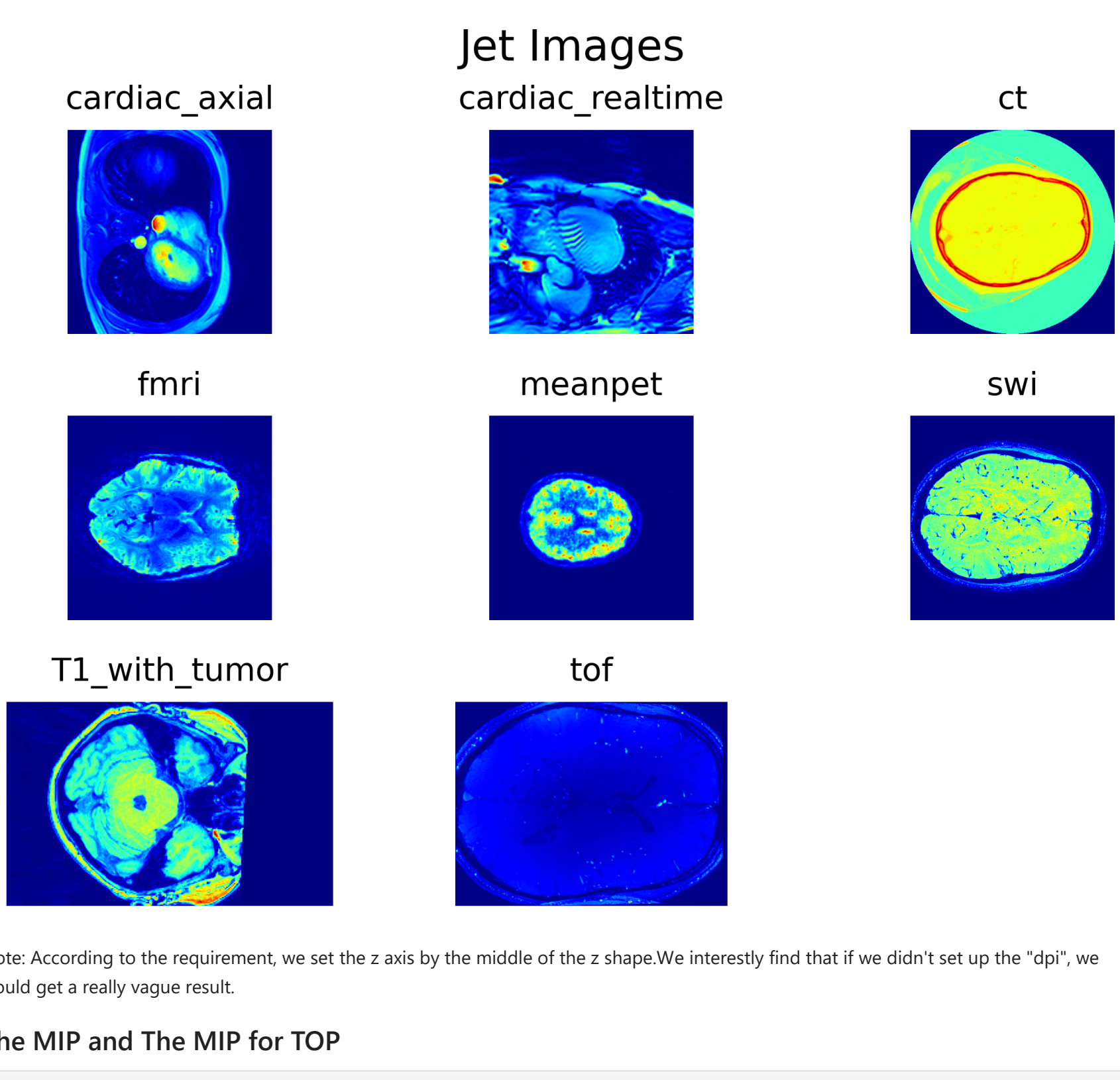
Note: The imagelist lists all 3D images and the imglist_t lists all original images

Part1:

Plot These Images

In [7]:
```python
plt.figure()
plt.figure(dpi=500)
for i in range(8):
    plt.subplot(3,3,i+1)
    plt.axis('off')
    plt.title(imgtitle[i],fontsize=9)
    plt.imshow(imglist[i][:,:,int(imglist[i].shape[2]/2)], cmap='jet')
plt.subplots_adjust(wspace=0.2, hspace=0.4)
plt.suptitle("Jet Images")
```

Out[7]:
```
Text(0.5, 0.98, 'Jet Images')
<Figure size 432x288 with 0 Axes>
```



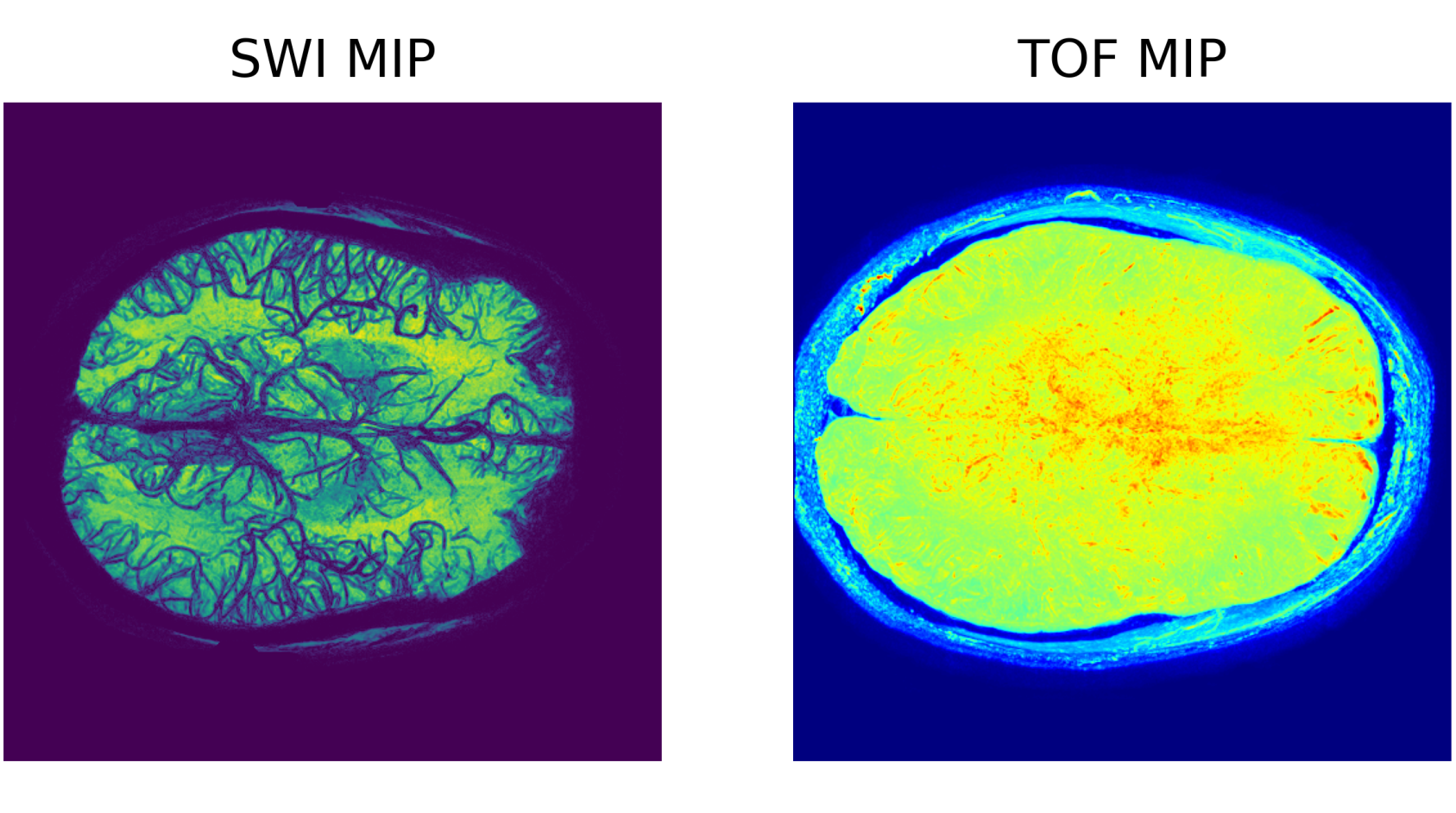
Note: According to the requirement, we set the z axis by the middle of the z shape.We interestly find that if we didn't set up the "dpi", we would get a really vague result.

The MIP and The MIP for TOP

In [8]:
```python
#MIP for the swi
plt.figure()
plt.figure(dpi=500)
img_swi_min = np.min(img_swi[:,:,200:300],axis=2)
plt.subplot(1,2,1)
plt.axis('off')
plt.title('SWI MIP')
plt.imshow(img_swi_min)

#MIP for the TOP
img_swi_max = np.max(img_swi[:,:,200:300],axis=2)
plt.subplot(1,2,2)
plt.axis('off')
plt.title('TOF MIP')
plt.imshow(img_swi_max,cmap='jet')
plt.suptitle("MIPs")
```

Out[8]:
```
Text(0.5, 0.98, 'MIPs')
<Figure size 432x288 with 0 Axes>
```



Note: After several times trying, the 200:300 z axis range is most suitable for presenting a clear view for the swi MIP.However, no matter how small or large range of trying, we still cannot get a clear blood vessel of MIP for TOP figure as it in the example.

Part 2: Contrast Estimation

Michelson

In [9]:
```python
def findMichelson(imglist):
    michelsonlist = []
    for i in range(8):
        if np.min(imglist[i])>0:
            imgmin = np.min(imglist[i])
        else:
            imgmin = 0
        imgmax = np.max(imglist[i])
        Cmichelson = round((imgmax-imgmin)/(imgmax+imgmin),1)
        michelsonlist.append(Cmichelson)
    return michelsonlist
Cmichelson = findMichelson(imglist_t)
```

In [10]:
```python
Cmichelson
```

Out[10]:
```
[1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]
```

In [11]:
```python
np.min(img_ct)
```

Out[11]:
```
-3024.0
```

Note: When we firstly tried to calculate the Michelson contrast, we surprisingly found that the min value of ct is negative which is obviously smaller than the lower limit of the Michelson contrast method. In order to solve this problem, we introduce a "if" function to convert the negative value into positive.

RMS

In [12]:
```python
def findRMS(imglist):
    RMSlist = []
    for i in range(8):
        RMS = round(np.sqrt(np.mean((imglist[i]-np.mean(imglist[i]))**2)),1)
        RMSlist.append(RMS)
    return RMSlist
Crms= findRMS(imglist_t)
```

In [13]:
```python
Crms
```

Out[13]:
```
[2177.1, 21412.6, 1181.4, 265.9, 3679.9, 29.7, 122.7, 41.1]
```

Note: To be honest, we had deeply stucked into self doublt by the big difference values from the Michelson contrast. As results shown above, the cardiac_axial_realtime has the largest RMS contrast, while the swi is the lowest.

Entropy

In [14]:
```python
def findEntropy(imglist):
    entropylist = []
    for i in range(8):
        imghist = np.histogram(imglist[i])
        imgfrq = imghist[0][np.nonzero(imghist[0])]
        imgpro = [float(h)/sum(imgfrq) for h in imgfrq]
        entropy = round(np.abs(np.sum(np.multiply(imgpro, np.log2(imgpro)))),1)
        entropylist.append(entropy)
    return entropylist
Centropy = findEntropy(imglist_t)
```

In [15]:
```python
Centropy
```

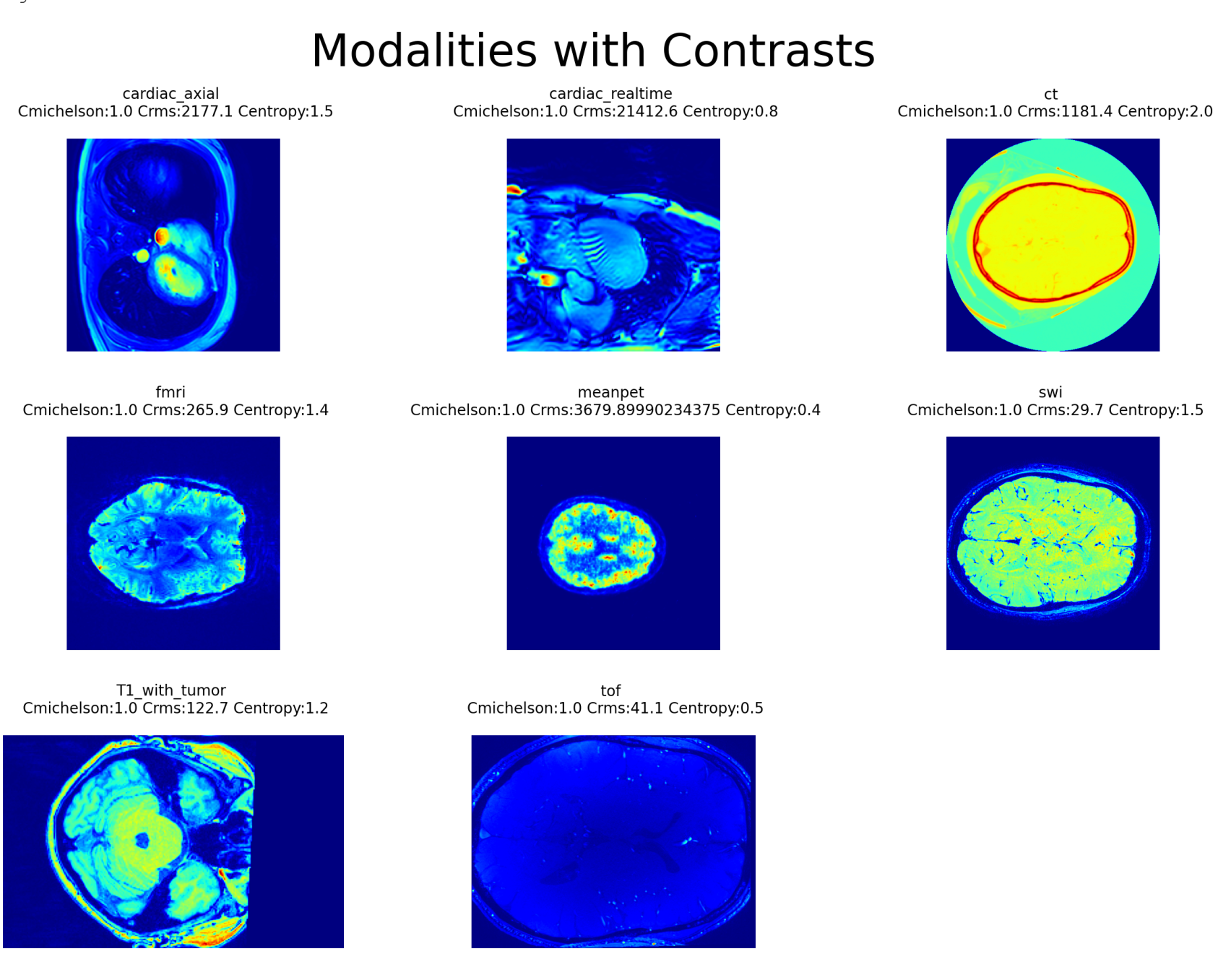
Out[15]:
```
[1.5, 0.8, 2.0, 1.4, 0.4, 1.5, 1.2, 0.5]
```

Note: Actually we spent a long time on calculating the entropy contrast. The reason is that we easily get the image frequency but still don't know the way of flatened the figure.Although after searching the internet, we finally get the right way of calculating the entropy contrast, we still want to know the entropy mathmatics concept.

Plot the Contrasts

In [16]:
```python
#Plot motalities with contrast
plt.figure()
plt.figure(dpi=500)
for i in range(8):
    plt.subplot(3,3,i+1)
    plt.axis('off')
    plt.title("{} \n Cmichelson:{} Crms:{} Centropy:{}".format\
              (imgtitle[i],Cmichelson[i],Crms[i],Centropy[i]),fontsize=4)
    plt.imshow(imglist[i][:,:,int(imglist[i].shape[2]/2)], cmap='jet')
plt.subplots_adjust(wspace=0.2, hspace=0.4)
plt.suptitle("Modalities with Contrasts")
```

Out[16]:
```
Text(0.5, 0.98, 'Modalities with Contrasts')
<Figure size 432x288 with 0 Axes>
```



Note: There is a really weird thing happened that the "Crms" value in the title is not rounded while seperatly printed, it is rounded.We don't know why this issue happened.

Part 3: SNR Estimation, Quantifying Noise

Noise Patches

In [17]:
```python
#SNR: We have to find and test some none zero noise patches, so in this
#question, we didn't apply a "for" function to get all resaults.
img_car_axial_snr = np.mean(img_car_axial)\
    /np.std(img_car_axial_vol0[260:280,260:280,2])
img_car_realt_snr = np.mean(img_car_realt)\
    /np.std(img_car_realt_vol0[0:20,130:150,0])
img_ct_scr = np.mean(img_ct)/np.std(img_ct[60:80,60:80,119])
img_fmti_scr = np.mean(img_fmti)/np.std(img_fmti_vol0[0:20,0:20,18])
img_meanp_scr = np.mean(img_meanp)/np.std(img_meanp[40:60,40:60,103])
img_swi_scr = np.mean(img_swi)/np.std(img_swi[80:100,80:100,249])
img_T1_t_scr = np.mean(img_T1_t)/np.std(img_T1_t[0:20,0:20,127])
img_tof_scr = np.mean(img_tof)/np.std(img_tof[0:20,0:20,124])
SNRlist = [img_car_axial_snr,img_car_realt_snr,img_ct_scr,\
       img_fmti_scr,img_meanp_scr,img_swi_scr,img_T1_t_scr,img_tof_scr]
SNRlist = [np.abs(round(i,1)) for i in SNRlist]
```

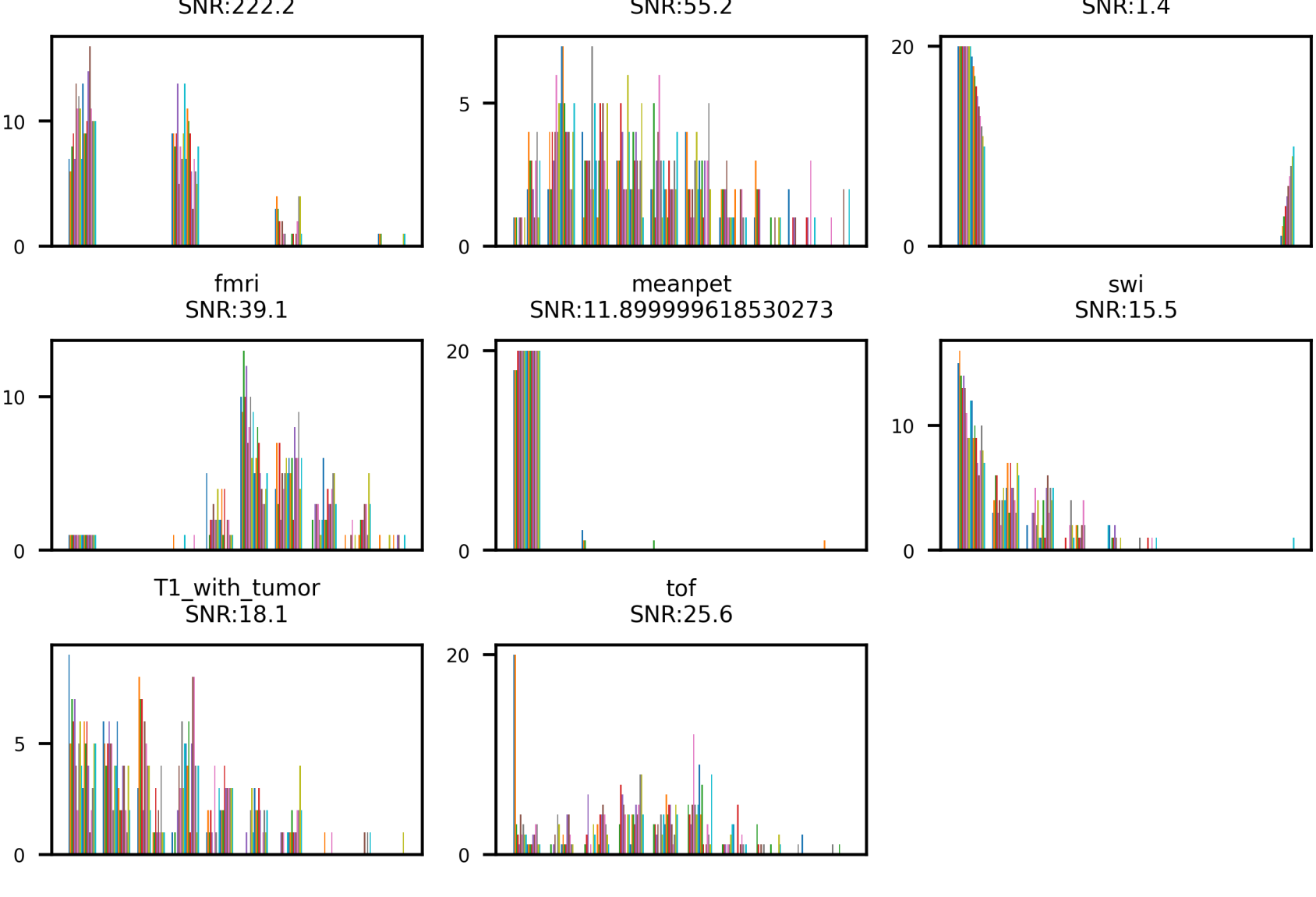
In [18]:
```python
for i in range(8):
    print("{}:{}".format(imgtitle[i],SNRlist[i]))
```

```
cardiac_axial:222.2
cardiac_realtime:55.2
ct:1.4
fmri:39.1
meanpet:11.899999618530273
swi:15.5
T1_with_tumor:18.1
tof:25.6
```

Note: As shown on the printed result, the CT has the lowest contrast while the cardiac_axial is the highest.

In [19]:
```python
#Plot the noise histogram with SNRs
positionlist = [img_car_axial_vol0[260:280,260:280,2],
                img_car_realt_vol0[0:20,130:150,0],
                img_ct[60:80,60:80,119],
                img_fmti_vol0[0:20,0:20,18],
                img_meanp[40:60,40:60,103],
                img_swi[80:100,80:100,249],
                img_T1_t[0:20,0:20,127],
                img_tof[0:20,0:20,124]]
plt.figure()
plt.figure(dpi=500)
for i in range(8):
    plt.subplot(3,3,i+1)
    plt.title("{}\nSNR:{}".format(imgtitle[i],SNRlist[i]),fontsize=6)
    plt.xticks([])
    plt.yticks(fontsize=5)
    plt.hist(positionlist[i])
plt.subplots_adjust(wspace=0.2, hspace=0.45)
plt.suptitle("Noise Histogram")
```

Out[19]:
```
Text(0.5, 0.98, 'Noise Histogram')
<Figure size 432x288 with 0 Axes>
```



Note: the same problem occured that the meanpet SNR cannot be rounded.

Part 4: Linear Filtering

Gaussfilt Function

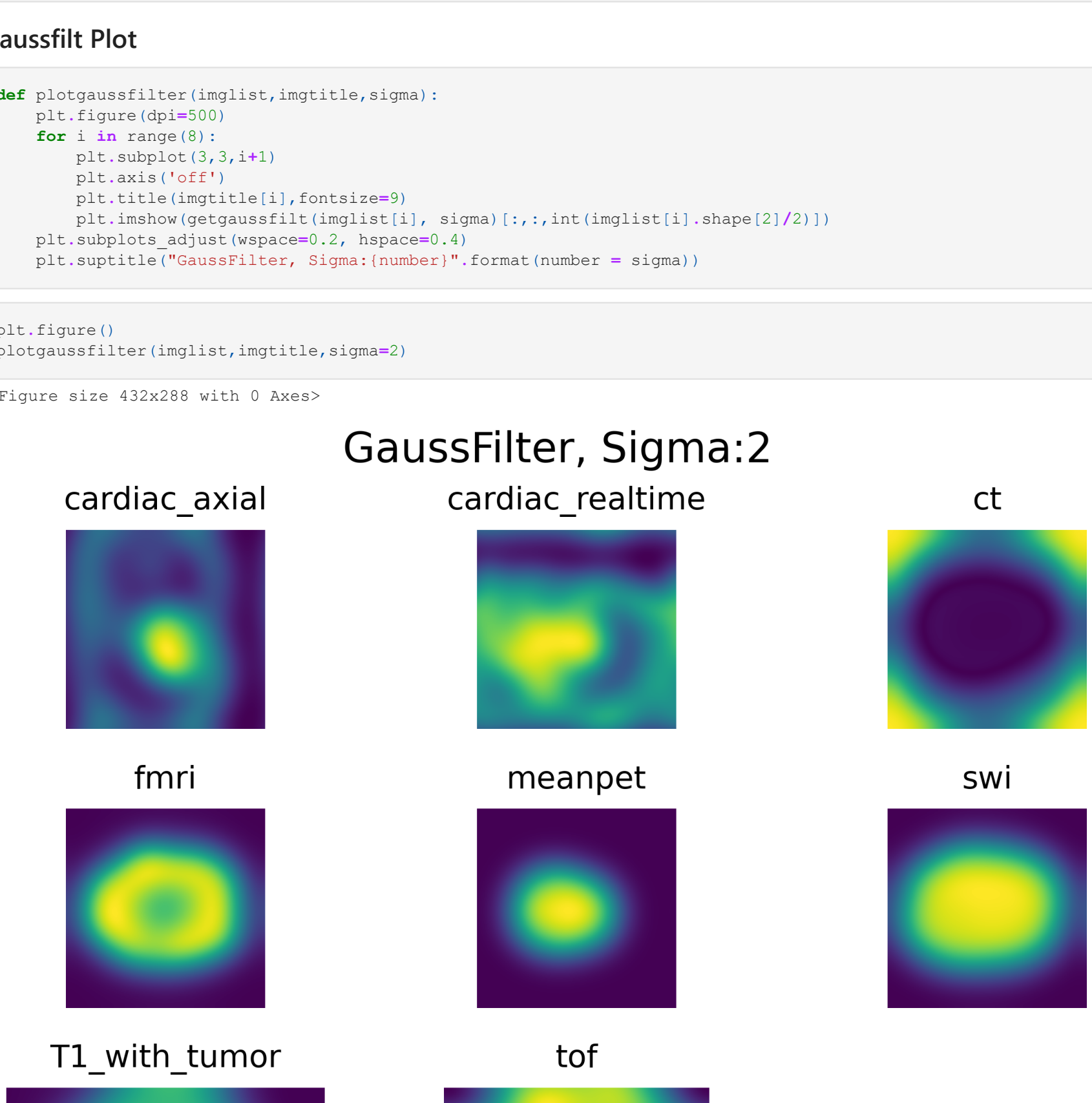
In [20]:
```python
def getgaussfilt(img,sigma):
    img_freqs = f.fftshift(f.fftn(img))
    [X,Y,Z] = np.mgrid[0:img.shape[0],0:img.shape[1],0:img.shape[2]]
    xpr,ypr,zpr = X-(img.shape[0])//2,Y-(img.shape[1])//2,Z-(img.shape[2])//2
    gaussfilt = np.exp(-((xpr**2+ypr**2+zpr**2)/(2*sigma**2)))/(2*np.pi*sigma**2)
    gaussfilt = gaussfilt/np.max(gaussfilt)
    filtered_freqs = img_freqs*gaussfilt
    filtered = np.abs(f.ifftn(f.fftshift(filtered_freqs)))
    return filtered
```

Gaussfilt Plot

In [21]:
```python
def plotgaussfilter(imglist,imgtitle,sigma):
    plt.figure(dpi=500)
    for i in range(8):
        plt.subplot(3,3,i+1)
        plt.axis('off')
        plt.title(imgtitle[i],fontsize=9)
        plt.imshow(getgaussfilt(imglist[i], sigma)[:,:,int(imglist[i].shape[2]/2)])
    plt.subplots_adjust(wspace=0.2, hspace=0.4)
    plt.suptitle("GaussFilter, Sigma:{number}".format(number = sigma))
```

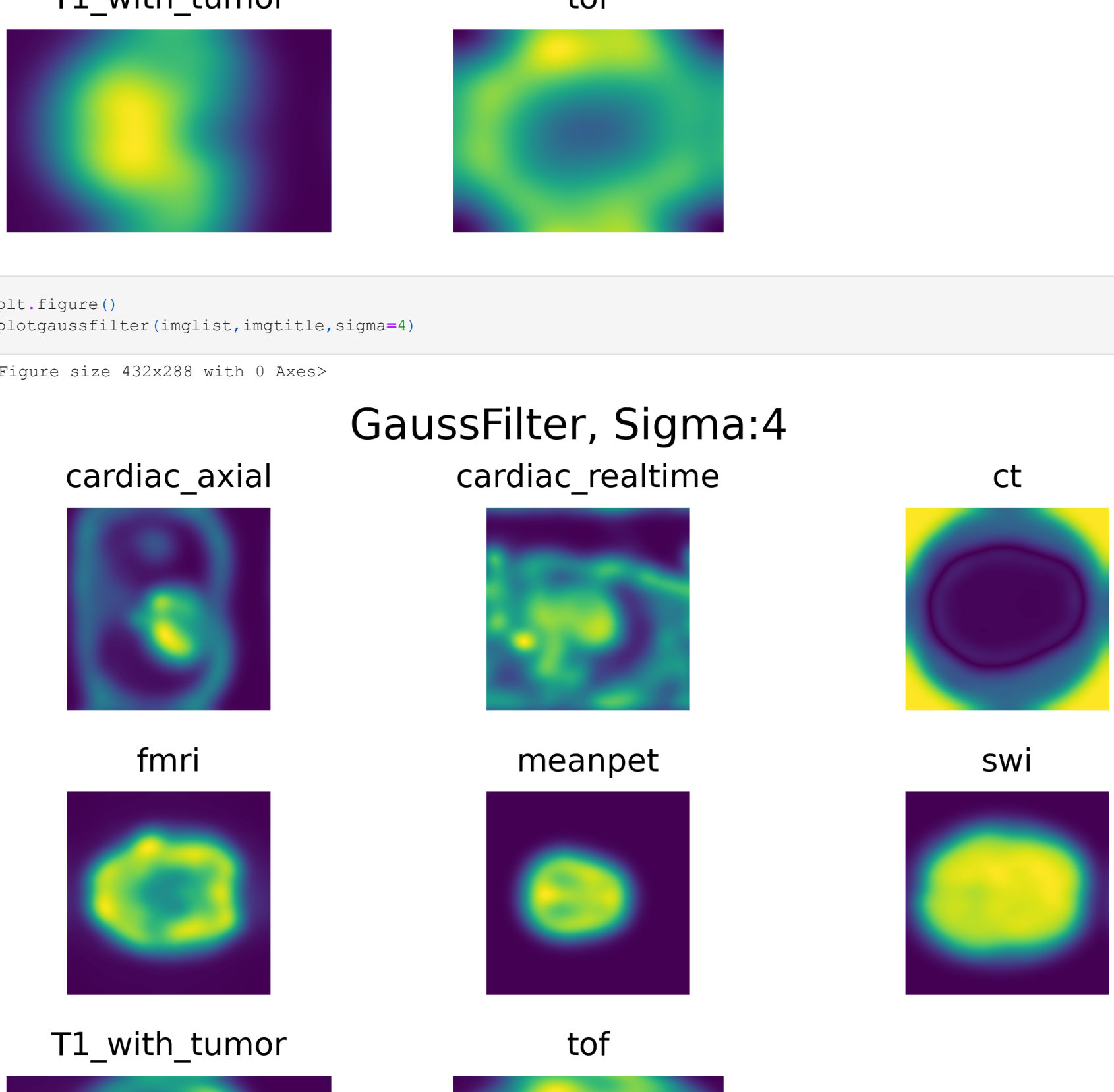
In [22]:
```python
plt.figure()
plotgaussfilter(imglist,imgtitle,sigma=2)
```

```
<Figure size 432x288 with 0 Axes>
```



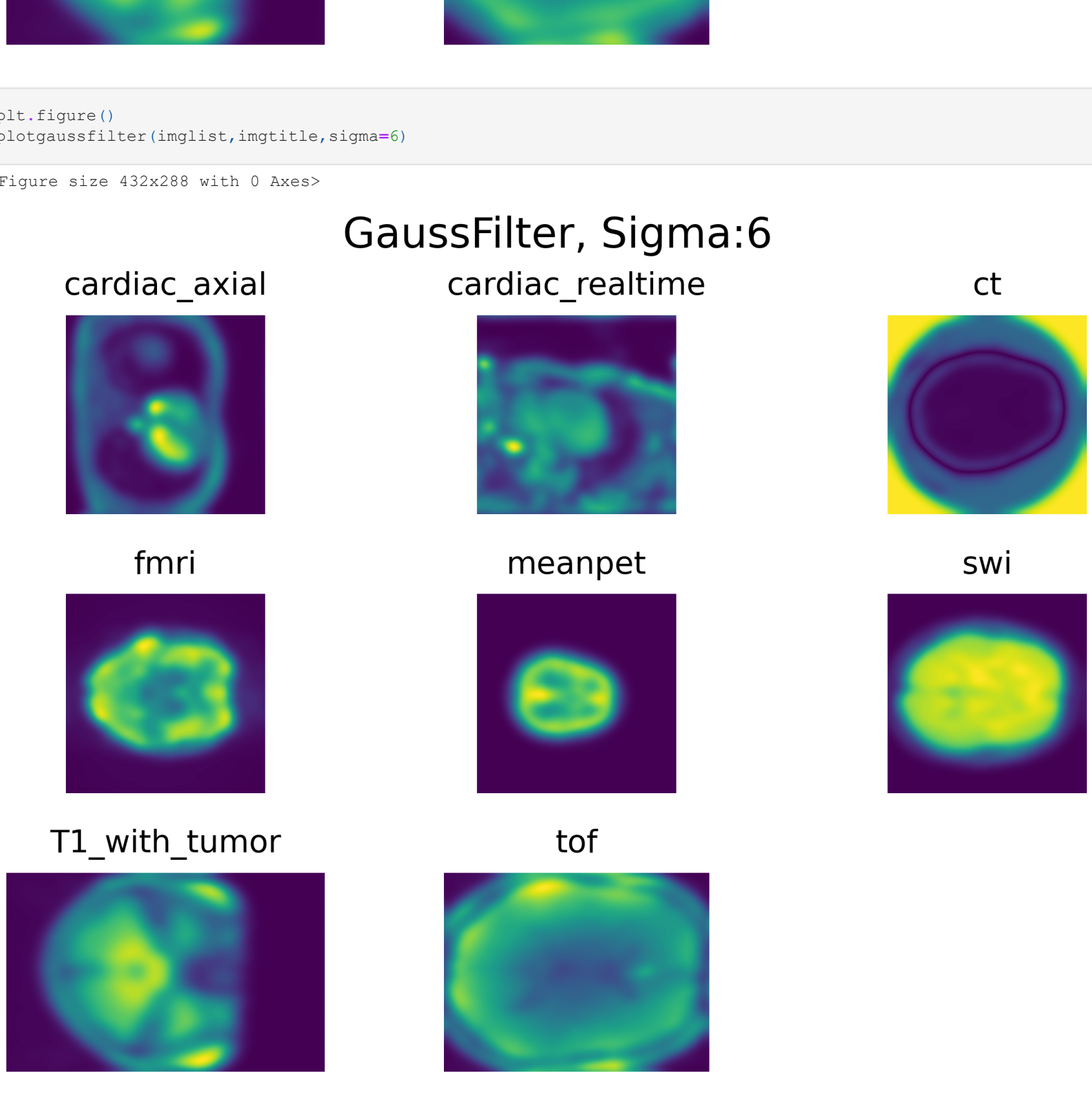
In [23]:
```python
plt.figure()
plotgaussfilter(imglist,imgtitle,sigma=4)
```

```
<Figure size 432x288 with 0 Axes>
```



In [24]:
```python
plt.figure()
plotgaussfilter(imglist,imgtitle,sigma=6)
```

```
<Figure size 432x288 with 0 Axes>
```



Note: As showned on figures above, when sigma becomes larger, the image is less blurer.