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Portsmouth Hospitals University NHS Trust

CT Dose Audit –
interpreting results with the aid of patient size evaluation

Holubinka M(1), Griffiths C(2),
Mioduszewski R(2), Davis A(1)

(1) Portsmouth Hospitals University NHS Trust

(2) University of Portsmouth – Applied Physics MSc

Motivation:

Previous reviews revealed gender differences median CTDIvol & DLP

Machine dependent, or audit samples ?

Weight / BMI data collection – longstanding issue – resolution?

Impact local DRLs ?

Serial audits / trends – data quality

We have the images – can they be used?

Standard dose audit process:

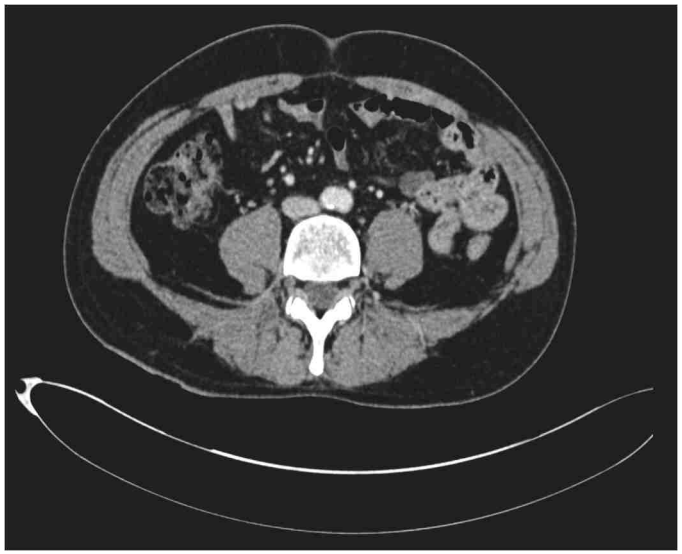
Select a modality	CT
Choose a study	Abdomen-Pelvis
Collect dose data	Care Analytics & OpenREM
Identify metrics	CTDIvol, DLP, Age, *Weight*, *Gender*
Clean data	Rogue studies, extreme outliers
Identify metric medians	Whole sample, (*gender sub-sets*)
Compare with other data	Previous audits Other systems LDRLs and NDRLs
Report & review	Optimisation Team – action/no action
Optimise	Standardise? adjust protocol? image review? Training?

Two studies same protocol (via CARE Analytics):

	Males		Females		Combined	
	CTDIvol	DLP	CTDIvol	DLP	CTDIvol	DLP
CT Abdomen Pelvis General						
Sensation S40	9.3	480	10.9	595	9.9	510
Definition AS+	11.2	600	8.8	420	9.5	475
CT Abdomen GI1a Abdo Pelvis Gen						
Sensation S40	9.0	485	9.3	485	9.1	485
Definition AS+	9.7	495	10.8	515	10.3	500

	CTDIvol	DLP
NDRL	15	745
LDRL	-	600

Studies reviewed for referral indications (Definition AS+)



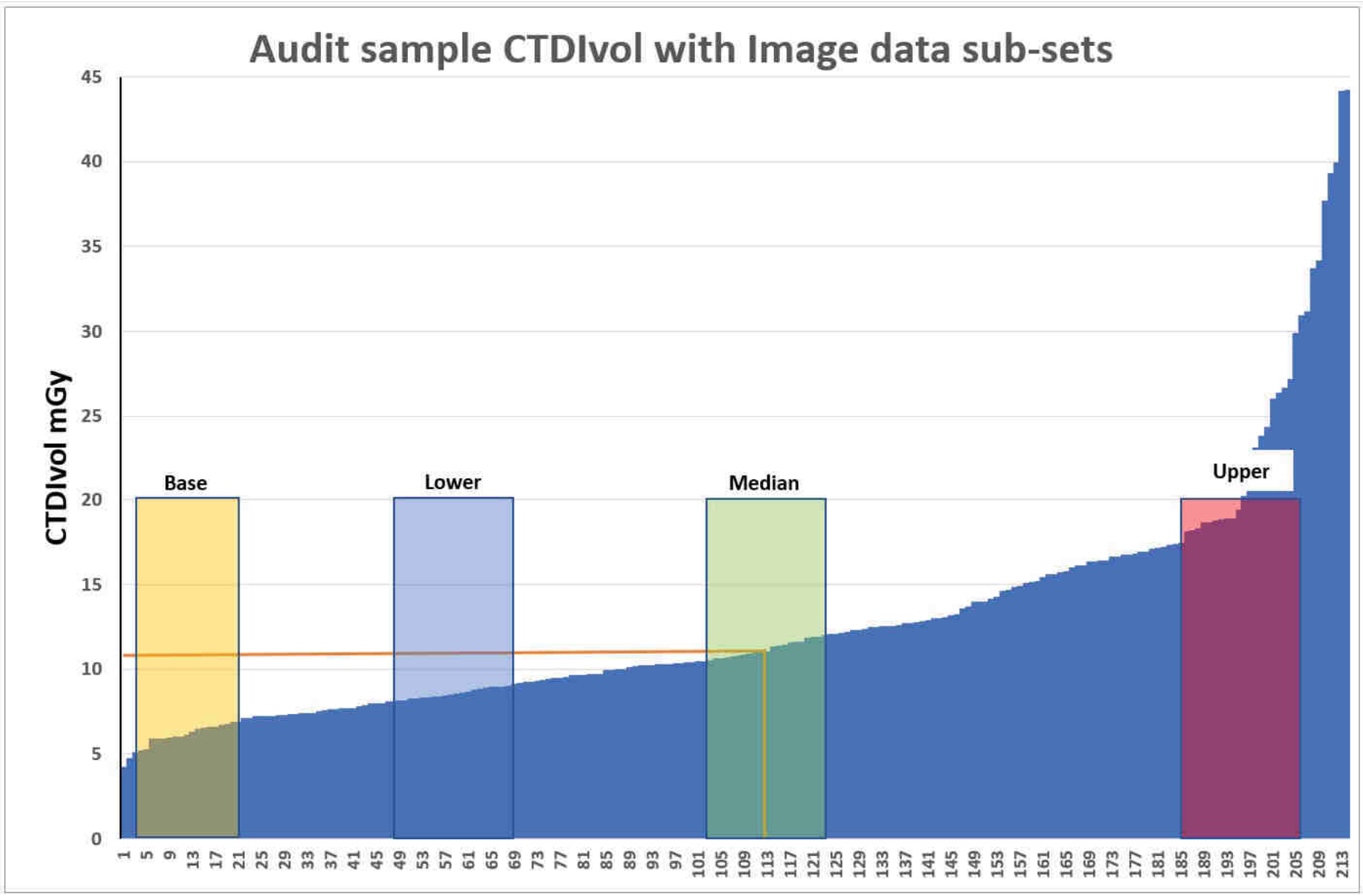
‘Median’ Male

‘Median’ Female

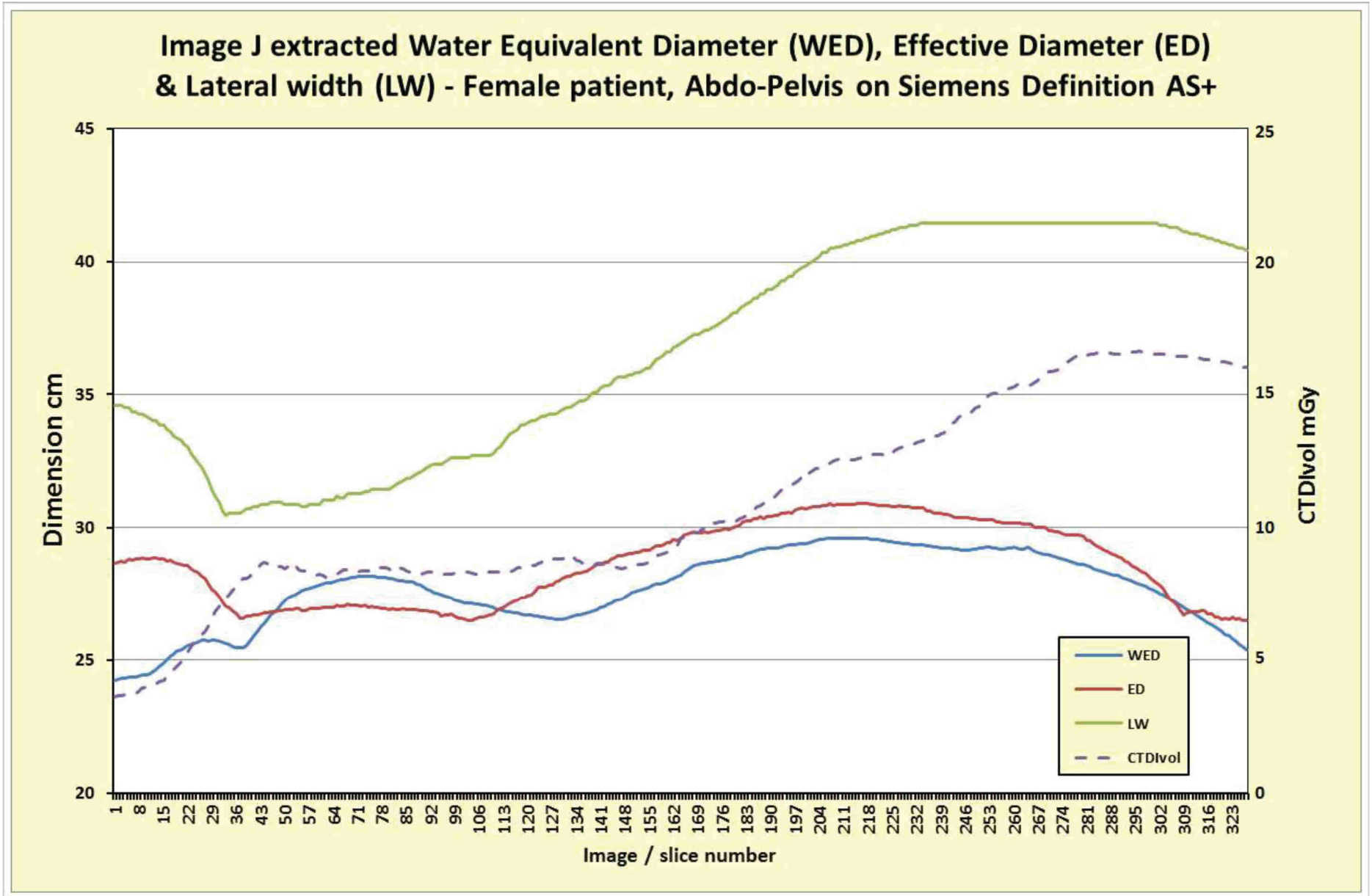
Representative selection of patient habitus from the Median sub-set

Normal weight ?

Example of Sub-sets of patient images selected for analysis:

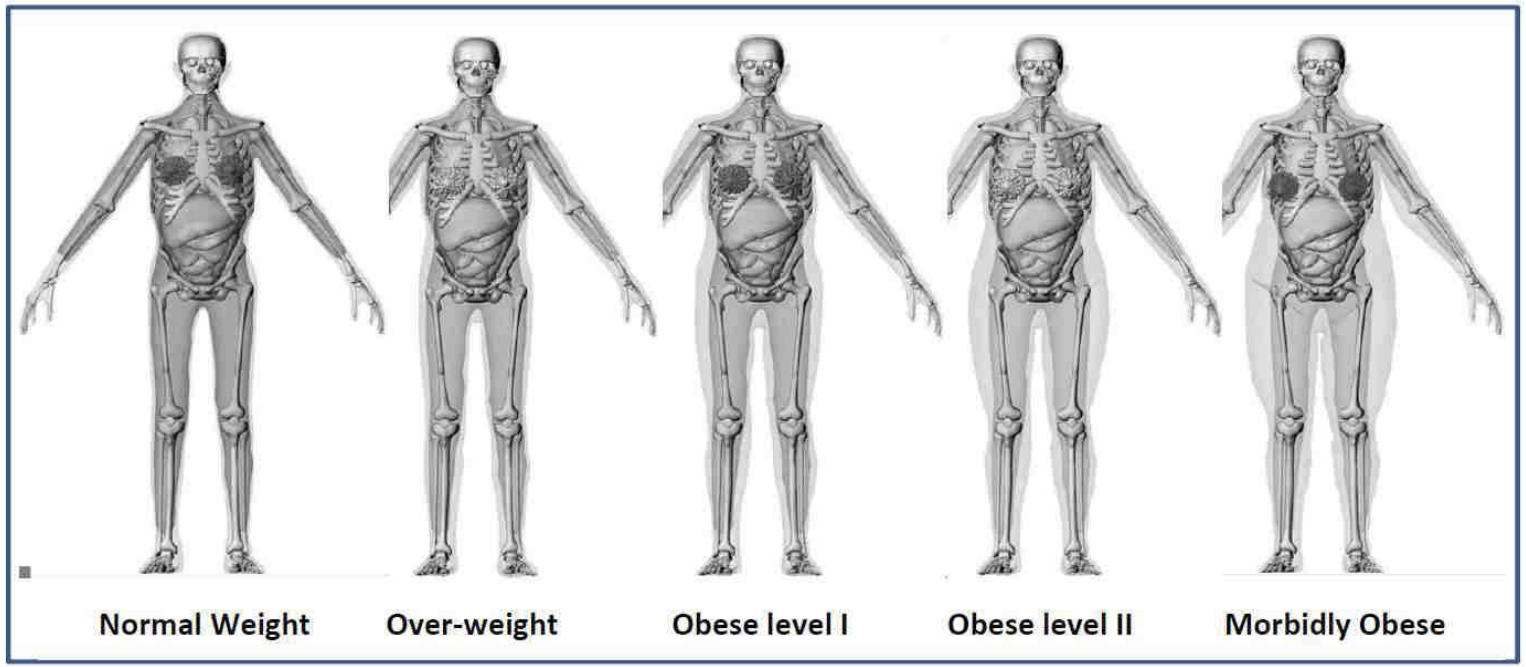


Analyse sub-sets of patient images within audit sample:

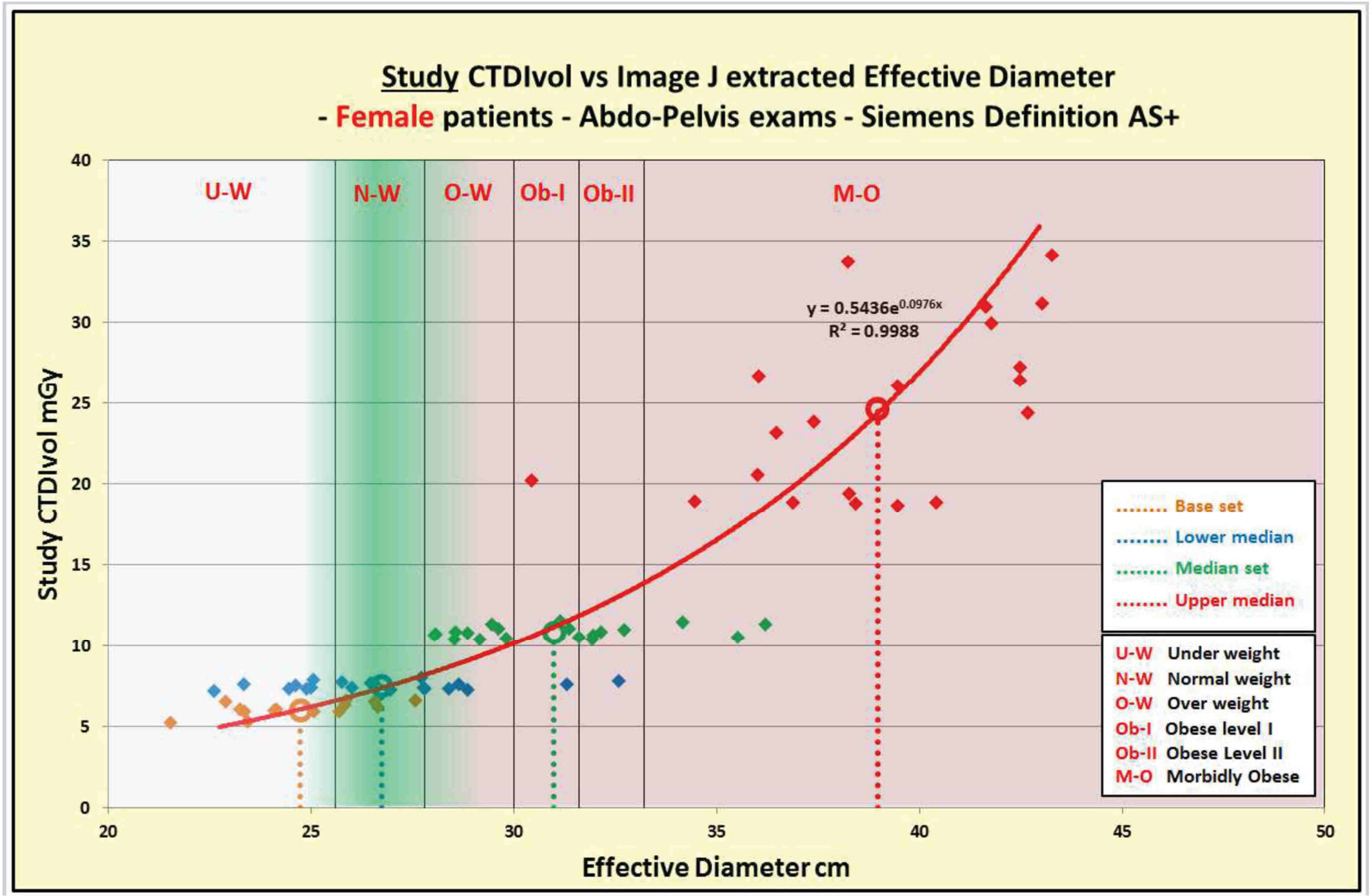


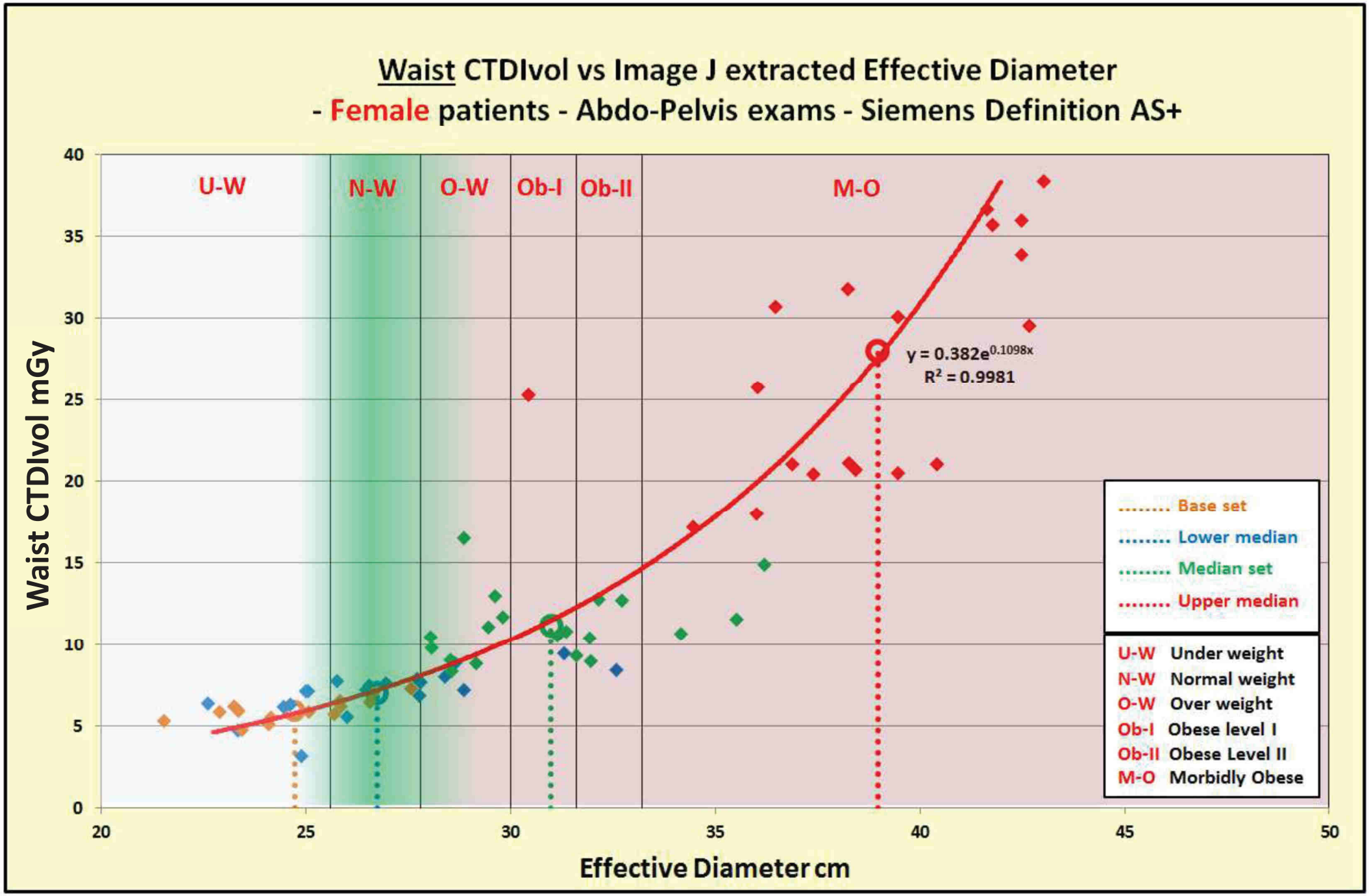
Correlate extracted size metrics with dosimetry reference phantoms:

VirtualDose-CT female phantoms (shown overlapping)



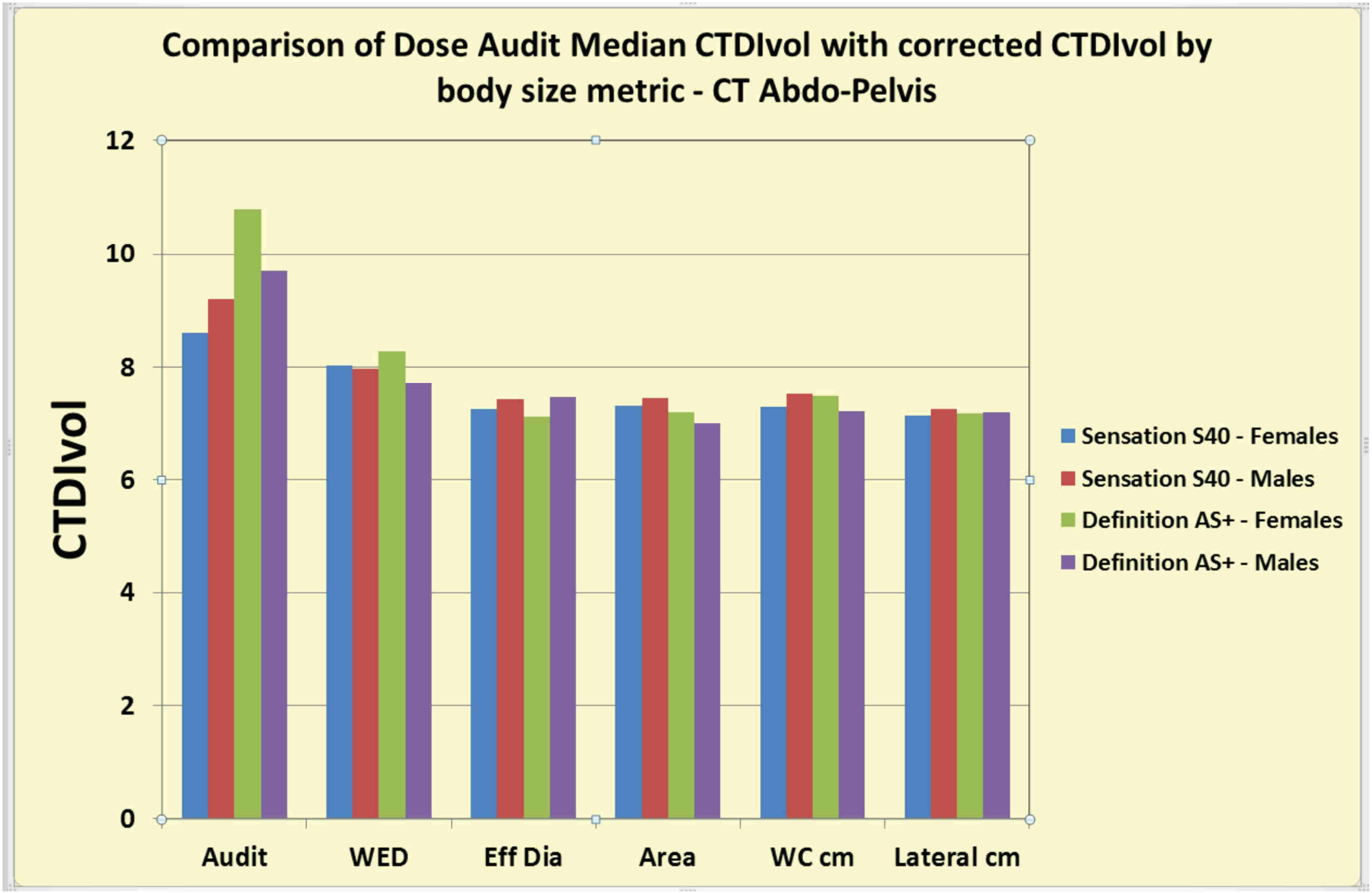
API script used to determine waist Effective Diameter boundaries for each phantoms size, males and females

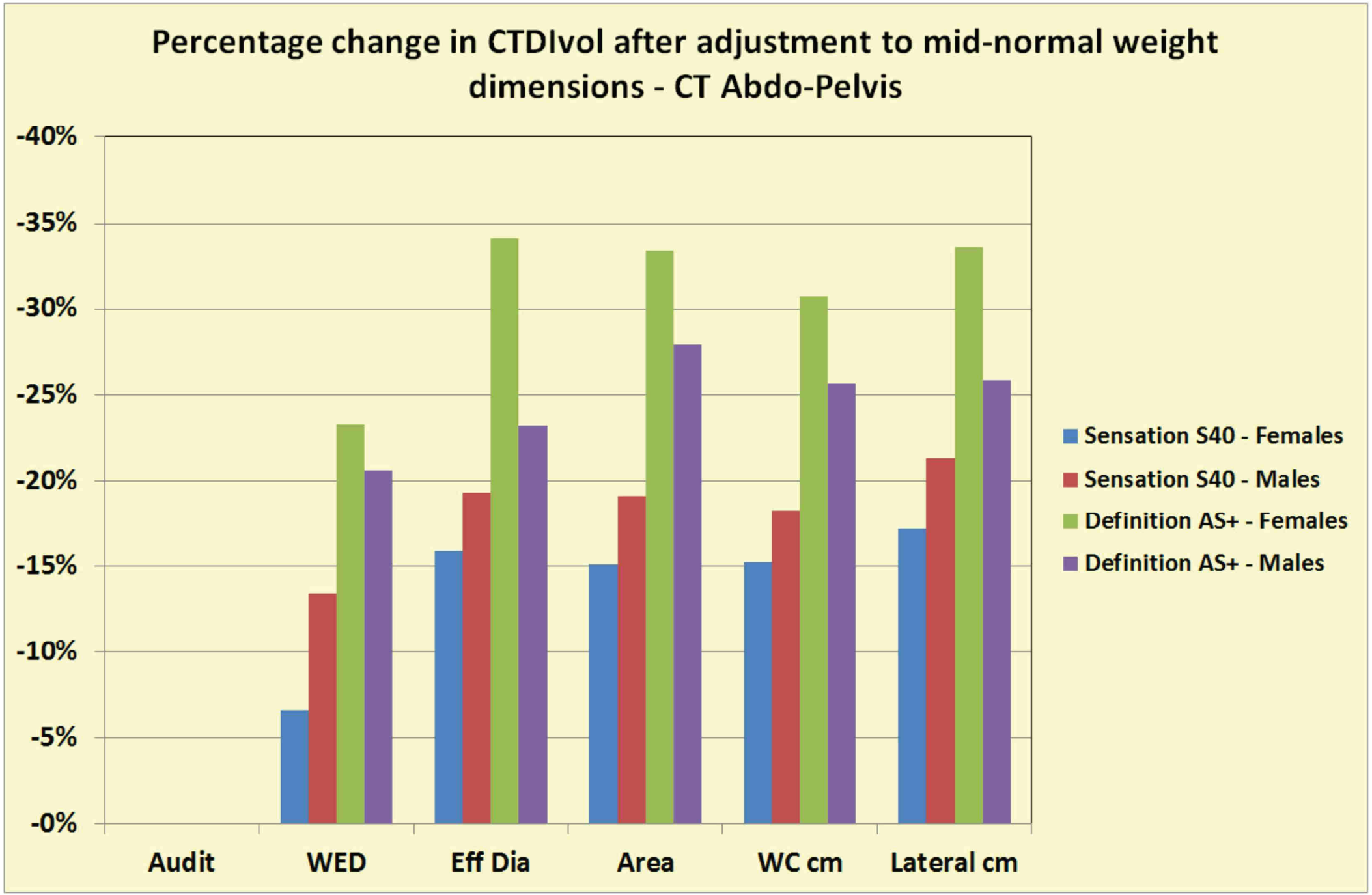

Study CTDIvol vs Image J extracted Effective Diameter
- Female patients - Abdo-Pelvis exams - Siemens Definition AS+
U-W
N-W
O-W
Ob-I
Ob-II
M-O
y = 0.5436e^0.0976x
R² = 0.9988
Study CTDIvol mGy
Effective Diameter cm
0
5
10
15
20
25
30
35
40
20
25
30
35
40
45
50
Base set
Lower median
Median set
Upper median
U-W Under weight
N-W Normal weight
O-W Over weight
Ob-I Obese level I
Ob-II Obese Level II
M-O Morbidly Obese

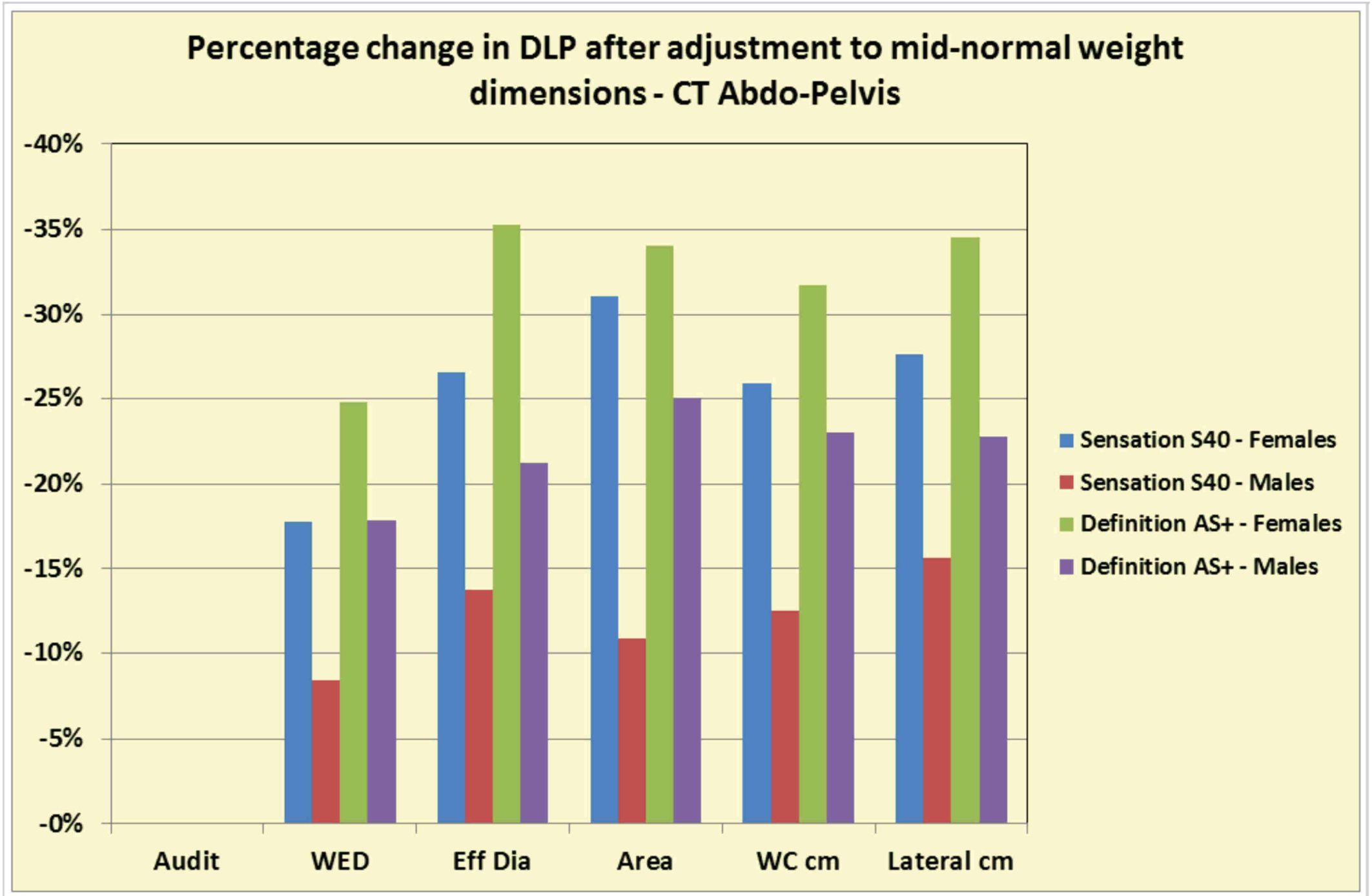

Waist CTDIvol vs Image J extracted Effective Diameter
- Female patients - Abdo-Pelvis exams - Siemens Definition AS+
U-W
N-W
O-W
Ob-I
Ob-II
M-O
y = 0.382e^0.1098x
R² = 0.9981
Waist CTDIvol mGy
Effective Diameter cm
0
5
10
15
20
25
30
35
40
20
25
30
35
40
45
50
Base set
Lower median
Median set
Upper median
U-W Under weight
N-W Normal weight
O-W Over weight
Ob-I Obese level I
Ob-II Obese Level II
M-O Morbidly Obese

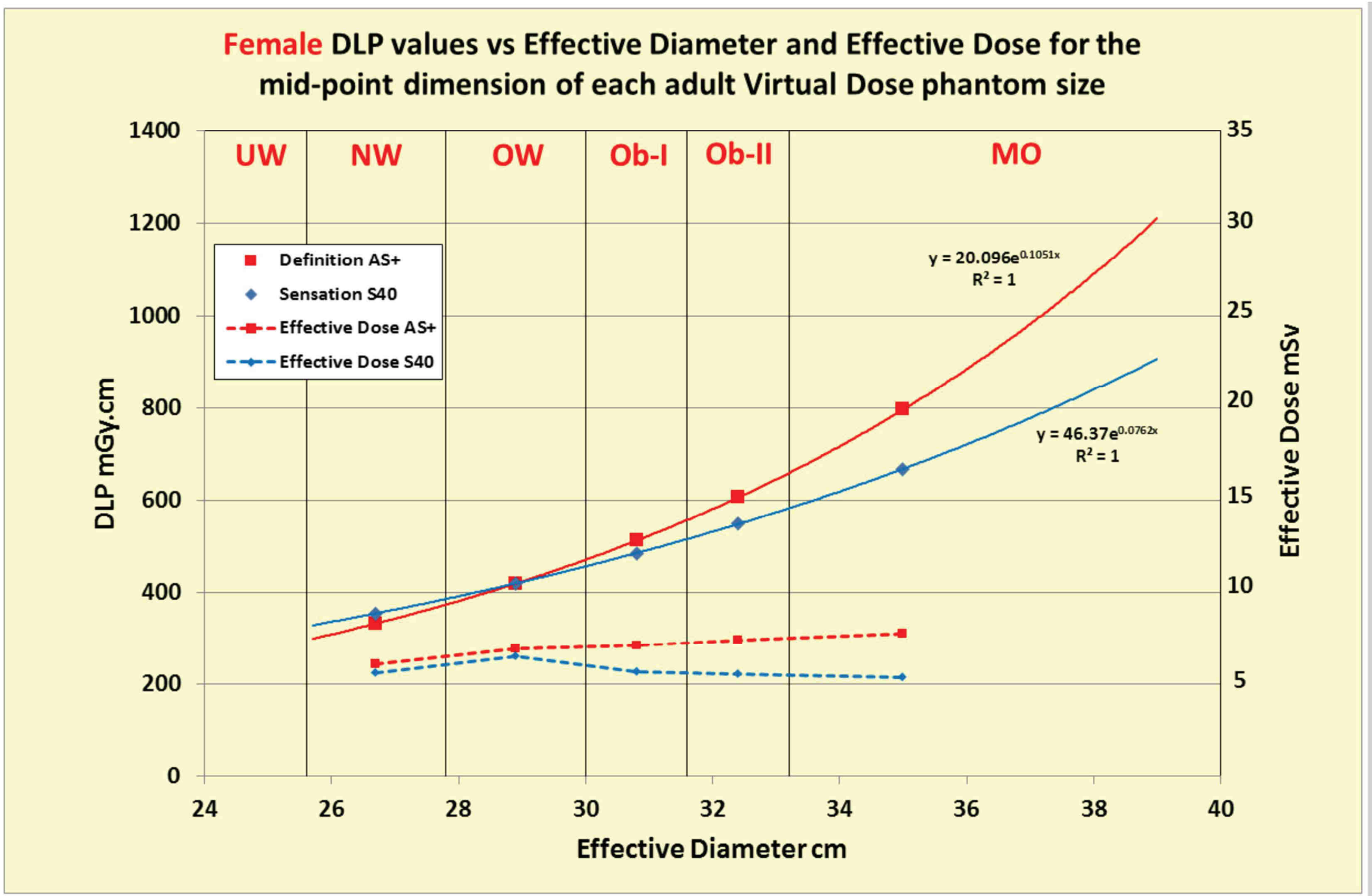
Representative selection of patient habitus from the Median sub-set

Median Dose corresponds to VirtualDose Obese Level I


Comparison of Dose Audit Median CTDIvol with corrected CTDIvol by body size metric - CT Abdo-Pelvis
CTDIvol
12
10
8
6
4
2
0
Audit
WED
Eff Dia
Area
WC cm
Lateral cm
Sensation S40 - Females
Sensation S40 - Males
Definition AS+ - Females
Definition AS+ - Males


Percentage change in CTDIvol after adjustment to mid-normal weight dimensions - CT Abdo-Pelvis
-40%
-35%
-30%
-25%
-20%
-15%
-10%
-5%
-0%
Audit
WED
Eff Dia
Area
WC cm
Lateral cm
Sensation S40 - Females
Sensation S40 - Males
Definition AS+ - Females
Definition AS+ - Males


Percentage change in DLP after adjustment to mid-normal weight dimensions - CT Abdo-Pelvis
-40%
-35%
-30%
-25%
-20%
-15%
-10%
-5%
-0%
Audit
WED
Eff Dia
Area
WC cm
Lateral cm
Sensation S40 - Females
Sensation S40 - Males
Definition AS+ - Females
Definition AS+ - Males


Female DLP values vs Effective Diameter and Effective Dose for the mid-point dimension of each adult Virtual Dose phantom size
UW
NW
OW
Ob-I
Ob-II
MO
Definition AS+
Sensation S40
Effective Dose AS+
Effective Dose S40
y = 20.096e^0.1051x
R² = 1
y = 46.37e^0.0762x
R² = 1
DLP mGy.cm
Effective Dose mSv
Effective Diameter cm
0
200
400
600
800
1000
1200
1400
5
10
15
20
25
30
35
24
26
28
30
32
34
36
38
40

Patient size analysis using axial CT referencing to VirtualDose:

Advantages:

Method to systematically analyse patient dimensions

Reproducible referencing to dosimetric phantom size ranges

CTDIvol and DLP curves covering a range of 'patient sizes'

CTDIvol – DLP – ED relationship can be used in optimisation decisions

Radiology time not required for patient weight collection

Confidence in data

Disadvantages:

Time consuming to manually download study images

Data storage (300+ images per patient)

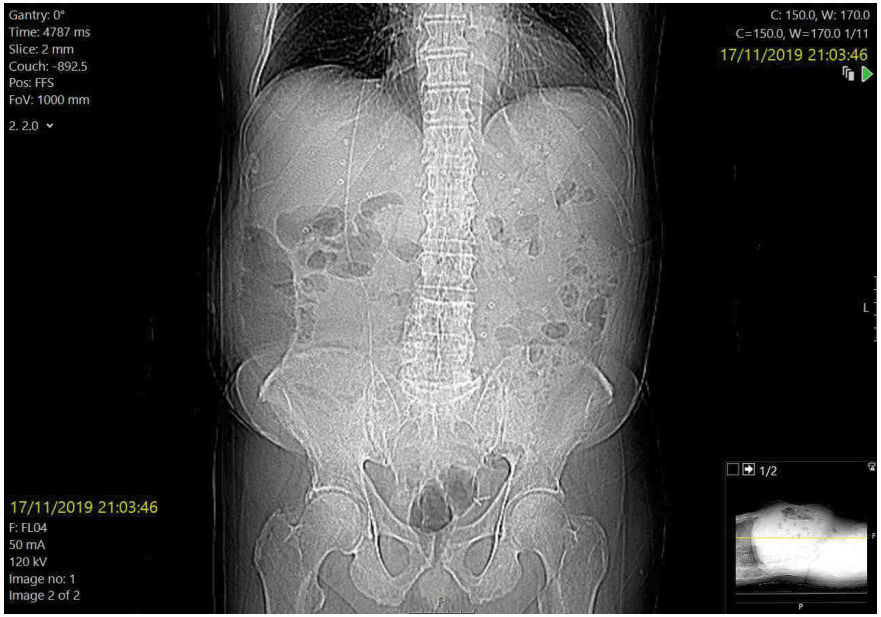
Image J analysis on one patient at a time (300+ images)

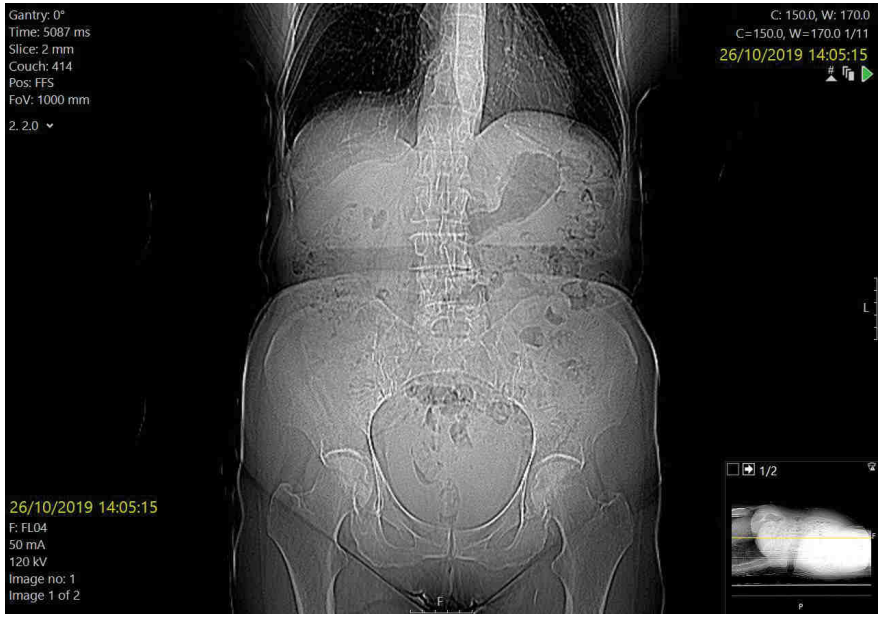
Manual identification of image at waist position for each data set for EffDia values

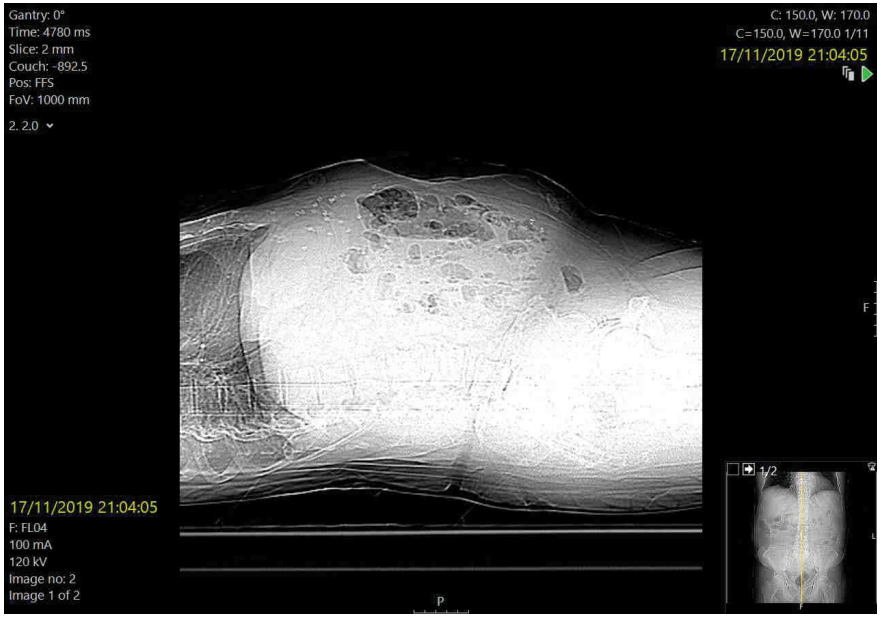
Some patients exceed recon field of view – identify and decide

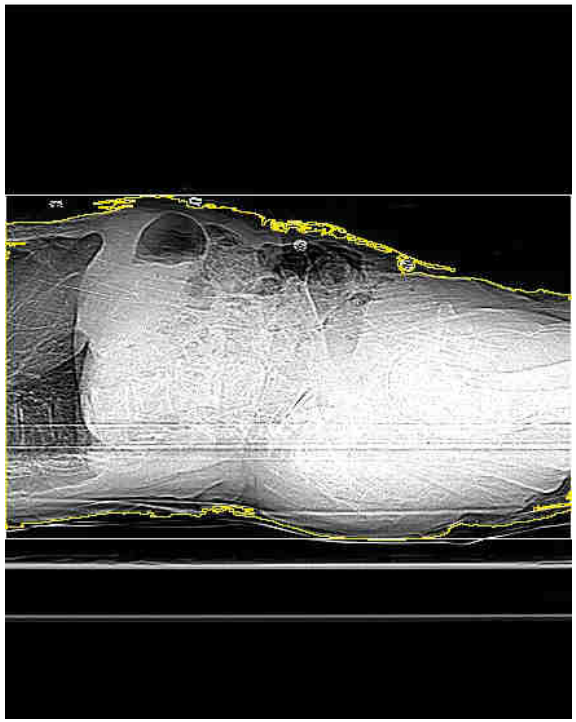
Time consuming

Can Topograms be used for patient size determination ?









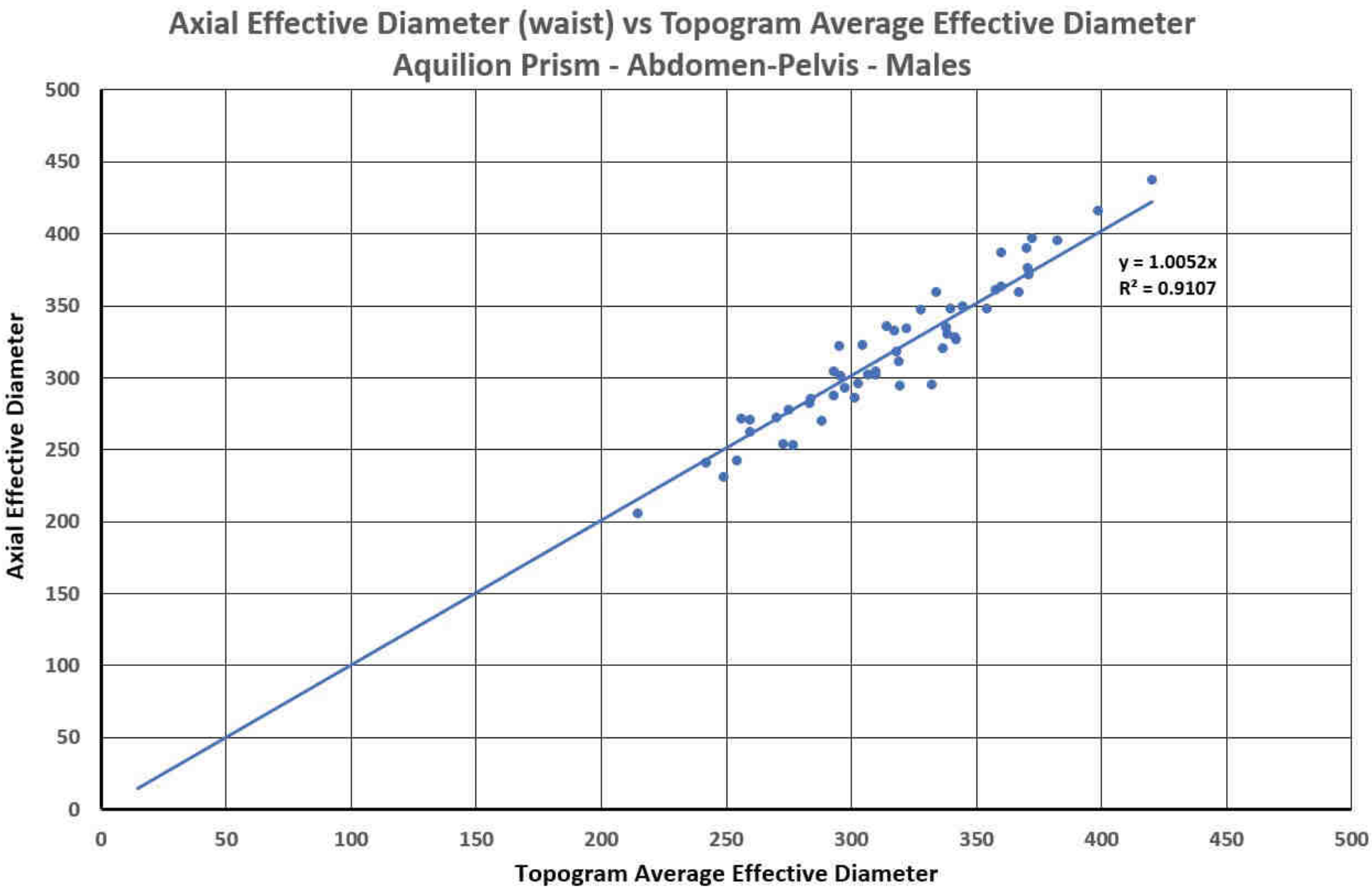
Topogram analysis:

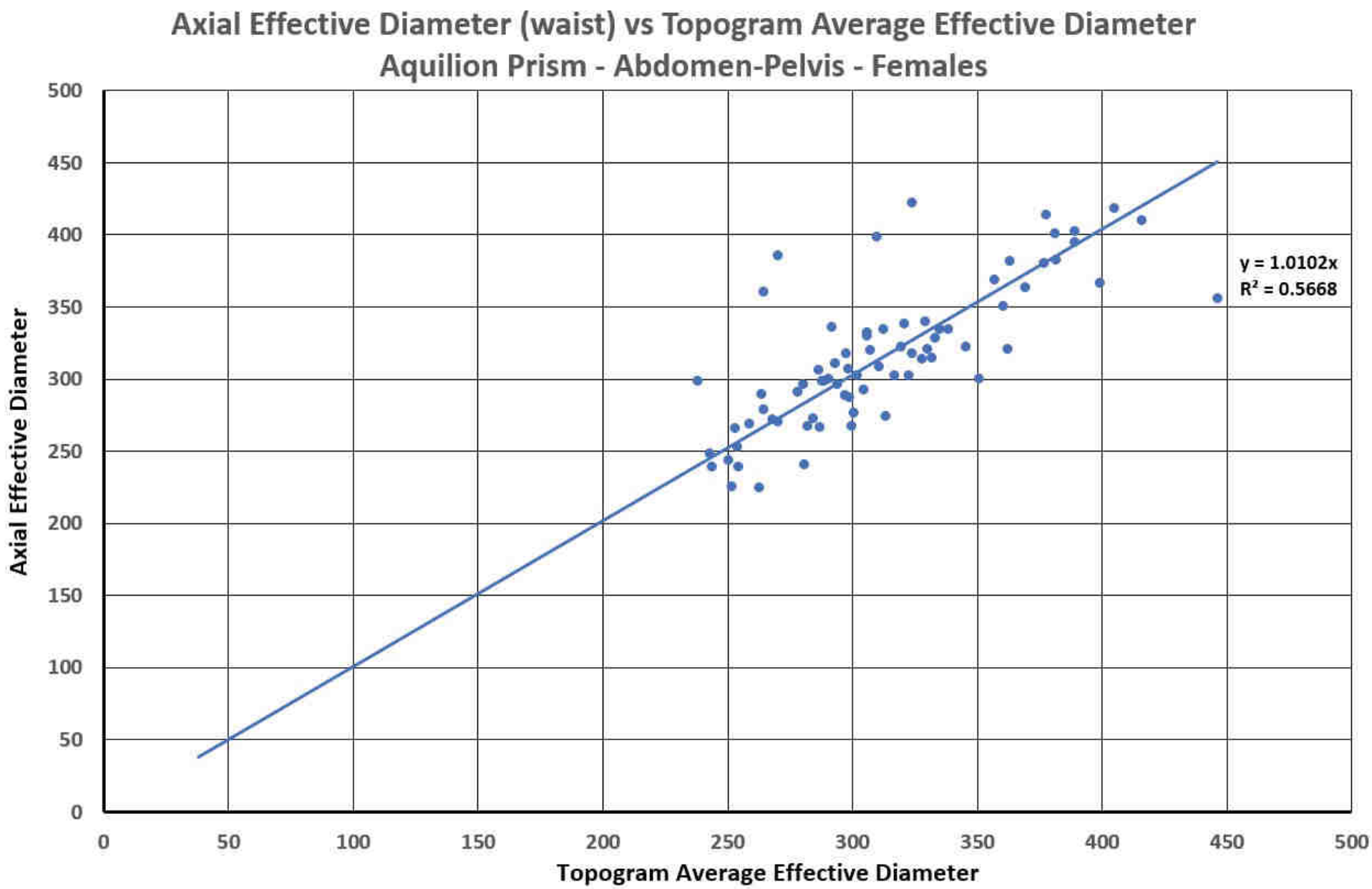
Download AP & Lat topograms (Aquillion One & Prism)

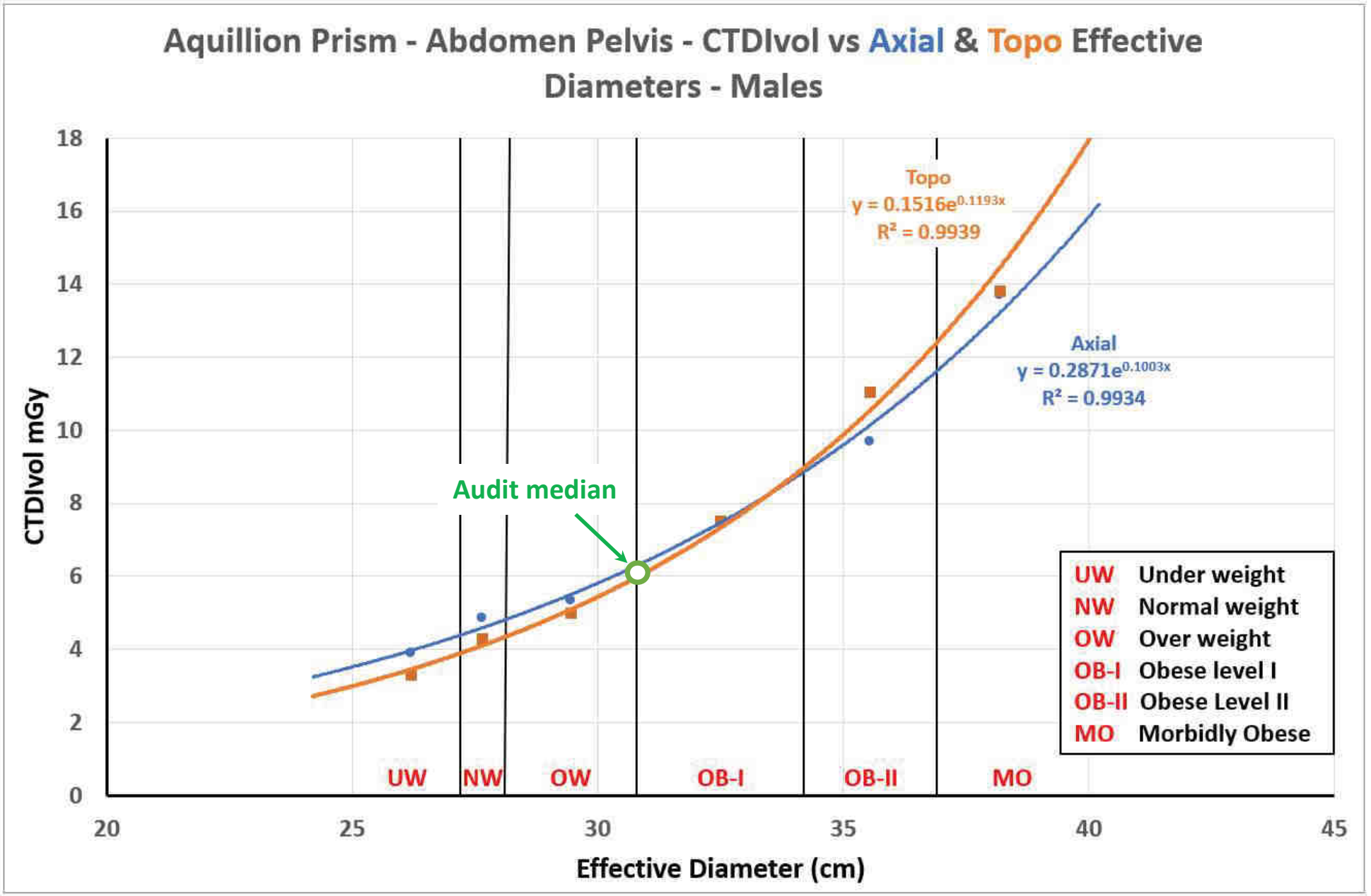
Apply modified Image J algorithm to outline and calculate patient ‘area’

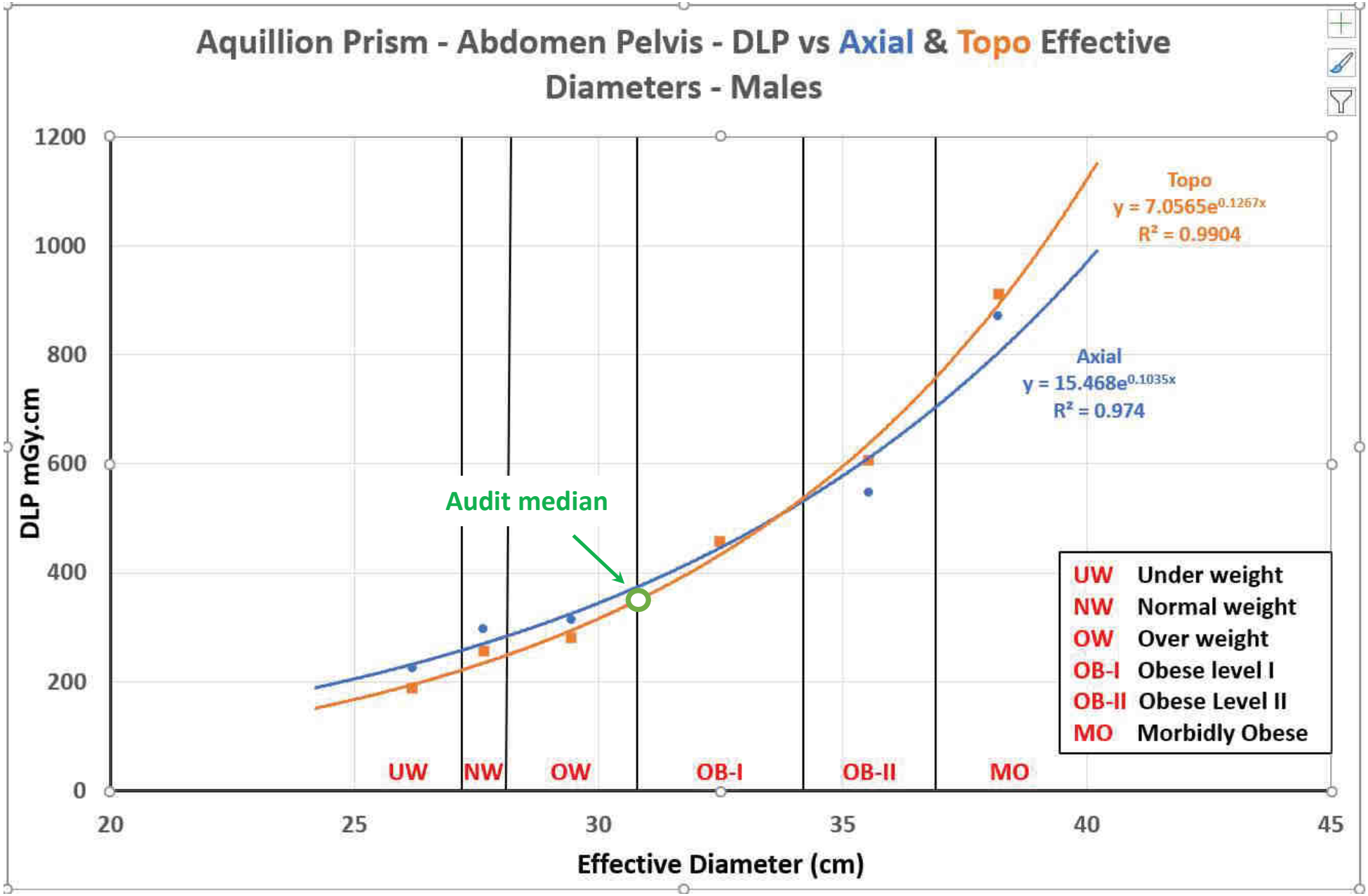
Calculate average AP and Lat dimensions (known Topo and patient ‘areas’)

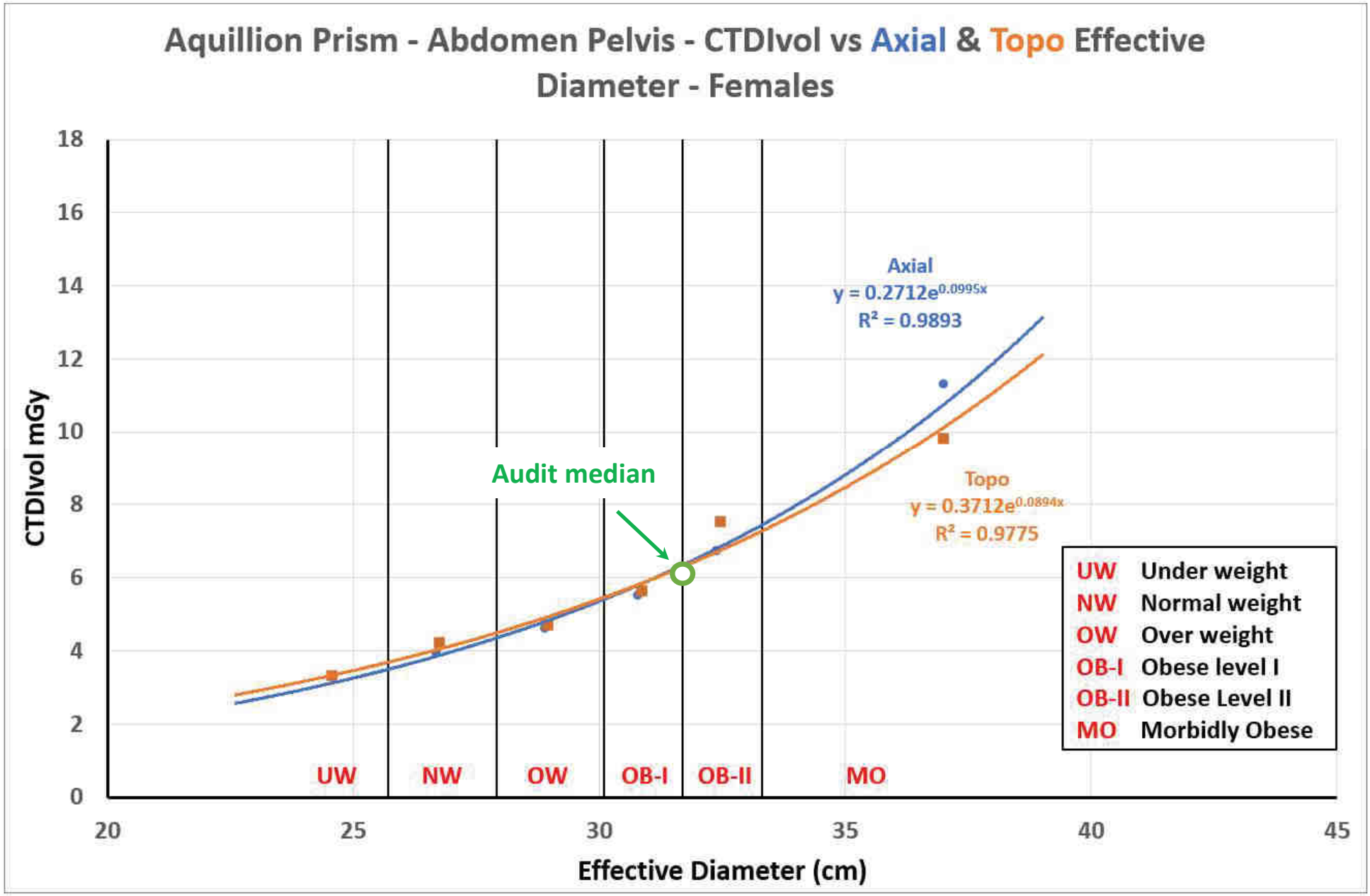
Determine ‘Average Effective Diameter’

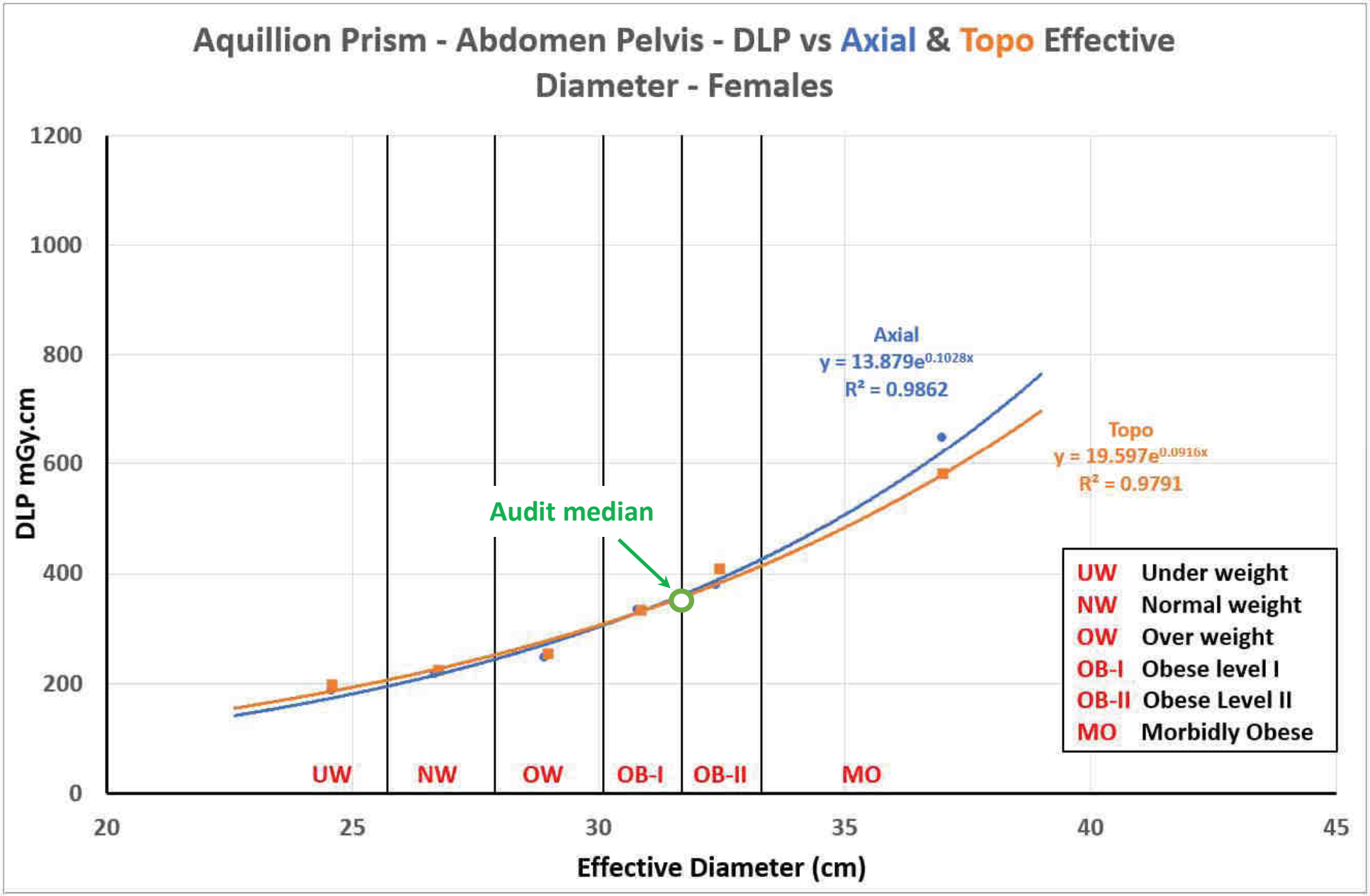

Axial Effective Diameter (waist) vs Topogram Average Effective Diameter
Aquilion Prism - Abdomen-Pelvis - Males
Axial Effective Diameter
Topogram Average Effective Diameter
y = 1.0052x
R² = 0.9107
0
50
100
150
200
250
300
350
400
450
500


Axial Effective Diameter (waist) vs Topogram Average Effective Diameter
Aquilion Prism - Abdomen-Pelvis - Females
Axial Effective Diameter
Topogram Average Effective Diameter
y = 1.0102x
R² = 0.5668
0
50
100
150
200
250
300
350
400
450
500


Aquillion Prism - Abdomen Pelvis - CTDIvol vs Axial & Topo Effective Diameters - Males
CTDIvol mGy
Effective Diameter (cm)
Topo
y = 0.1516e^0.1193x
R² = 0.9939
Axial
y = 0.2871e^0.1003x
R² = 0.9934
Audit median
UW Under weight
NW Normal weight
OW Over weight
OB-I Obese level I
OB-II Obese Level II
MO Morbidly Obese
UW
NW
OW
OB-I
OB-II
MO


Aquillion Prism - Abdomen Pelvis - DLP vs Axial & Topo Effective Diameters - Males
DLP mGy.cm
Effective Diameter (cm)
1200
1000
800
600
400
200
0
20
25
30
35
40
45
Topo
y = 7.0565e0.1267x
R² = 0.9904
Axial
y = 15.468e0.1035x
R² = 0.974
Audit median
UW
NW
OW
OB-I
OB-II
MO
UW Under weight
NW Normal weight
OW Over weight
OB-I Obese level I
OB-II Obese Level II
MO Morbidly Obese


Aquillion Prism - Abdomen Pelvis - CTDIvol vs Axial & Topo Effective Diameter - Females
CTDIvol mGy
Effective Diameter (cm)
0
2
4
6
8
10
12
14
16
18
20
25
30
35
40
45
UW
NW
OW
OB-I
OB-II
MO
Axial
y = 0.2712e0.0995x
R² = 0.9893
Topo
y = 0.3712e0.0894x
R² = 0.9775
Audit median
UW Under weight
NW Normal weight
OW Over weight
OB-I Obese level I
OB-II Obese Level II
MO Morbidly Obese


Aquillion Prism - Abdomen Pelvis - DLP vs Axial & Topo Effective Diameter - Females
DLP mGy.cm
1200
1000
800
600
400
200
0
20
25
30
35
40
45
Effective Diameter (cm)
Axial
y = 13.879e0.1028x
R² = 0.9862
Topo
y = 19.597e0.0916x
R² = 0.9791
Audit median
UW
NW
OW
OB-I
OB-II
MO
UW Under weight
NW Normal weight
OW Over weight
OB-I Obese level I
OB-II Obese Level II
MO Morbidly Obese

Abdomen-Pelvis – Aquilion Prism

Audit Medians

	CTDIvol	DLP
Whole sample	6.1	350
Females	5.6	335
Males	7.1	398

Adjusted to Normal Weight

	Eff Dia	CTDIvol	DLP	% Change CTDIvol	% Change DLP
Females - Axial	26.7	3.9	216	30	36
Females - Topo	26.8	4.1	228	27	32
Males - Axial	27.7	4.6	271	35	32
Males - Topo	27.7	4.1	235	42	41

Patient size analysis using CT Topograms

Advantages:

Automated Topo image send from each CT

Topo Images sent along with RDSRs – build data resource for analysis

Manageable data sets for storage and analysis

Topo fov captures all patient outlines

Good correlation Axial EffDia with Topo Average EffDia

Rapid processing by Image J

Offers 'good enough' alternative to CT Axials

Disadvantages:

Image J algorithm imperfect does not work on all patient images

Topo lengths vary, exceed scan lengths - sometimes significantly (affects EffDia)

Female body shape variability requires larger numbers of patients per study

Larger patients - picks up table edge (female shape more variable, especially larger patients)

Audit methodology enabling weight / patient size assessment in CT

Collection of dose audit data from CTs	DMS / OpenREM
Automated send of Topograms to audit folder	Dedicated IP
Data extraction from Topo DICOM headers	Image J
Automated assessment of average Effective Diameter from Topograms	Image J
Merging of Dose audit data with Patient Size analysis	Requires automation
Patient size based dose audit & review	

Summary:

Correlating patient image EffDia with VirtualDose phantoms provides a method of patient size assessment

Dose audit values can be adjusted to account for local patient size norms

Proof of concept using Topograms

Algorithm requires refinement

Dose values across patient size range = confidence in interpretation

Other methods could be used (AI ?)

Dose metric vs patient size curve more useful than a single value?

For further information:

mike.holubinka@porthosp.nhs.uk