Processing SPECT VQ Studies

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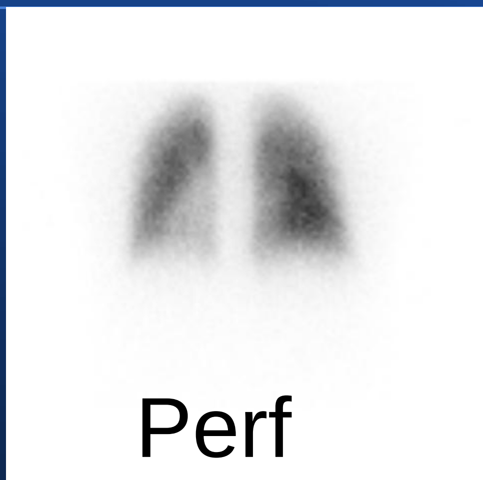
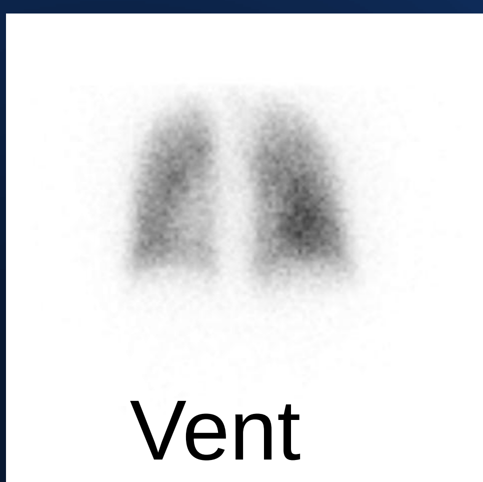
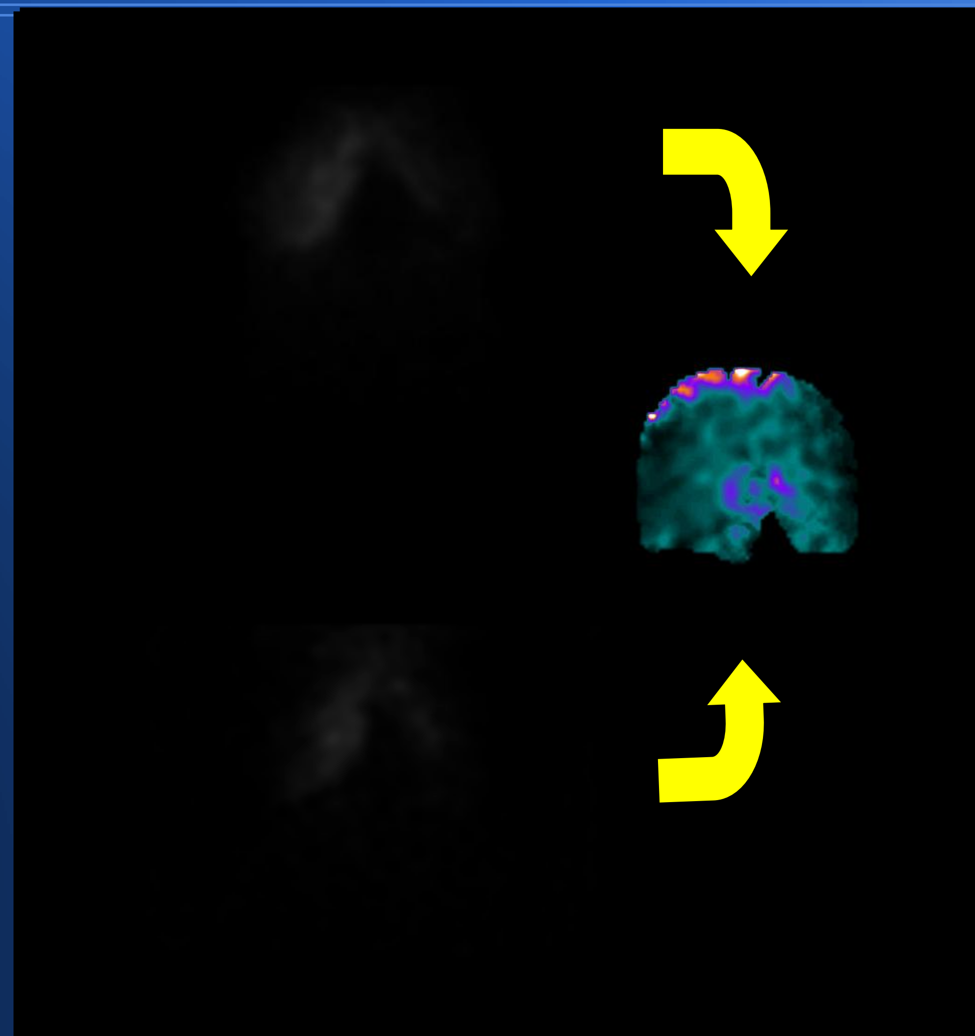
How do we get from this …

…to this ?







Topics

- QC Checks
- Processing
- Display

Raw Data Verification

- Majority of problems spotted using cine of raw data
- Normal:

Perfusion

Ventilation

Raw Data Verification

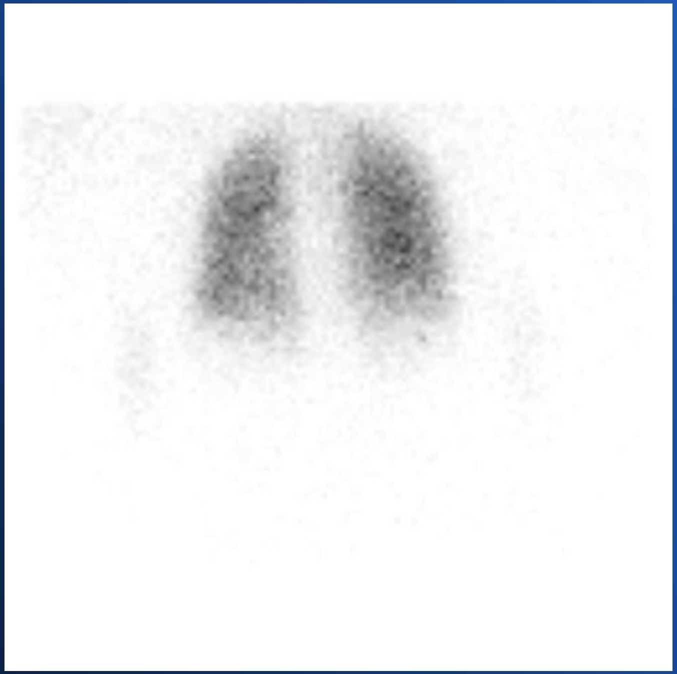
- Check for following artefacts:

- Patient artefacts
  - Attenuation objects (rare)
  - Motion (rare)

Raw Data Verification

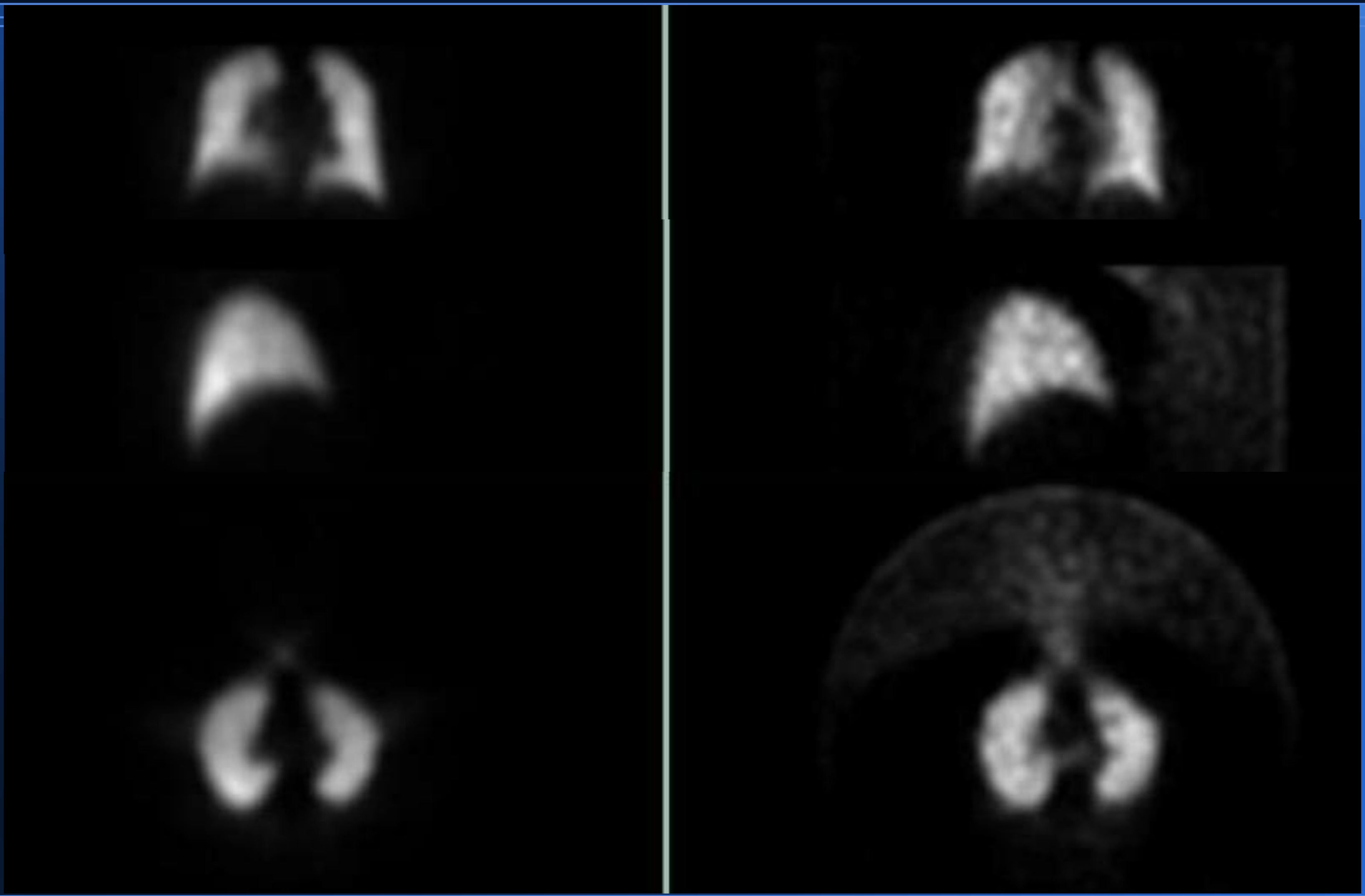
- Operator Artefacts
  - Tissued injection
  - Mask leakage

Ventilation Delivery Problems (leakage)

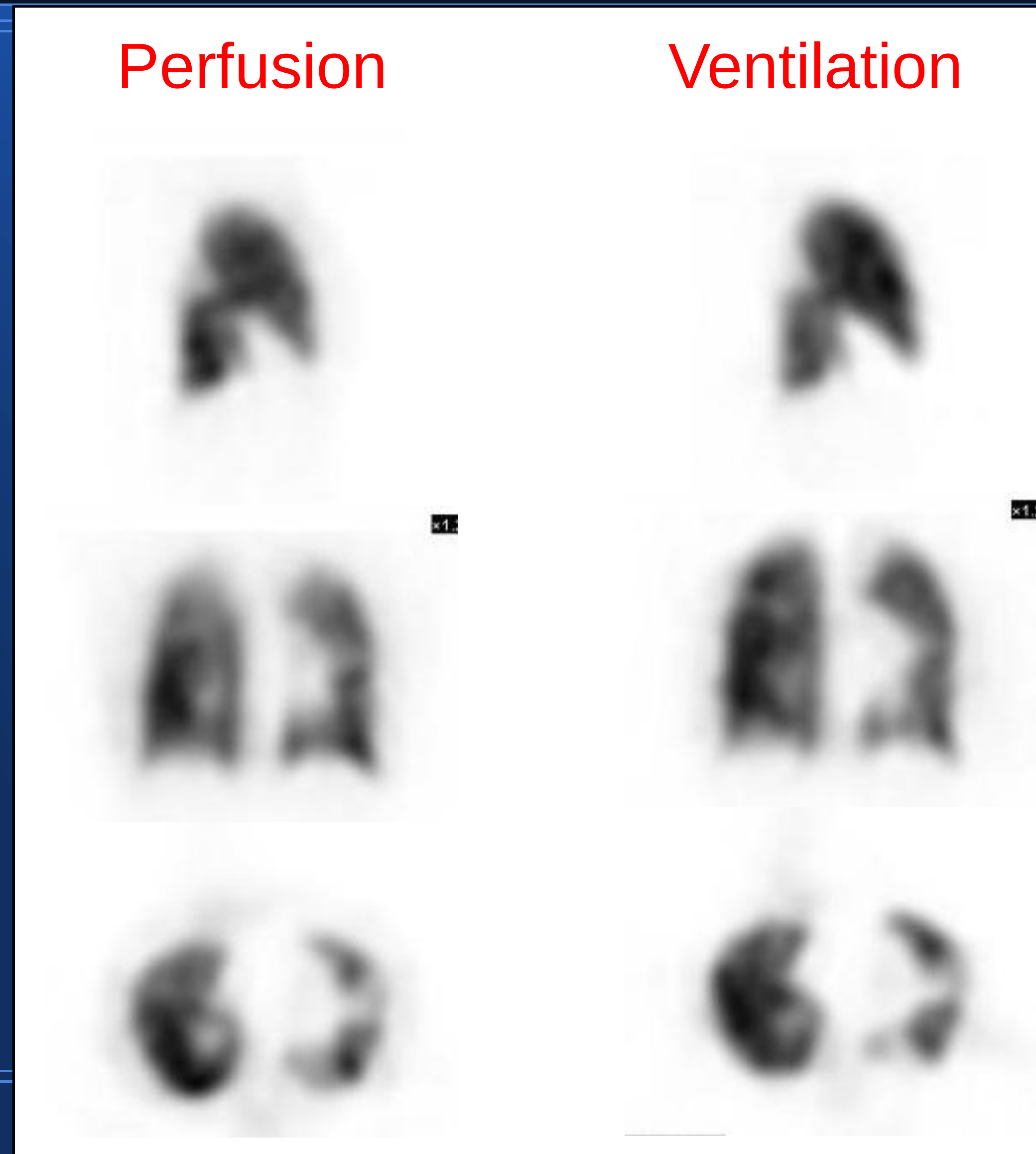
Small	Moderate	Excessive
		
• Leaks in a few frames	Constant leaks but in small amounts Lungs remain full of gas	Highly variable leakage. Very few counts within lungs in many frames.

Excessive leakage

Perfusion | Ventilation



Small Leakage (most common)



Raw Data Verification

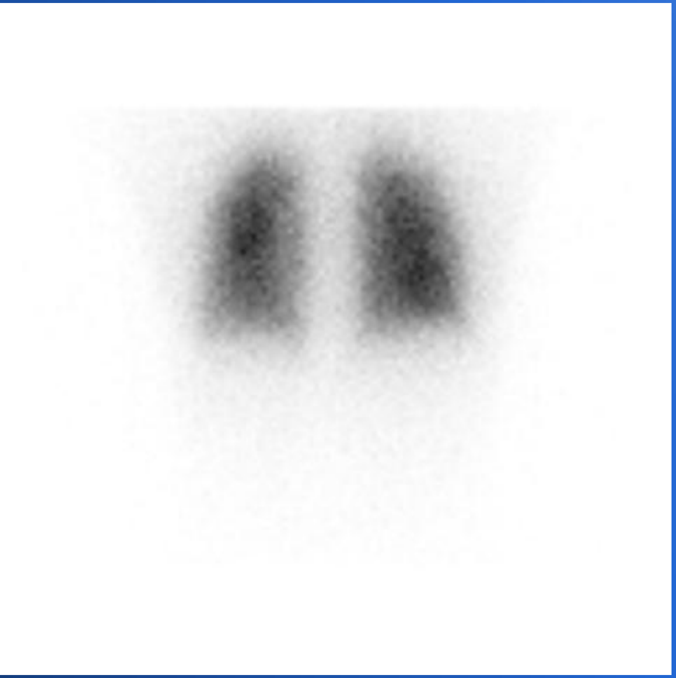
- Radiopharmaceutical Artefacts
  – MAA clumping
- Equipment Artefacts
  - Excessive down scatter (>25%)
  - Reduces contrast
  - Makes lesions less easier to detect

Excessive Downscatter

Low DS

< 25%

High DS

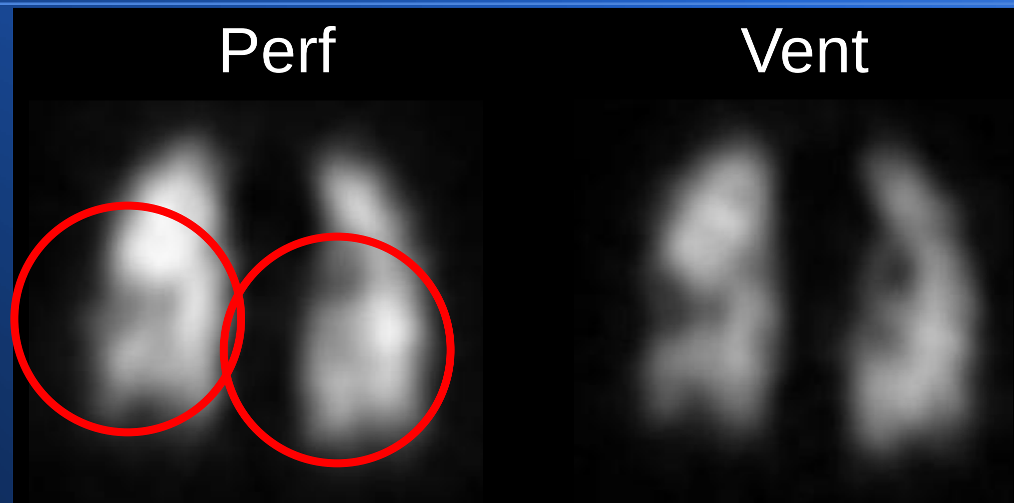


> 25%

Excessive Downscatter Example (41%)

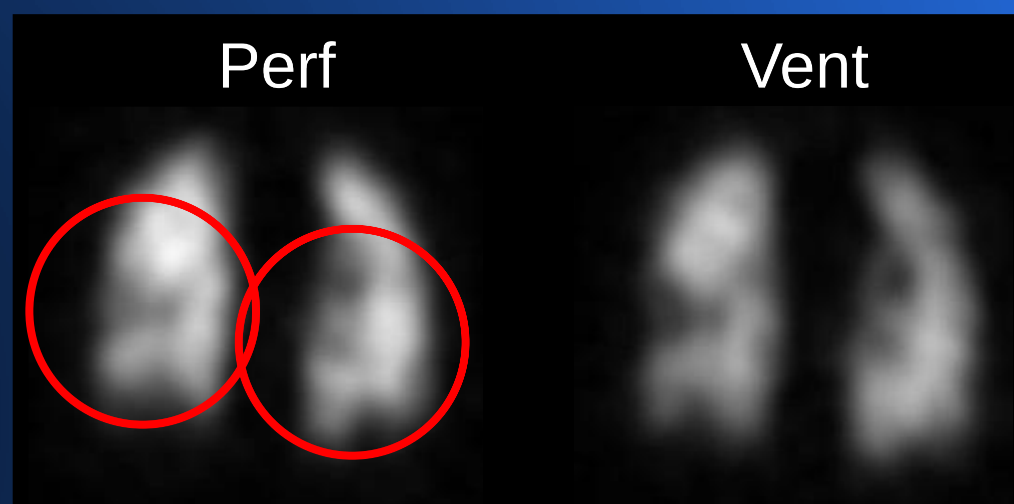
Dual

(with downscatter)



Sequential

(No downscatter)



Processing

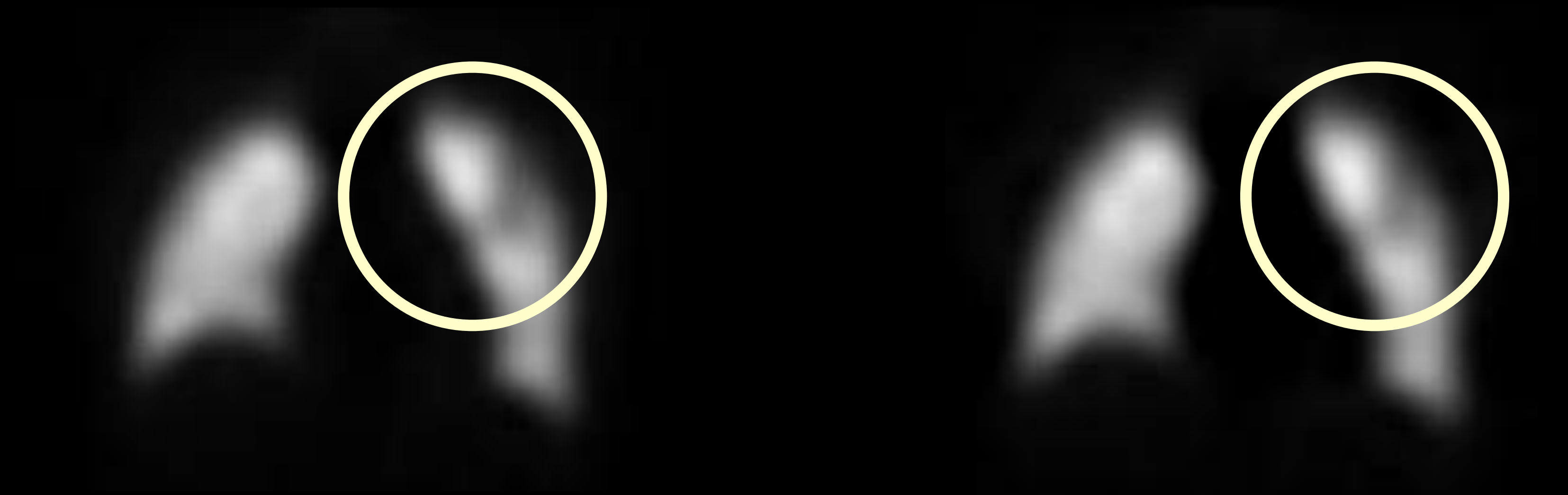
- Reconstruction Method
  - Filtered Back Projection (FBP) or
    Iterative Reconstruction (OSEM, MLEM) ?

- We use OSEM because:
  - has better contrast
  - deals better with Krypton leakage
  - has no ‘streak’ artefact

OSEM vs FBP - contrast

Perfusion OSEM

Perfusion FBP

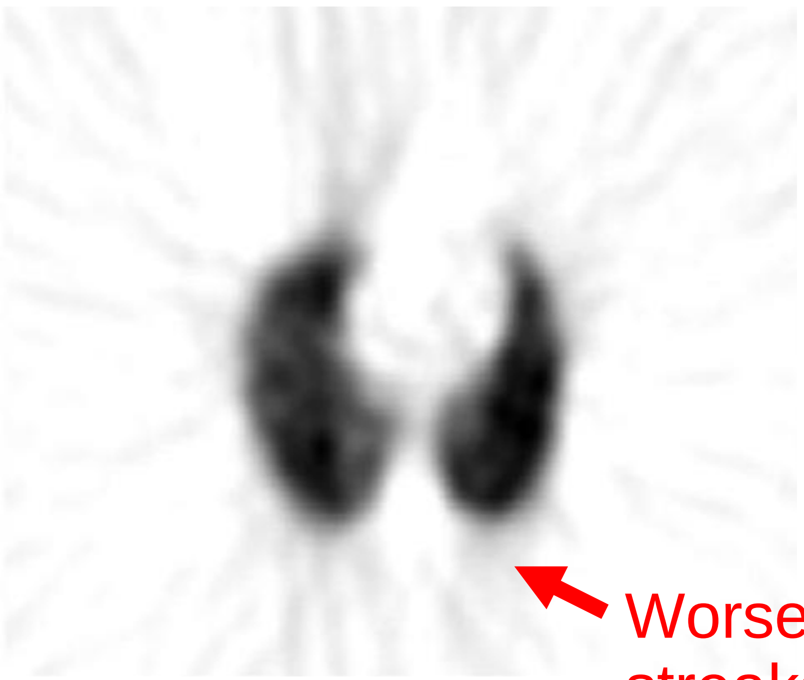


worse contrast (slightly!)

OSEM vs FBP – streaks with gas escape

Ventilation OSEM

Ventilation FBP



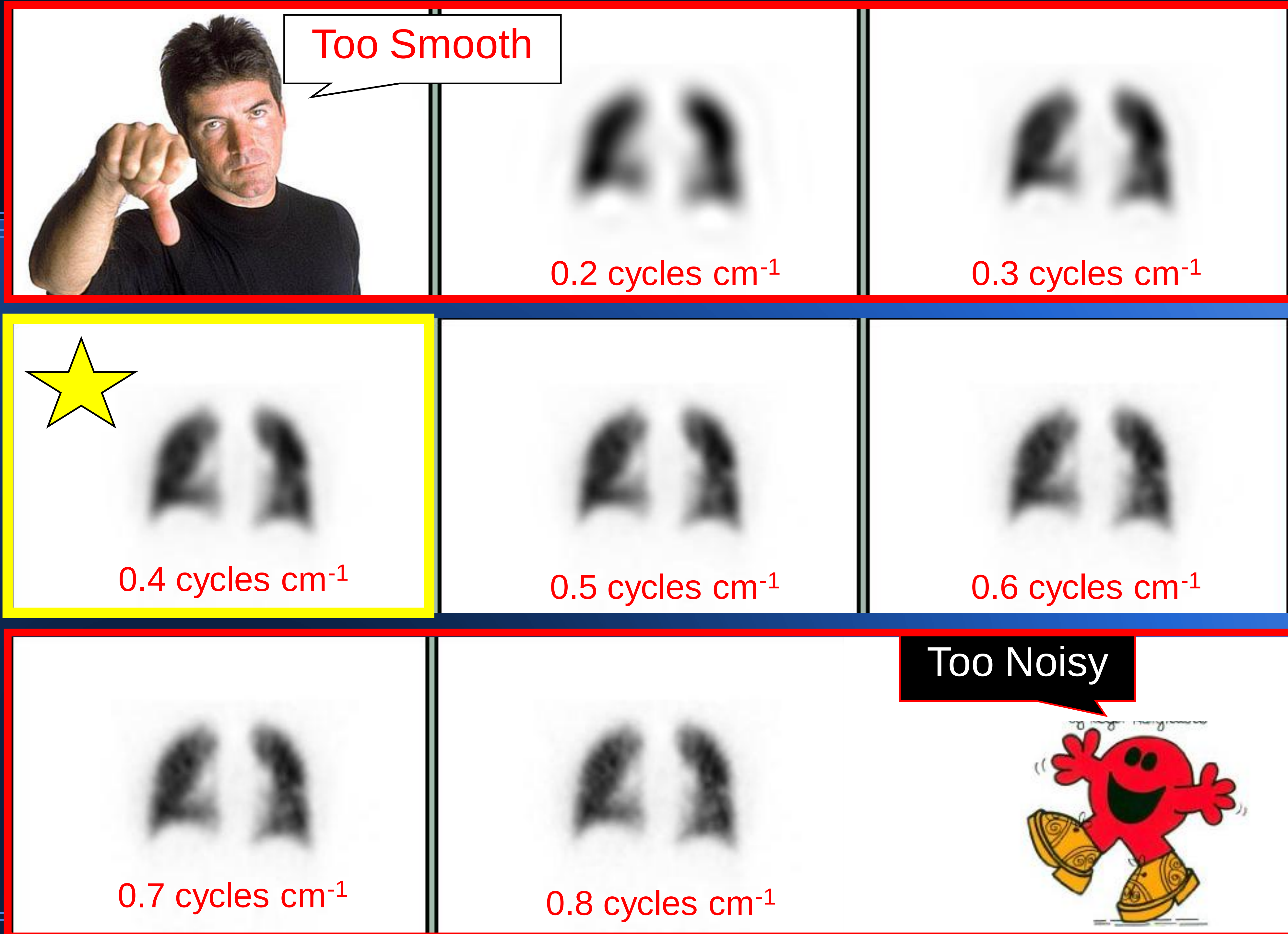
Worse streaks

Our settings

- GE Xeleris: OSEM (SMV):
  - 4 subsets, 10 iterations
- Philips Odyssey:
  - OSEM 4 iterations (subsets value unavailable)
- Same as MPI

Processing

- 3D Postfilter
- Contentious issue !
- ‘Butterworth’ filter commonly used
- Balance: Smooth vs Noisy images
- ‘Cutoff’ parameter is used
- Setting depends on operator


Too Smooth
0.2 cycles cm-1
0.3 cycles cm-1
0.4 cycles cm-1
0.5 cycles cm-1
0.6 cycles cm-1
0.7 cycles cm-1
0.8 cycles cm-1
Too Noisy

Processing

- We use:
  - Butterworth 3D Filter

    - Philips Odyssey LX: Order 6, 0.40 cycles per 2 pixels
    - GE Xeleris: Power Factor 18, 0.40 cycles per cm

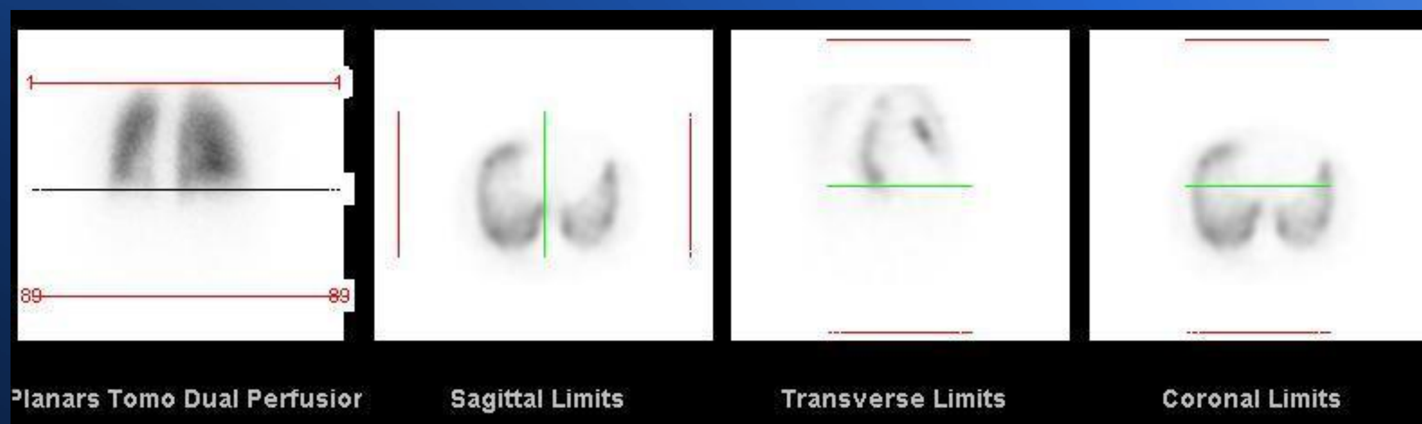
Consistent Processing

- Process ventilation and perfusion exactly the same
- Keeps lungs in the same position
- Allows side-by-side slice comparison of Perf vs Vent
- Also allows quotient images to be produced

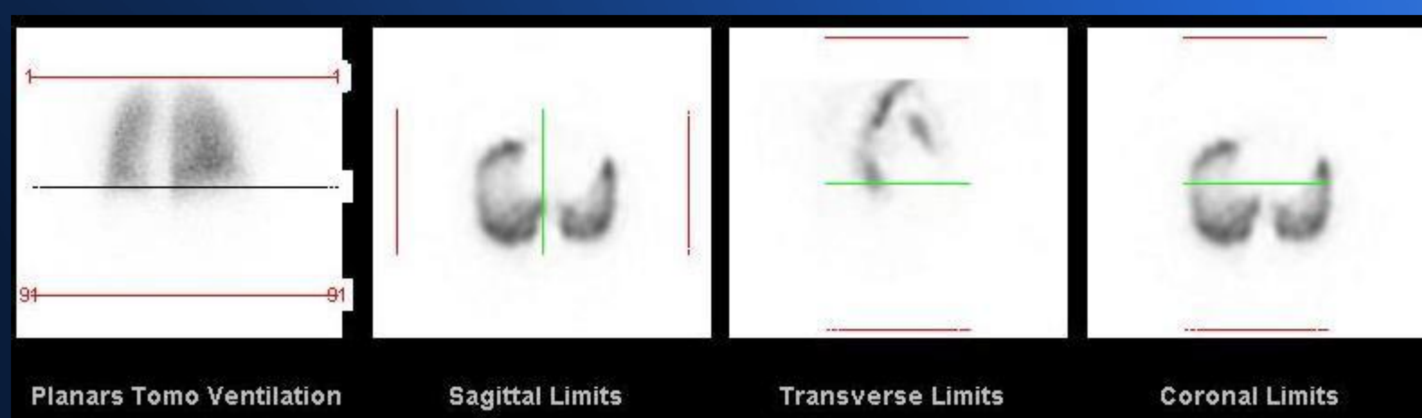
Consistent Processing

- Keep reconstruction slices at the same level

Perfusion



Ventilation

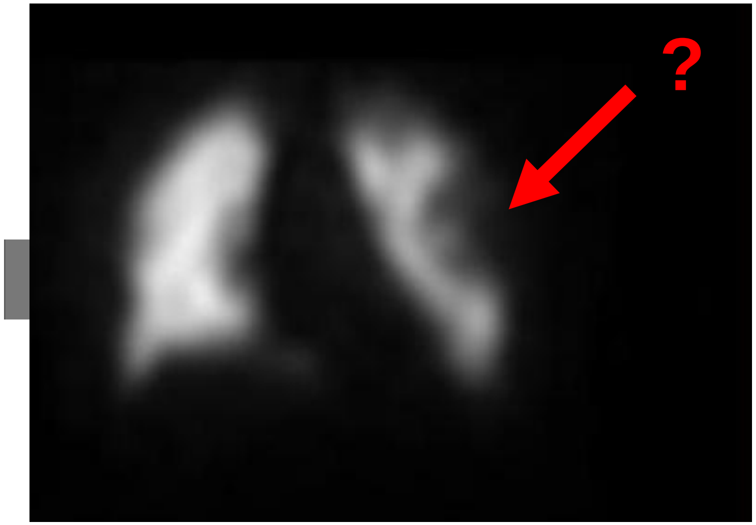


Reorientation

- SPECT VQ requires no reorientation
- Some systems automatically reorientate
  - Slices become out of sync
  - Reset to reorientation settings to default
  - Or record settings for perfusion so that same values can be used for ventilation

VQ Quotient

- Reporting SPECT VQ can be tricky!
- Optical illusions concerning greyscale



- http://www.wpclipart.com/signs_symbol/optical_illusions/gradient_optical_illusion.png.html

VQ Quotient

- Could our brains be misinterpreting perfusion defects?
- With 380 slices per study, could we miss a problem?
- Quotient images to provide a guide (EANM)
- Method described by Palmer (Lund) applies to Tc99m DTPA aerosol.
- Corrections for :
  - Underlying Tc99m DTPA activity in MAA data
  - DTPA 'Hot spots' (common artefact with aerosol)
  - Physics decay (acquired at different times)
  - Differences in acquisition frame time

VQ Quotient – LUND Procedure

Notes on the Lund ventilation-perfusion SPECT procedure and processing.
(These notes derive from earlier documentation 2005)

1. Ventilate in supine position using a monitor above chest, to approx 30 MBq inhaled.

2. SPECT: 128 frames in 64×64 matrix (6.8 mm/pixel) @ 10 sec/frame.

3. Without moving patient, inject approx 120 MBq MAA.

4. SPECT: 128 frames in 64×64 matrix (6.8 mm/pixel) @ 5 sec/frame.

5. Select projection files (subscript "p").
   V_p^* = ventilation (The "*" indicates that hot-spots may be present)
   Pv_p = perfusion (The "v" indicates that ventilation background is present)

6. Check consistency (same patient, ventilation performed first, etc).

7. Calculate and correct V_p^* for clearance. See separate document.

8. Reconstruct V_p^* to V_s^* and Pv_p to Pv_s (subscript "s" indicates transverse slices).

9. Assure that slice counts in the reconstructed range is equal to the projection counts in the same axial range, i.e. normalise V_s^* to V_p^* and Pv_s to Pv_p in the current slice range. (This step is probably not appropriate with current reconstruction algorithms 2010, because they maintain a proper normalization between projection data and reconstructed date. The implementation we used initially did not.)

10. Remove hotspots in ventilation: V_s denotes V_s^* with hotspots removed (see note).
    Note: extreme ventilation hotspots may be seen as background in the perfusion raw data. We do not remove these by hotspot removal in Pv_s, and since the vent hotspots are removed before background is subtracted (p13), they will remain as elevated spots in P_s. This will somewhat prevent the V/P ratio to be high (signalling embolism) in a hotspot.

11. Save transversals, frontals sagittals using V_s (i.e. excluding hotspots) to disk.

12. Save transversals, frontals sagittals using Pv_s (i.e. including vent background) to disk.

13. Filter V_s using kernelQ (see note on filters below); denote it by V_s^F.

14. Subtract the ventilation background from perfusion and denote the result by P_s
    $P_s = Pv_s - k \times V_s^F$,where k takes into account both the delay between vent and perf, and the difference in acquisition duration.
    With Tc-gas, the half-time can be taken as 6.01 h, but since we sometimes use DTPA, the half-time is estimated from the first and last pairs of projections. Doing this, we sometimes encountered a situation where P_s became negative in some part of the image. Therefore, we apply a condition: $k = \mathrm{MIN}(k, Pv_s / V_s^F)$, where data for this calculation of k only uses the volume where Pv_s > 10% of $\mathrm{MAX}(Pv_s)$.

15. Save transversals, frontals sagittals using P_s (i.e. excluding vent background) to disk.

16. Filter P_s using kernelQ (see note on filters below); denote it by P_s^F. Now both V_s^F and P_s^F are filtered by identical filters, ready for division.

17. Find a robust high count level, called T90, for V_s^F and P_s^F. Use the following principle:
    a) Get the number of voxels that have a count of at least 10% of the maximum count.
    b) Get the count level at which the number of voxels is 90% of those found in a).
    This level is the 90:th volumetric percentile. This level is more reliable than the maximum voxel count, because it stays below peaks that constitute less than 10% of the lung volume. (It is still dependent on the maximum, through a). It might be possible to further diminish this dependence, but probably not worth-while).

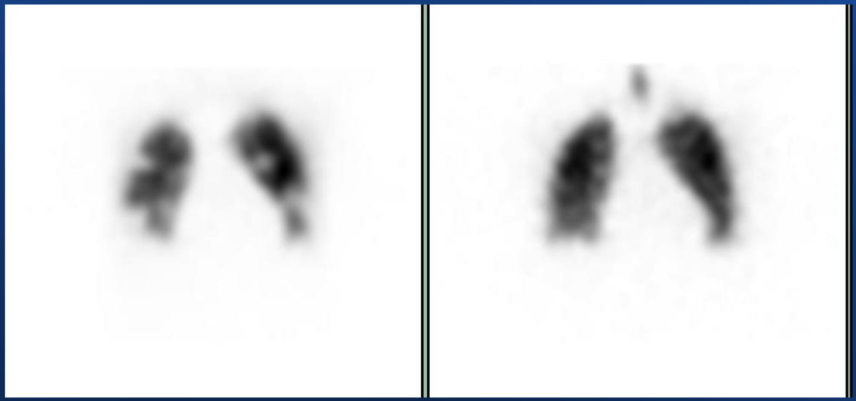
18. Create a binary mask for the lung using both vent and perf (=0 outside lung; = 1 inside lung). This mask will be applied both to the quotient image and to the 3D MIP image.
    $mask_V$ = voxels with at least 10% of the maximum count of V_s^F.
    $mask_P$ = voxels with at least 10% of the maximum count of P_s^F.
    $mask_L$ = $mask_V$ OR $mask_V$ (this is the overall Lung mask).

19. Apply $mask_L$ to V_s^F.
    For P_s^F, simply set it equal to 10% of the maximum count of P_s^F outside $mask_P$.
    This will prevent division by zero when calculating the quotient.
    When used below, the symbols V_s^F and P_s^F are the so modified data.

20. Find the "normalisation region". This is a part of the lung volume which by some criterion can be assumed to be normal. As a criterion we use the condition

VQ Quotient with Kr81m

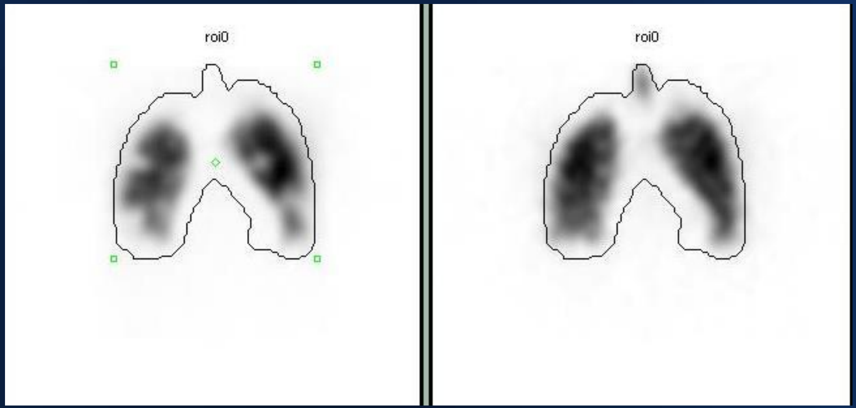
1. Select Tc99m & Kr81m coronal slices



2. Sum Kr81m slices

3. Draw ROI

4. Copy ROI to Tc99m & Kr81m slices



5. Obtain max counts

e.g. MAA = 834
Kr81m = 194

Normalisation Factor (N)

N = 834 / 194 = 4

6. Zero Mask Kr slices

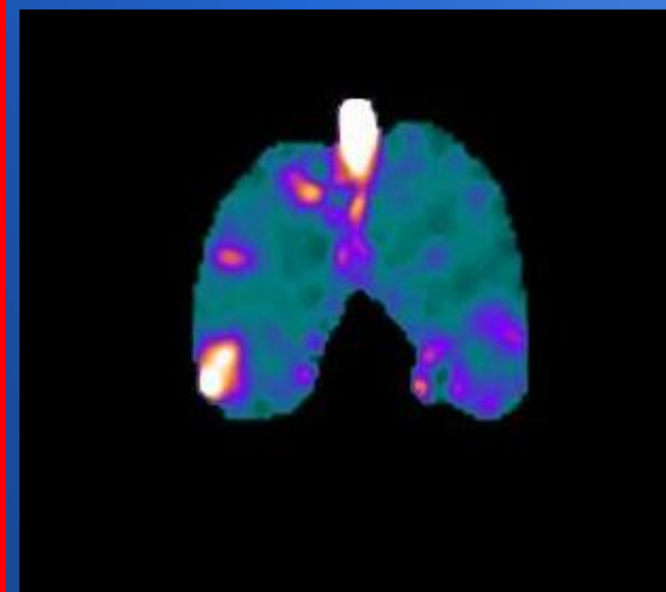
All counts outside ROI = 0

VQ Quotient with Kr81m
(continued)

6. Multiply ‘masked’ Kr81m image by 50 x N

7. Divide Perfusion slices by ‘masked’ rescaled Kr81m slices.

8. Apply cool colour scale
Rescale to max count of 50



- Areas of poor perfusion have ‘high‘ quotient counts (yellow-white)
- Areas of poor ventilation have ‘low' quotient counts (black)
- Balanced areas appear mid scale (blue-black)
- Hot trachea shows up hot (white)

VQ Quotient

Perfusion

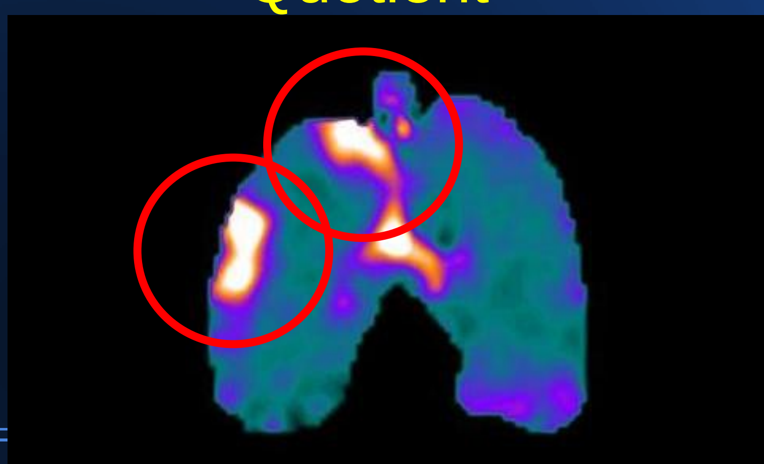
Ventilation

Quotient

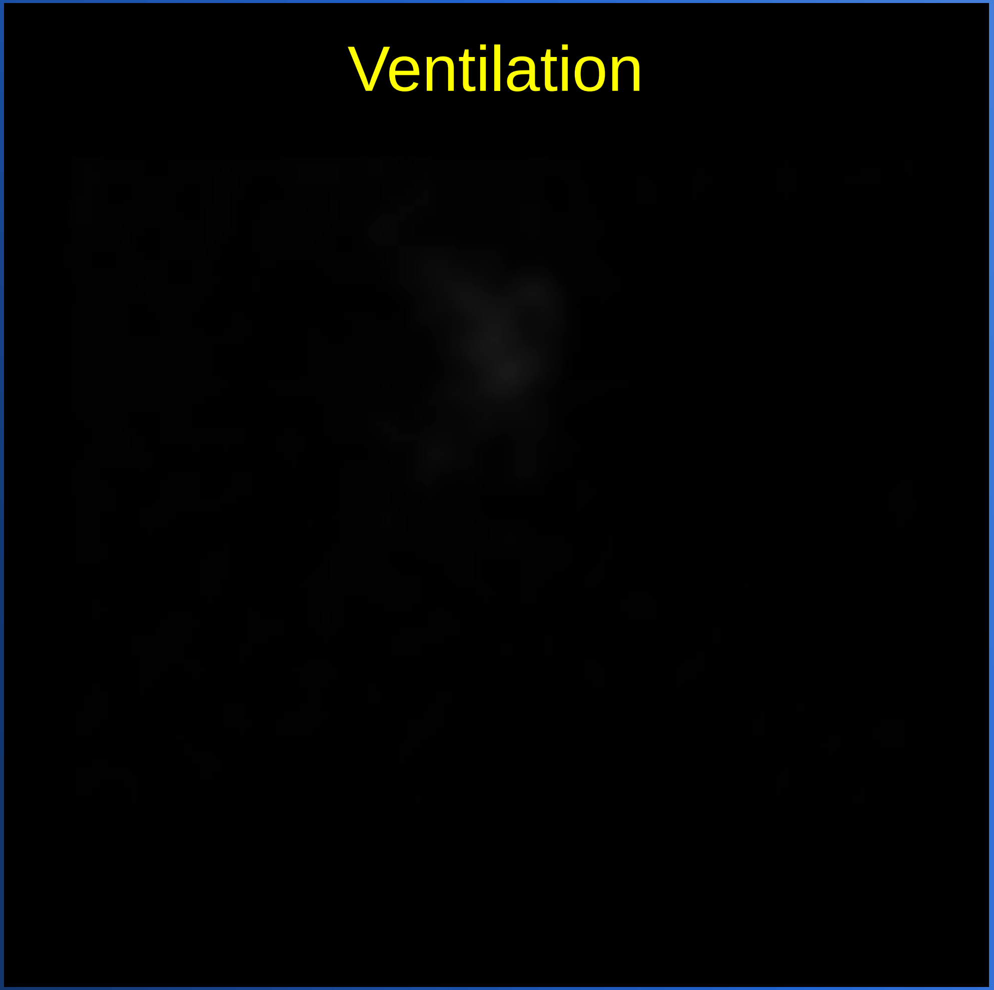
VQ Quotient

Perfusion | Ventilation

Quotient



Reporting Display
- Coronal -



Reporting Display
- Sagittal -

Perfusion

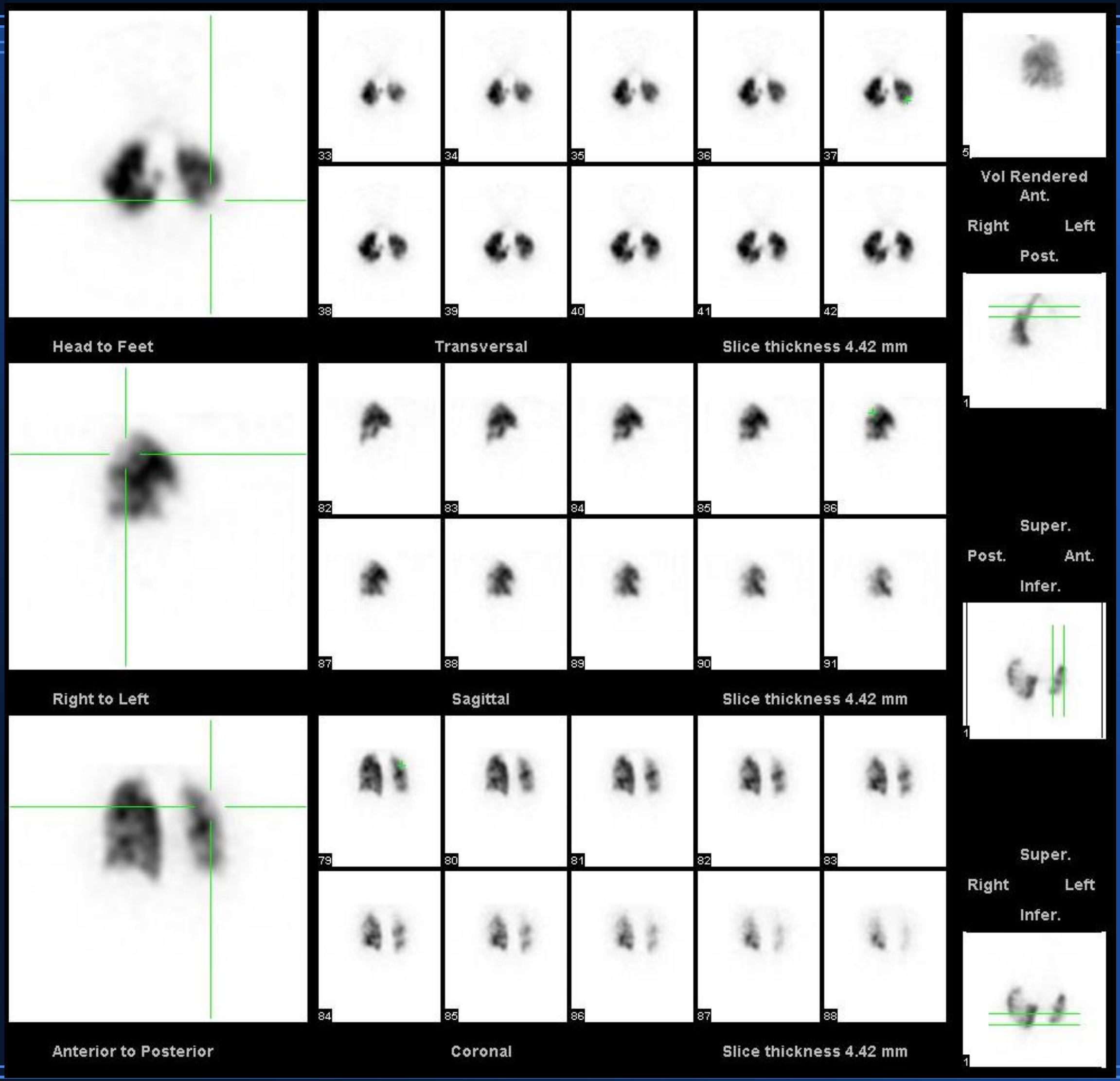
Ventilation

Reporting Display
- Transaxial -

Perfusion

Ventilation

Triangulation



Ideally, we would like to triangulate suspected perfusion defect to the ventilation slices

Output

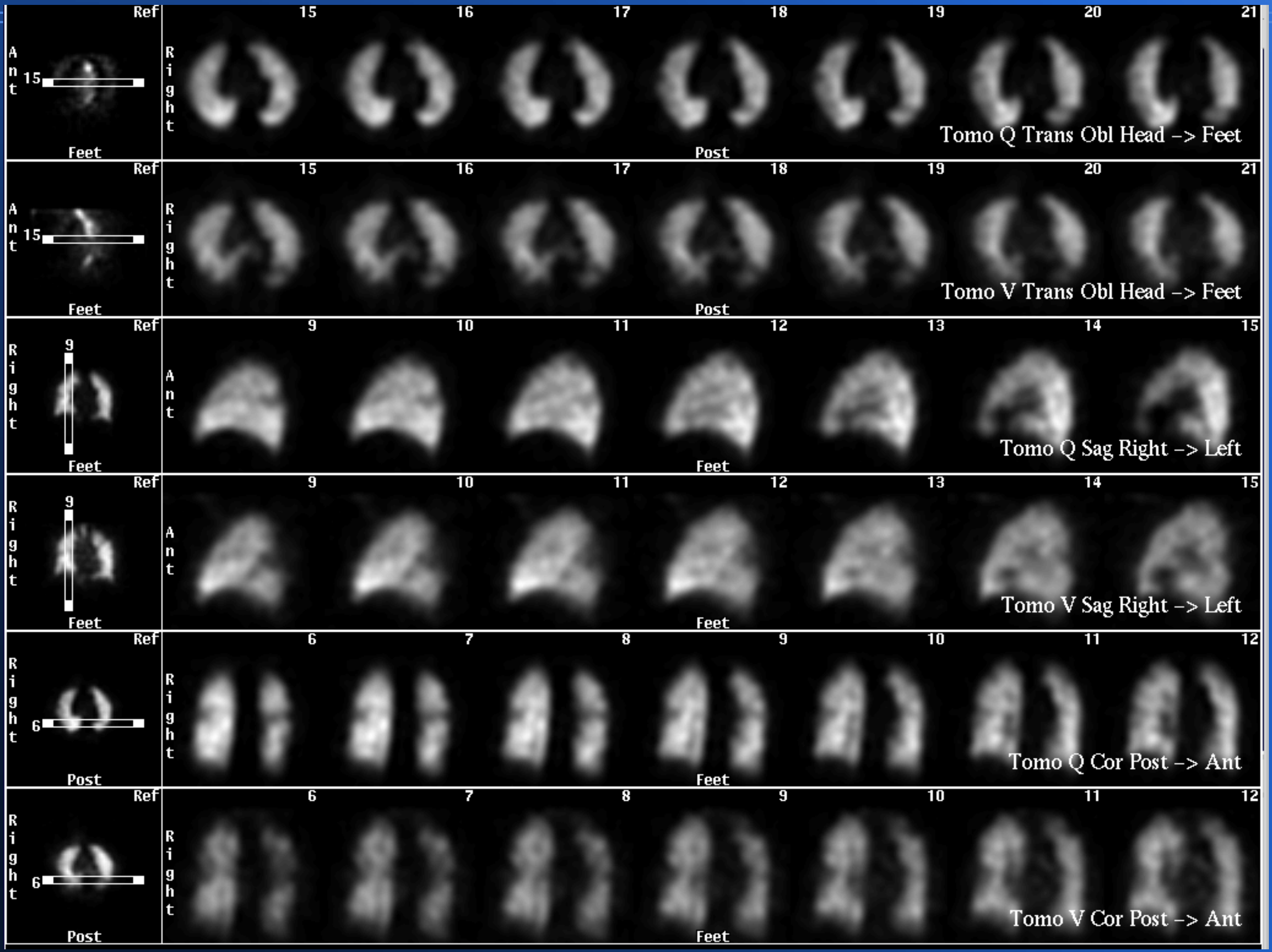
- Send slices direct to PACS (like PET-CT)

  or
- Screencaptures

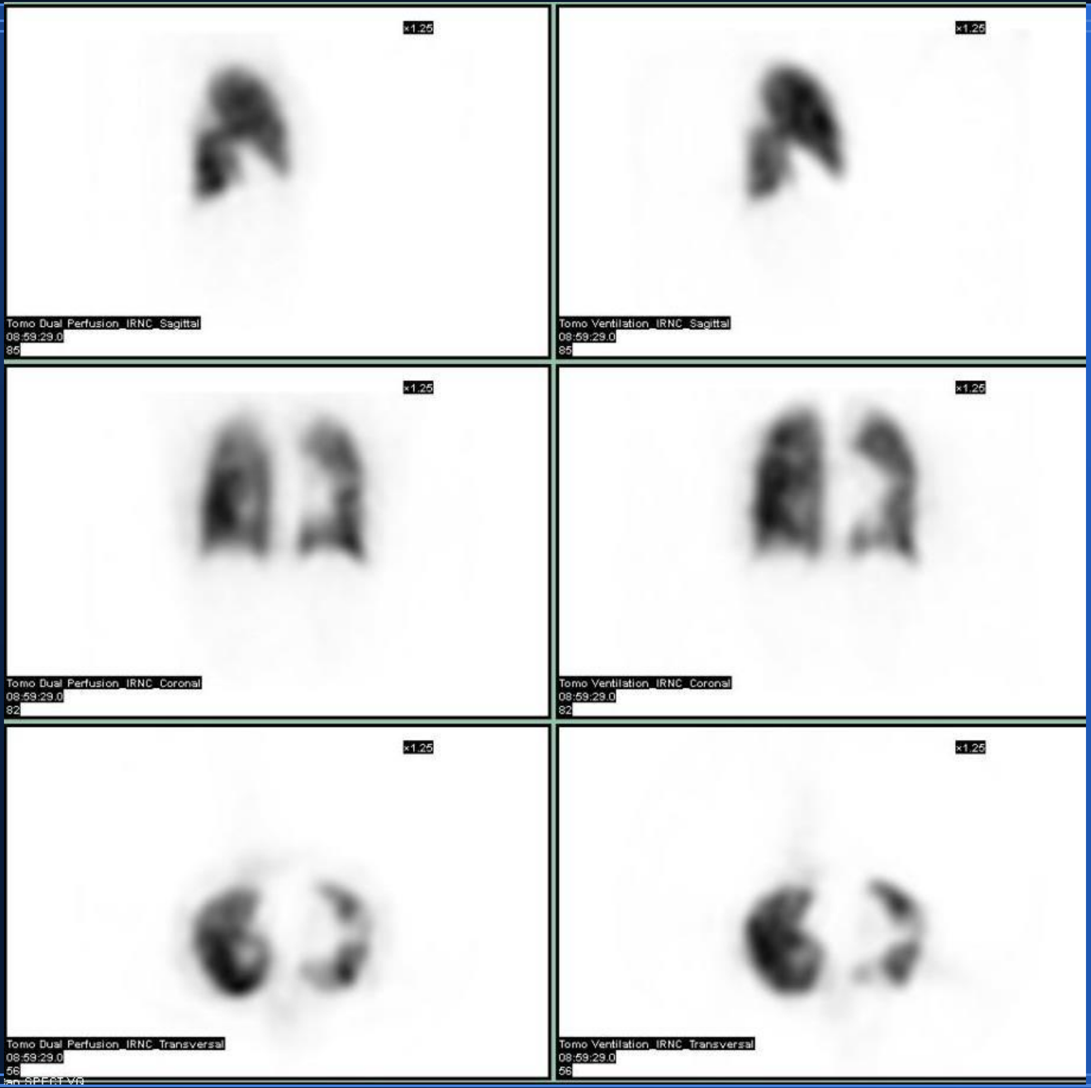
  or
- Both!

- Display routines not available or developed

Output - Odyssey



Output - Xeleris



Summary

QC Checks essential

Optimal processing settings per system

VQ Quotient very useful

Lots of further work to do:

- Optimal reconstruction (resolution recovery?)
- Display routines
- Anatomical overlap maps