

Tumor Tracking in Lungs for Fiducial Placement Research for CyberKnife

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What is CyberKnife

- ◆ CyberKnife is a radiation treatment machine capable of high accuracy that can be used to perform Stereotactic Body Radio Therapy (SBRT)
- ◆ CyberKnife is primarily used to treat areas that require precision and accuracy such as lung and head and neck tumors. In these cases it is important to have high accuracy to avoid structures such as the spine and heart
- ◆ CyberKnife uses a system call synchrony to track and treat in real time

Synchrony

- ◆ Synchrony uses 3 tracking LEDs and gold markers to track the tumor
- ◆ The gold markers are seen through two orthogonal x-rays that are set 45° offset of the couch on both sides above
- ◆ The computer system uses the LEDs on the chest and the gold seeds to track the tumor and treat while in motion
- ◆ A breathing model is built before the beam is turned on and this model is used to track throughout the treatment process

Synchrony



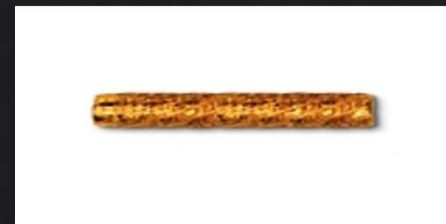
<https://casereports.bmj.com/content/2011/bcr.07.2010.319>

Fiducials

- ◈ Gold markers placed in or around the lung lesion to allow the tumor motion to be tracked
- ◈ Can be placed percutaneously or bronchoscopically
- ◈ Placed with a needle through the skin or placed using a scope through the throat
- ◈ The markers are about the size of a grain of rice 5 mm long and 1 mm in diameter



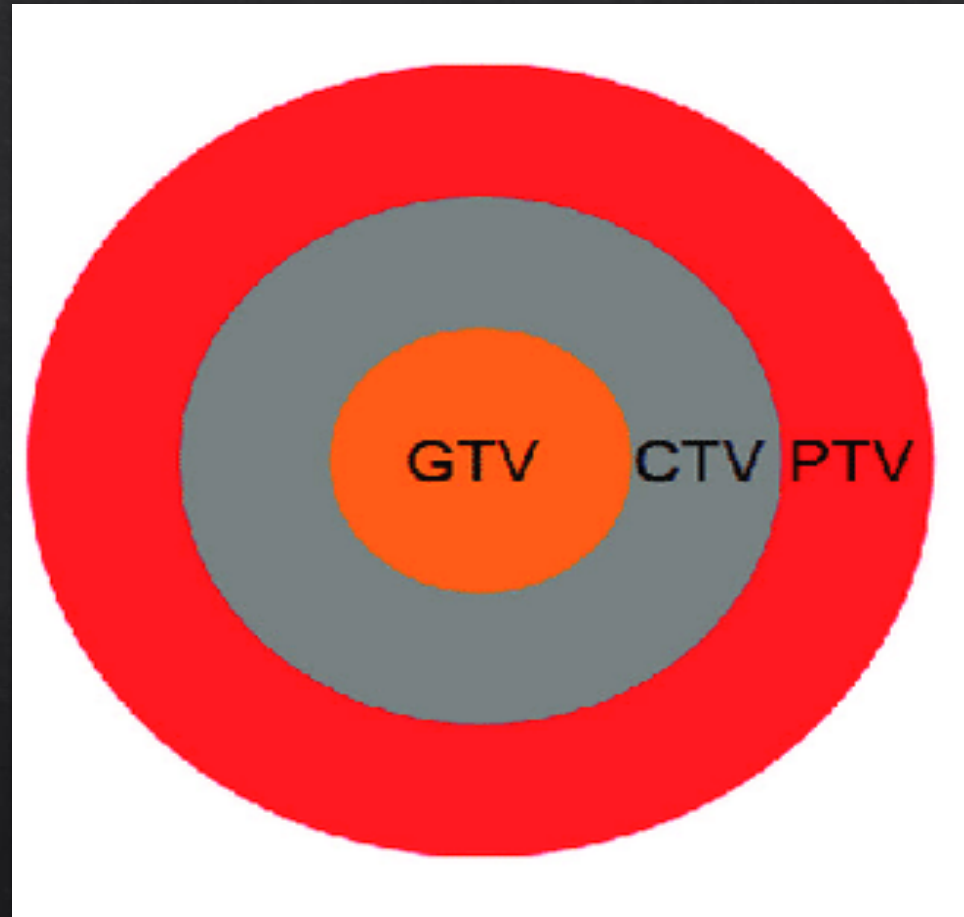
<https://gammagurus.com/products/cybermark-fiducial-markers>



Background

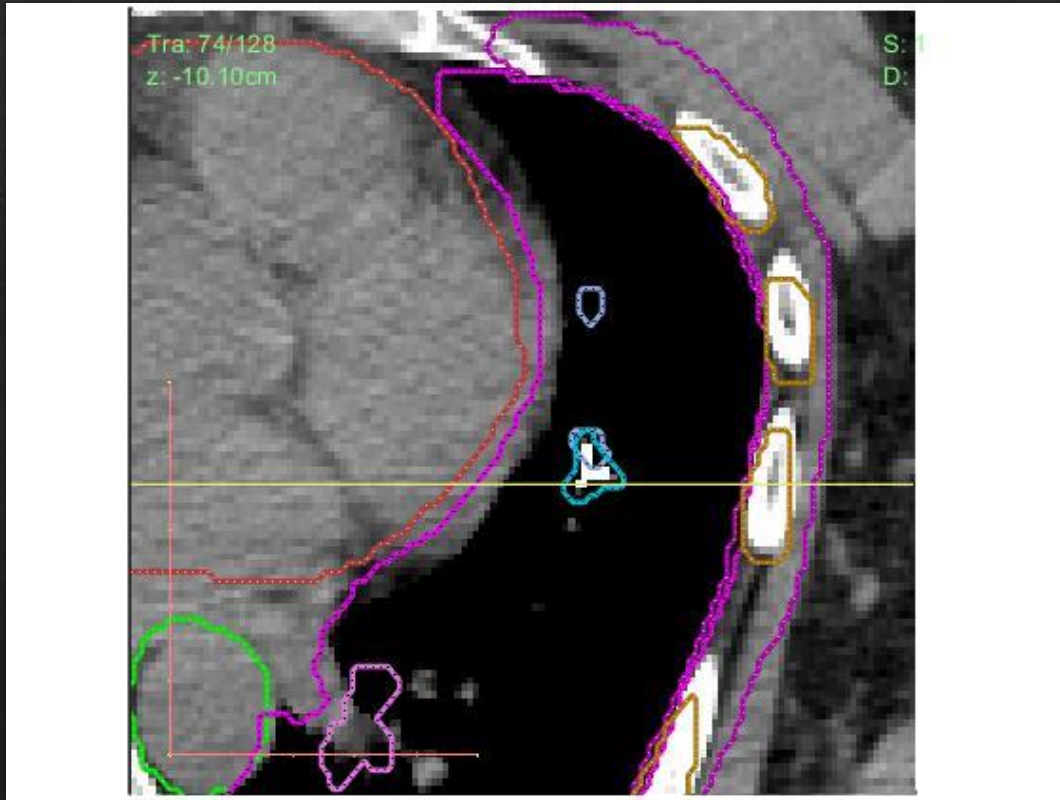
- ◆ Fiducial locations are used to track the Gross Tumor Volume (GTV) while treating a patient
- ◆ Fiducials (fids) are much easier to locate in an X-ray because of their high Hounsfield Unit (HU) or CT number
- ◆ Tracking is needed because the lung moves throughout the breathing process, thus the GTV moves. At ECU we use a 5 mm margin for treatment. However, some clinics use 3mm and some go as large as 7mm.
- ◆ For this to be a good method of tracking the tumor, the movement of the fiducial must be similar to that of the GTV
- ◆ Proper tumor tracking leads to appropriate dose distribution

GTV, CTV, PTV



https://www.researchgate.net/figure/Plot-of-the-three-ICRU-tumour-volumes-with-1-cm-margins-between-the-GTV-and-CTV-and_fig2_320634840

Fiducial in CT Image



- ◇ This shows what the fiducial looks like in a CT image
- ◇ As you can see it lights up much brighter than normal tissue

Big Picture

- ◊ We want to establish a protocol for fid marker placement to ensure proper tracking
- ◊ The current protocol is that the markers must be at least 2 cm apart and any three in a line must have a 15 degree offset
- ◊ With tracking verified it will lead to a better dose distribution
- ◊ It will become easier to ensure that dose is being deposited in the GTV not the surrounding normal tissue
- ◊ This will also lessen the negative affects of radiation because less normal tissue will be receiving dose

Research Plan

- ◆ To find the center of mass for the fids and for the GTV
 - ◆ We will be recontouring the GTV and fids in every phase and using MatLab to find their COMs
- ◆ Once we find the center of mass, I will use those to analyze the distance between the fids and the GTV throughout the breathing process and the distance between its closest neighbor fids
- ◆ To determine if the fid accurately kept the same distance from the GTV
- ◆ Using deformation fields to look at tumor and fid movement in 3-D

Research Plan Continued

- ◆ Good and bad fid placement will be determined by looking to see if the fid kept a constant distance away from the tumor
- ◆ We will then analyze the fids deemed good and bad to see what is causing them to be good or bad
- ◆ We have two hypotheses regarding what can influence it
 - ◆ The distance between the fid and GTV having an ideal placement
 - ◆ The relative position of the fid to the GTV (i.e. fids placed superior are good but inferior are bad, just an example - no data analyzed at this time to support this)
- ◆ This will also be looked at for upper lung vs lower lung

Methods

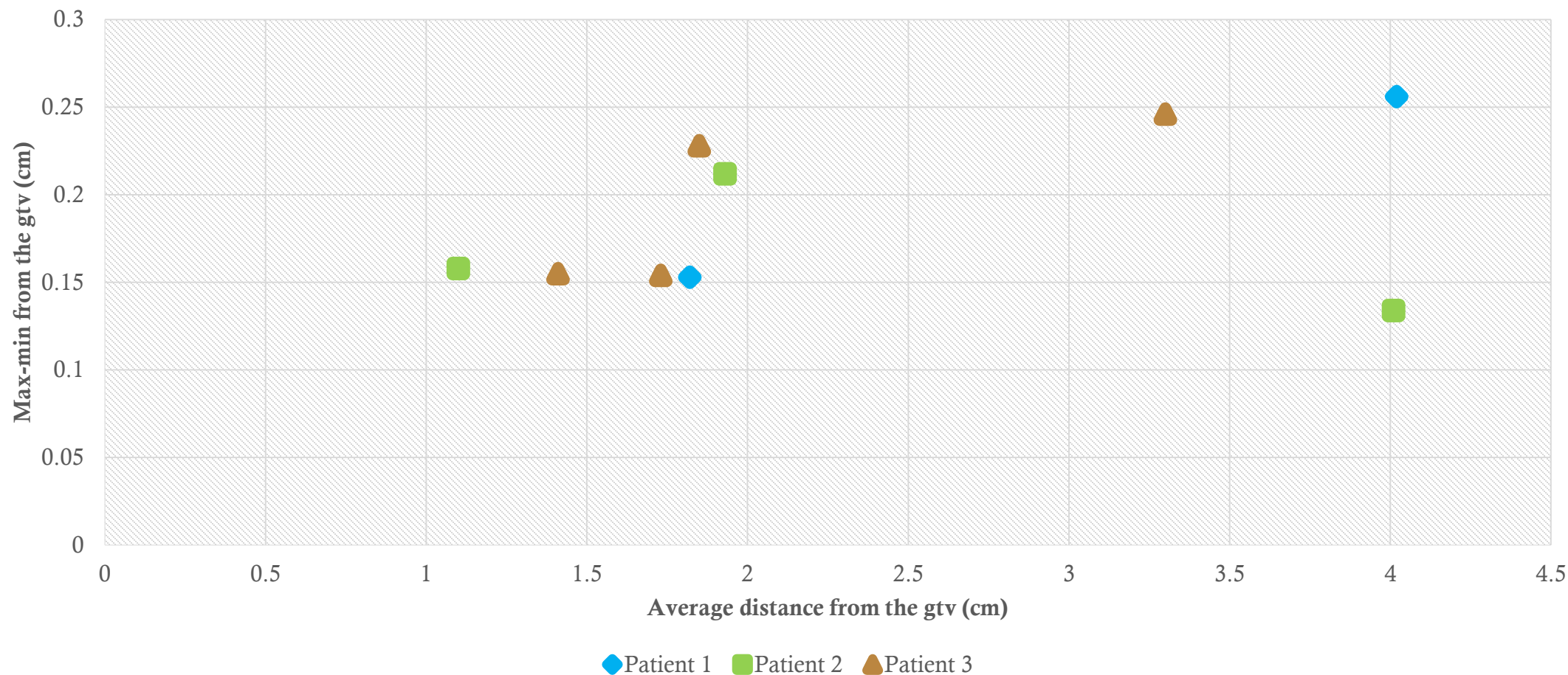
- ◊ This is an IRB approved study using real patient data
- ◊ MatLab and CERR was used to do all the contouring and find the center of mass
- ◊ Bspline and Elastix was used to create the deformation fields

Distance Evaluation

Distance (cm) between GTV and Fids for Patient 1 in 3-D

Phase	GTV-Marker 1	GTV- Marker 2	GTV- Marker 3	GTV- Marker 4
0	4.14	3.58	1.80	3.38
10	4.12	3.41	1.85	3.24
20	3.95	3.32	1.85	3.08
30	3.97	3.35	1.81	3.16
40	3.94	3.31	1.78	3.12
50	3.93	3.36	1.77	3.16
60	3.96	3.35	1.74	3.14
70	4.03	3.42	1.86	3.20
80	4.07	3.48	1.89	3.18
90	4.18	3.61	1.87	3.40
Average	4.03	3.42	1.82	3.20
Max-Min	0.26	0.30	0.15	0.32

Graph Showing Distances for Good Tracking Markers for Three Patients



Patient 1 Images with Deformation Fields

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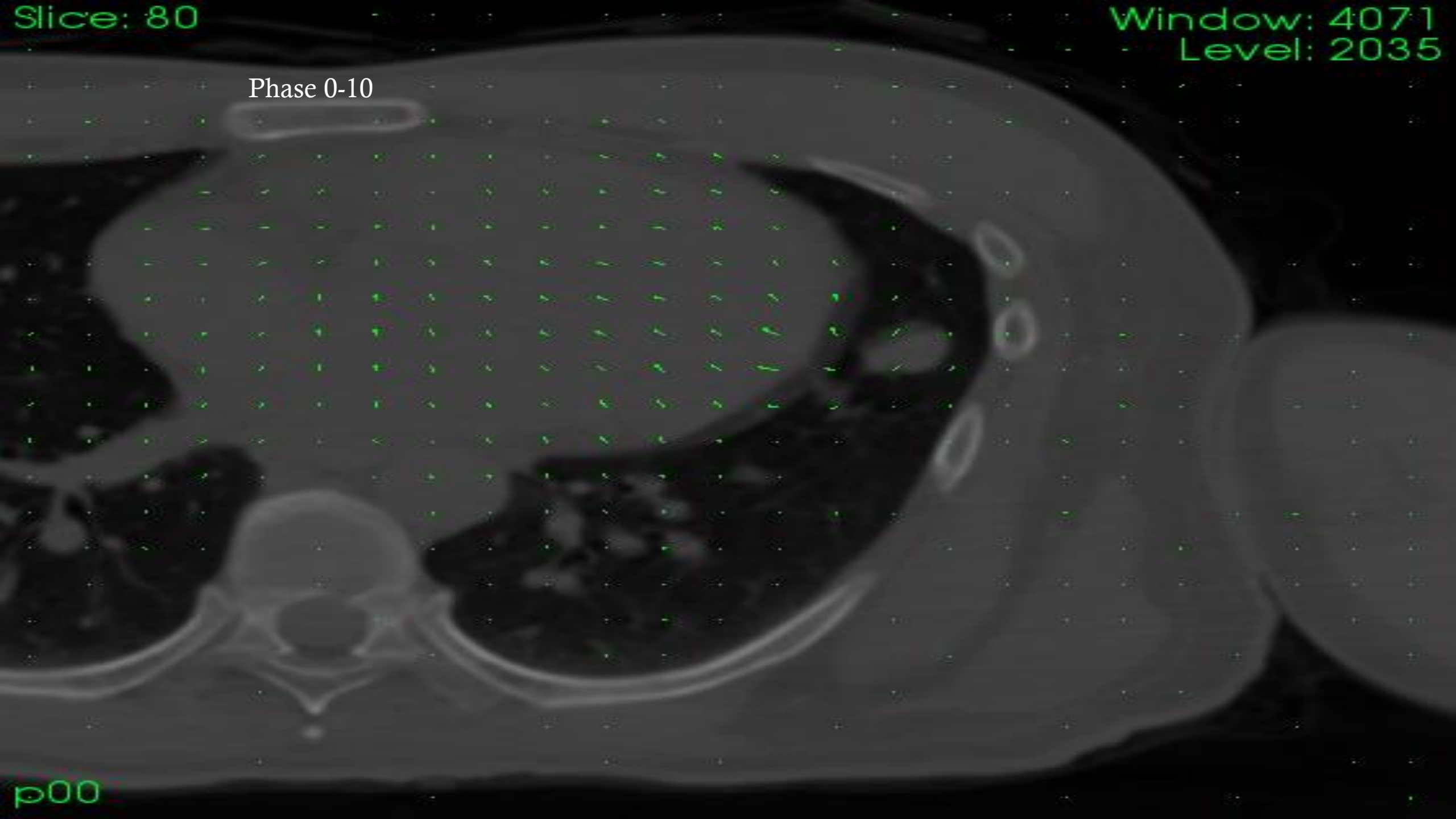
Patient 1 phase 0-10, 10-20, 20-30,
30-40, 40-50, 50-60, 60-70, 70-80,
80-90,

Slice: 80

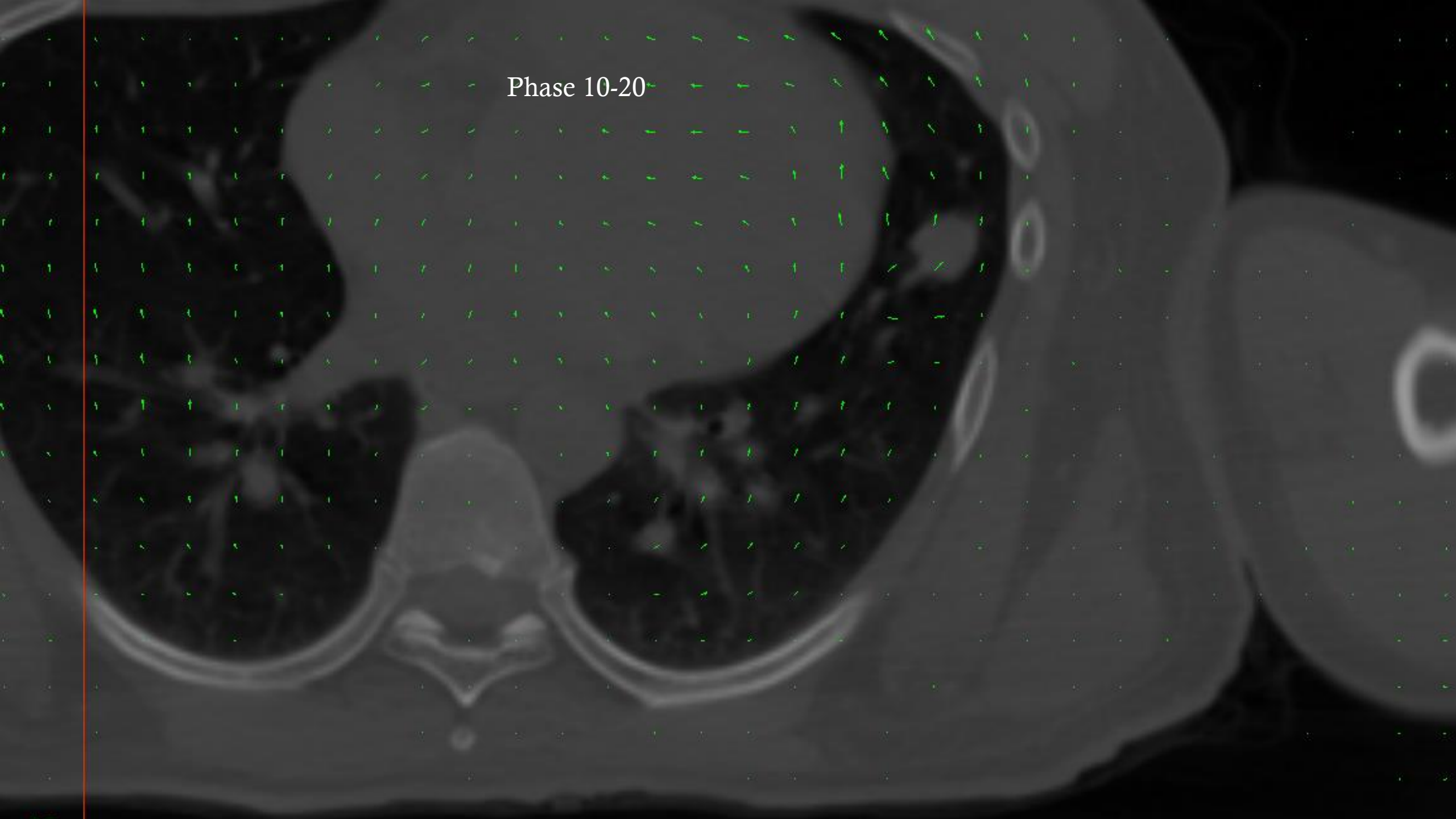
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Level: 2035

Phase 0-10

p00



Phase 10-20

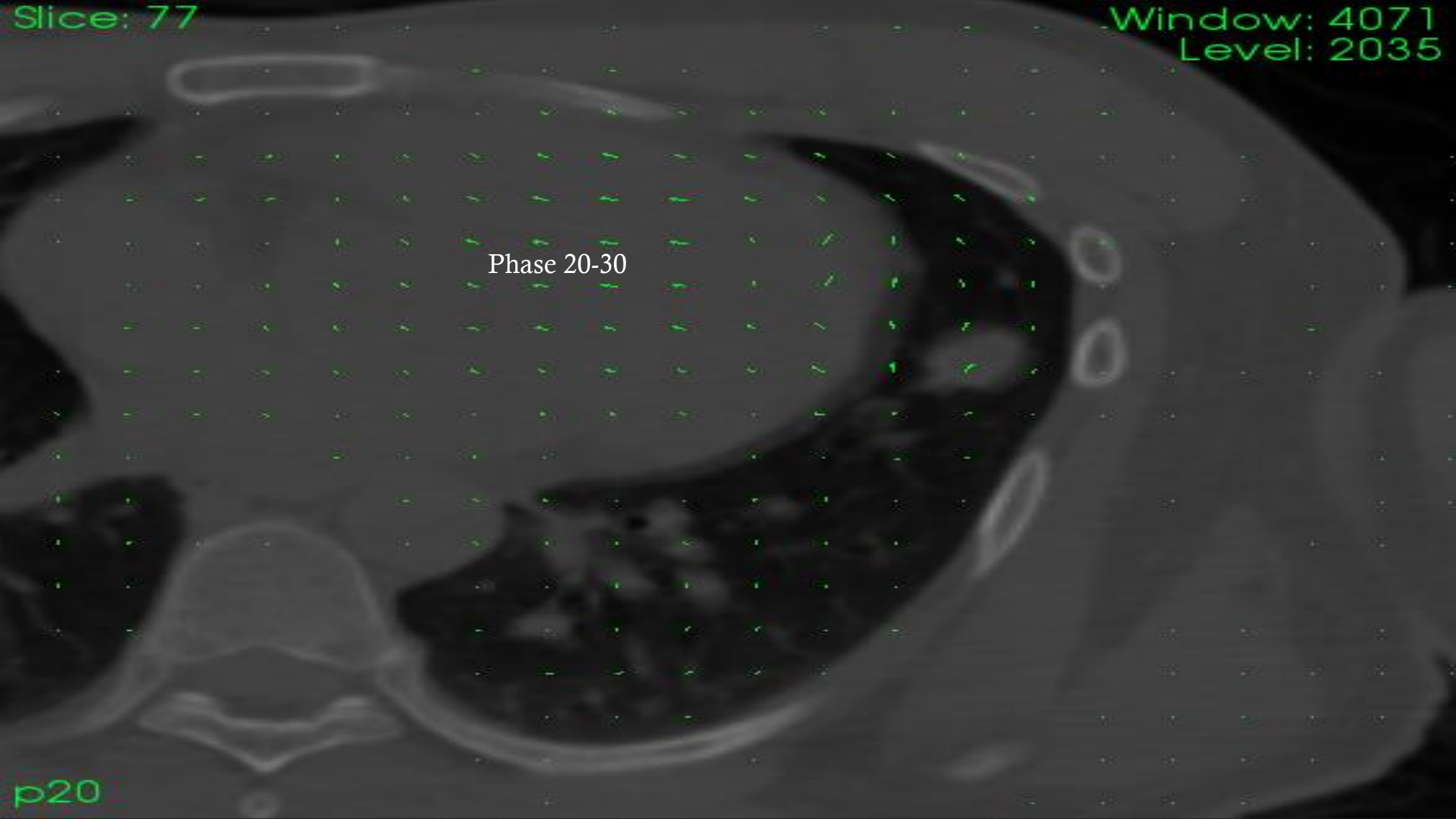


Slice: 77

Window: 4071
Level: 2035

Phase 20-30

p20

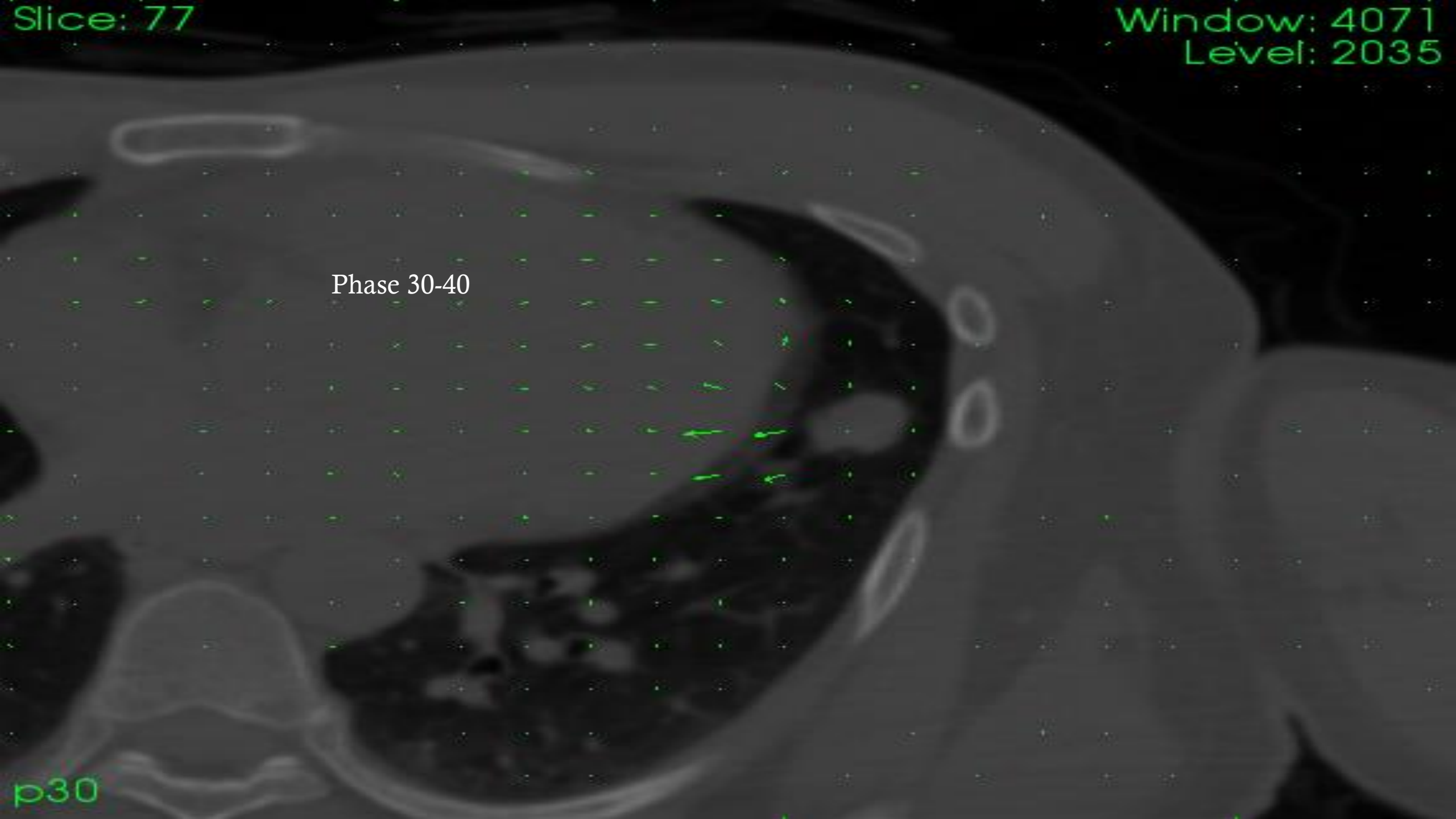


Slice: 77

Window: 4071
Level: 2035

Phase 30-40

p30

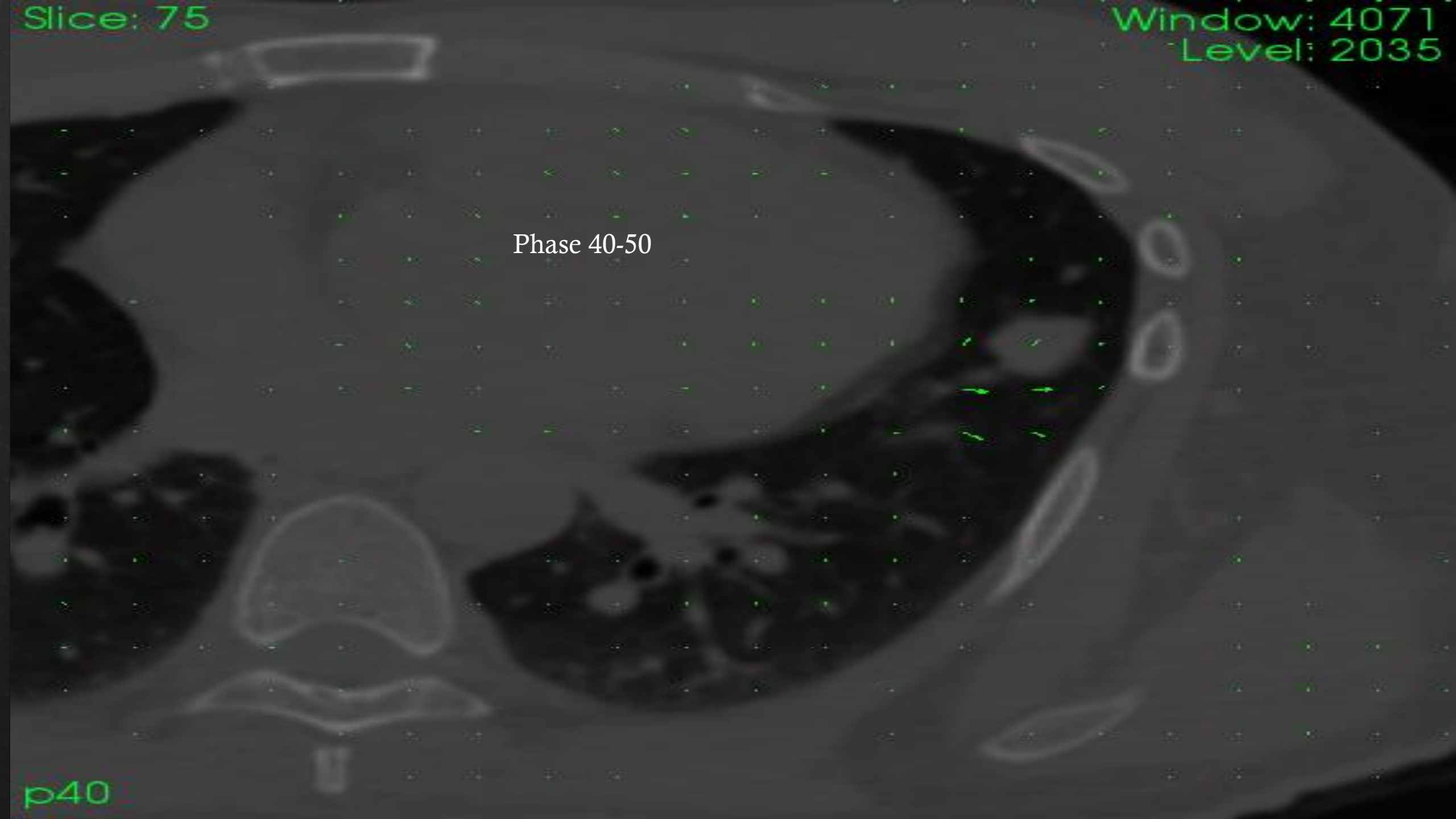


Slice: 75

Window: 4071
Level: 2035

Phase 40-50

p40

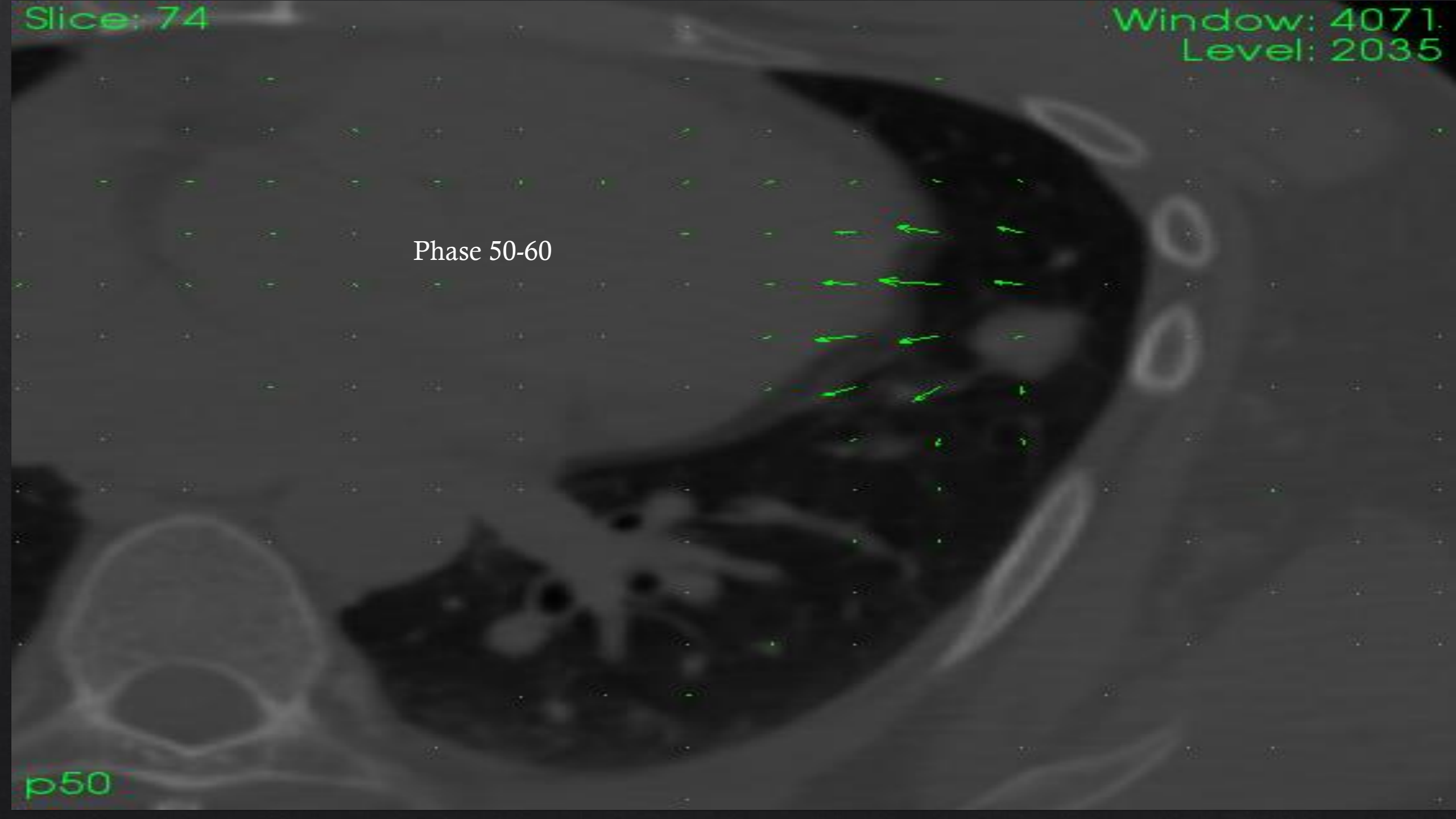


Slice: 74

Window: 4071.
Level: 2035

Phase 50-60

p50

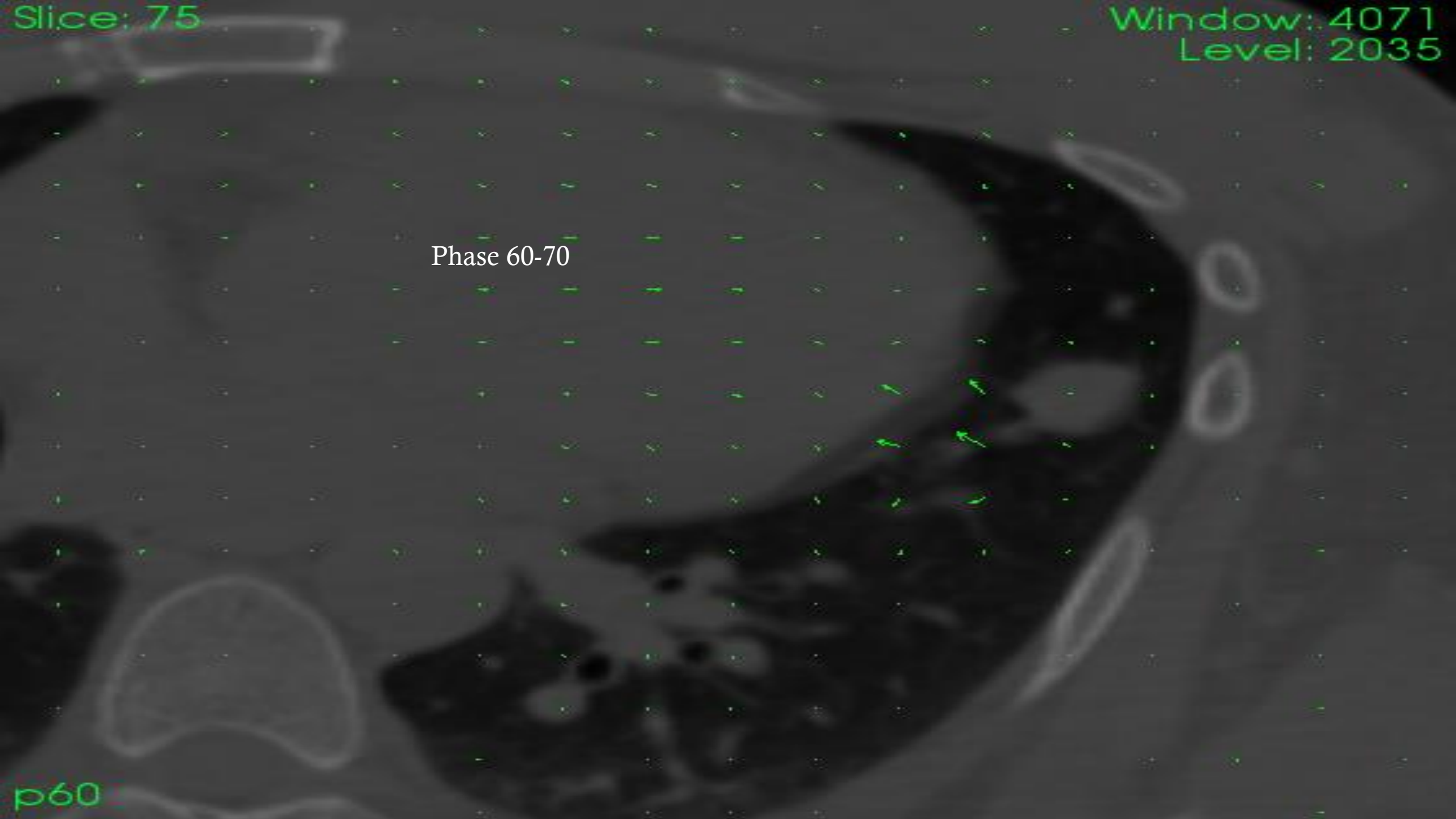


Slice: 75

Window: 4071
Level: 2035

Phase 60-70

p60

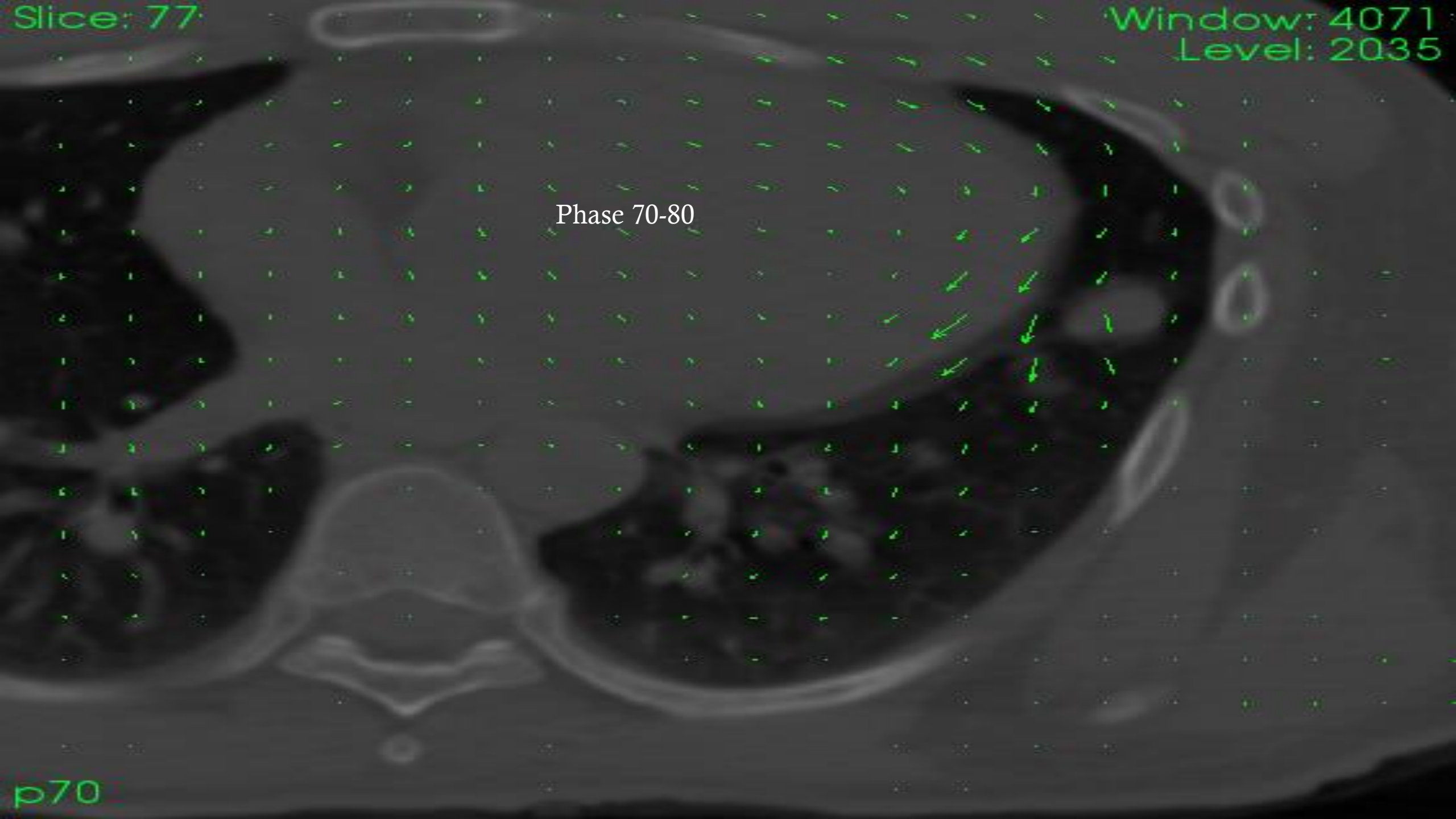


Slice: 77

Window: 4071
Level: 2035

Phase 70-80

p70

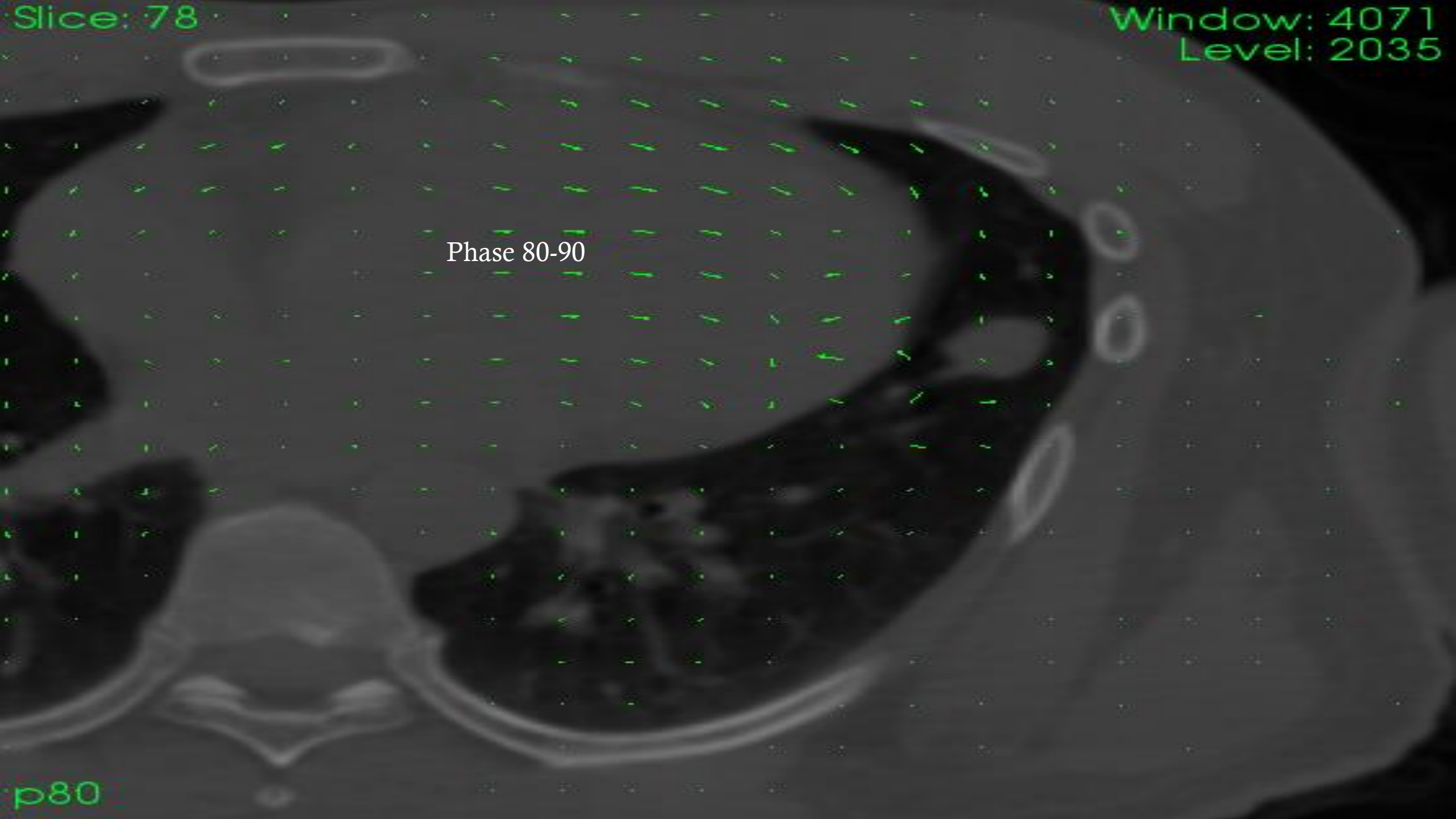


Slice: 78

Window: 4071
Level: 2035

Phase 80-90

p80



Patient 1 Phase 0-50 In all
views

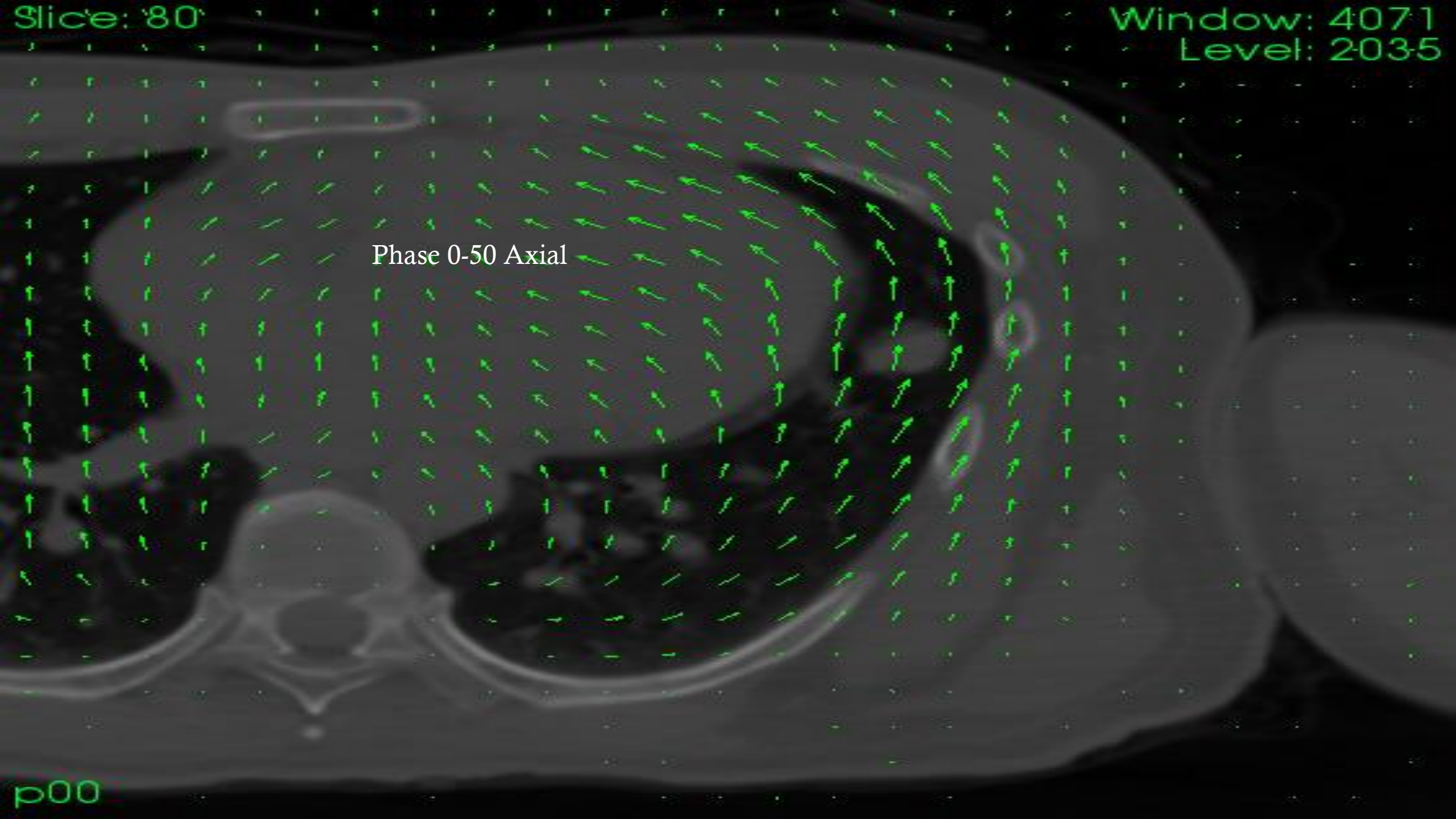
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Window: 4071

Level: 2035

Phase 0-50 Axial

p00

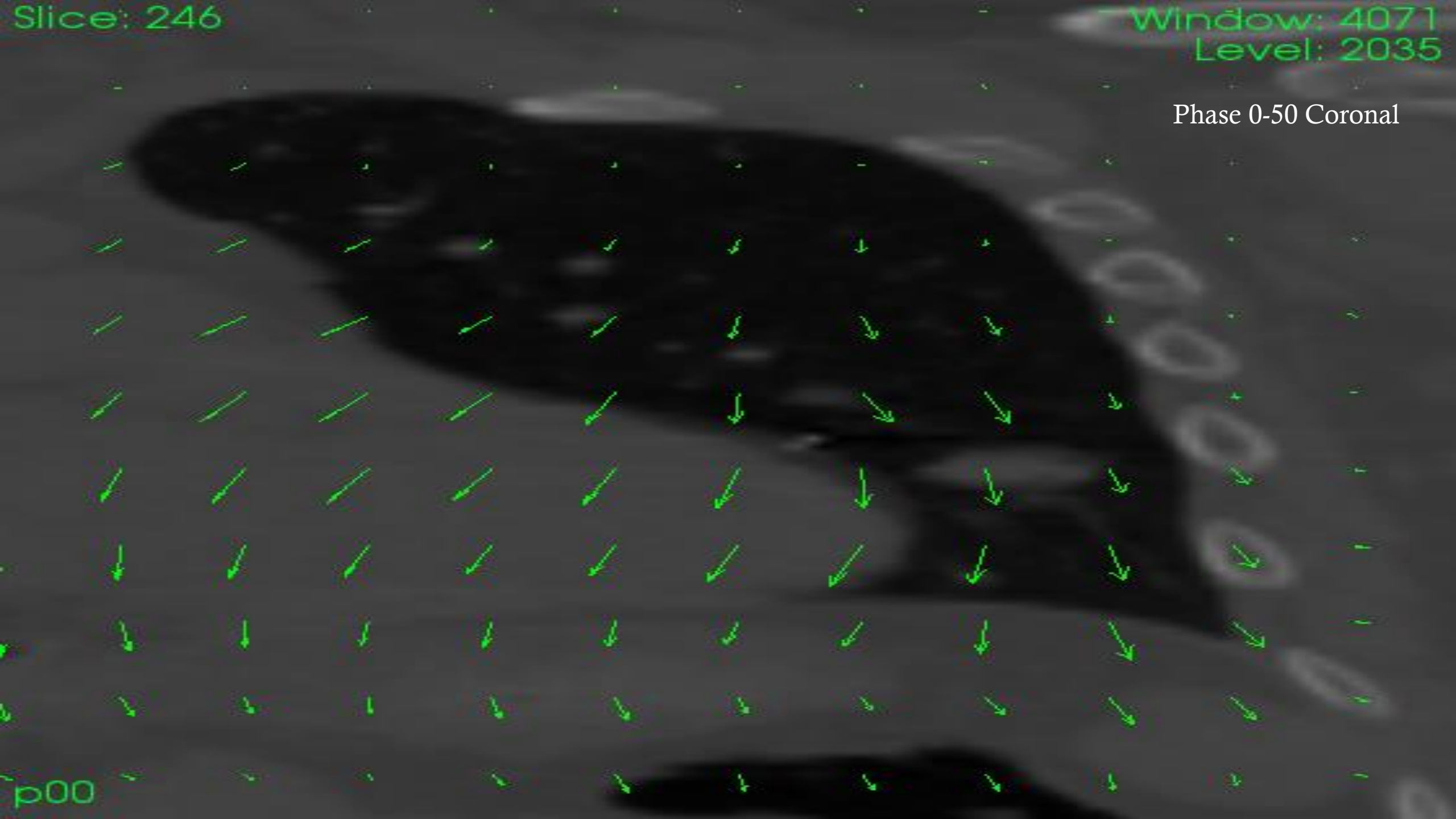


Slice: 246

Window: 4071
Level: 2035

Phase 0-50 Coronal

p00

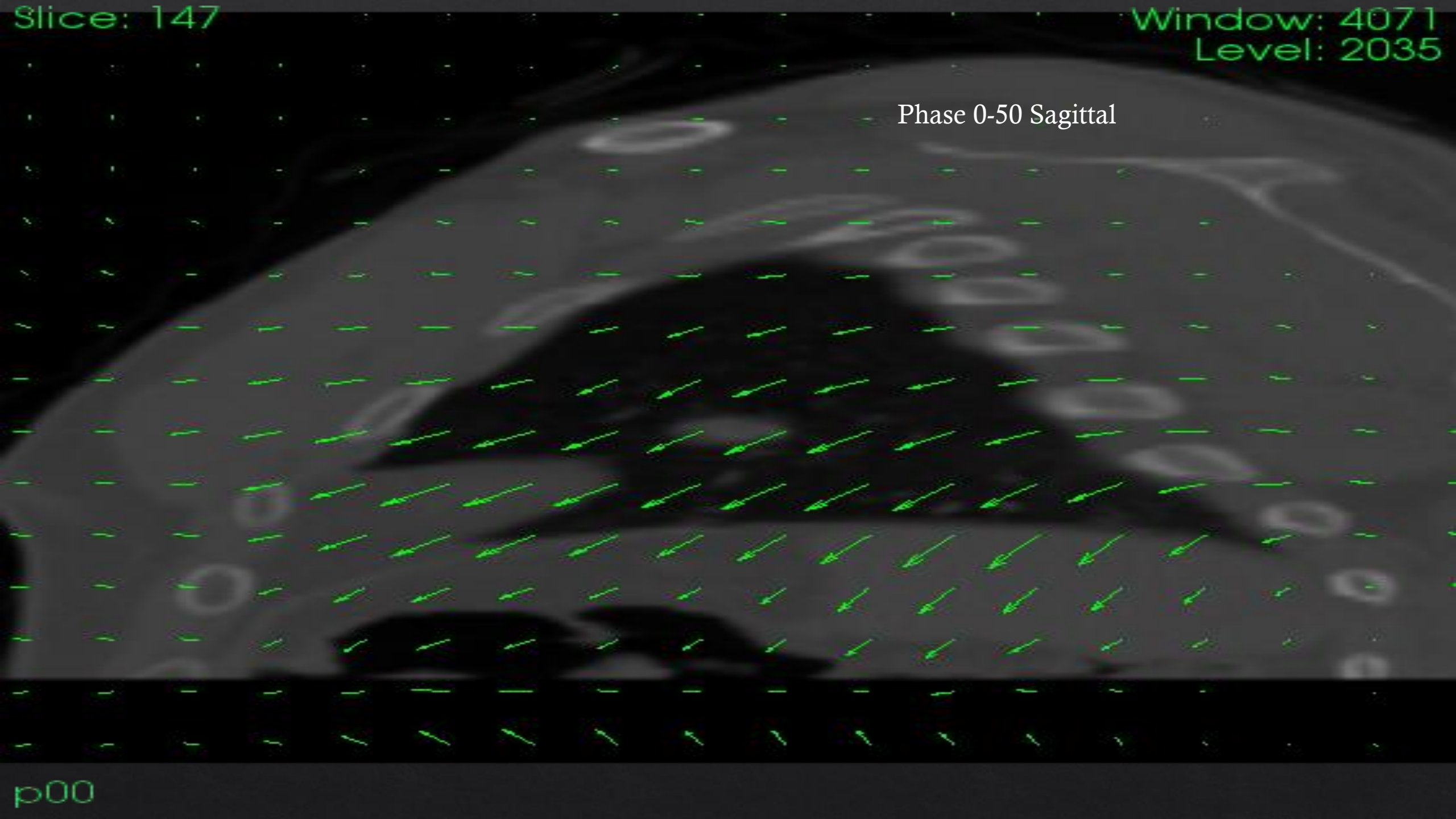


Slice: 147

Window: 4071
Level: 2035

Phase 0-50 Sagittal

p00



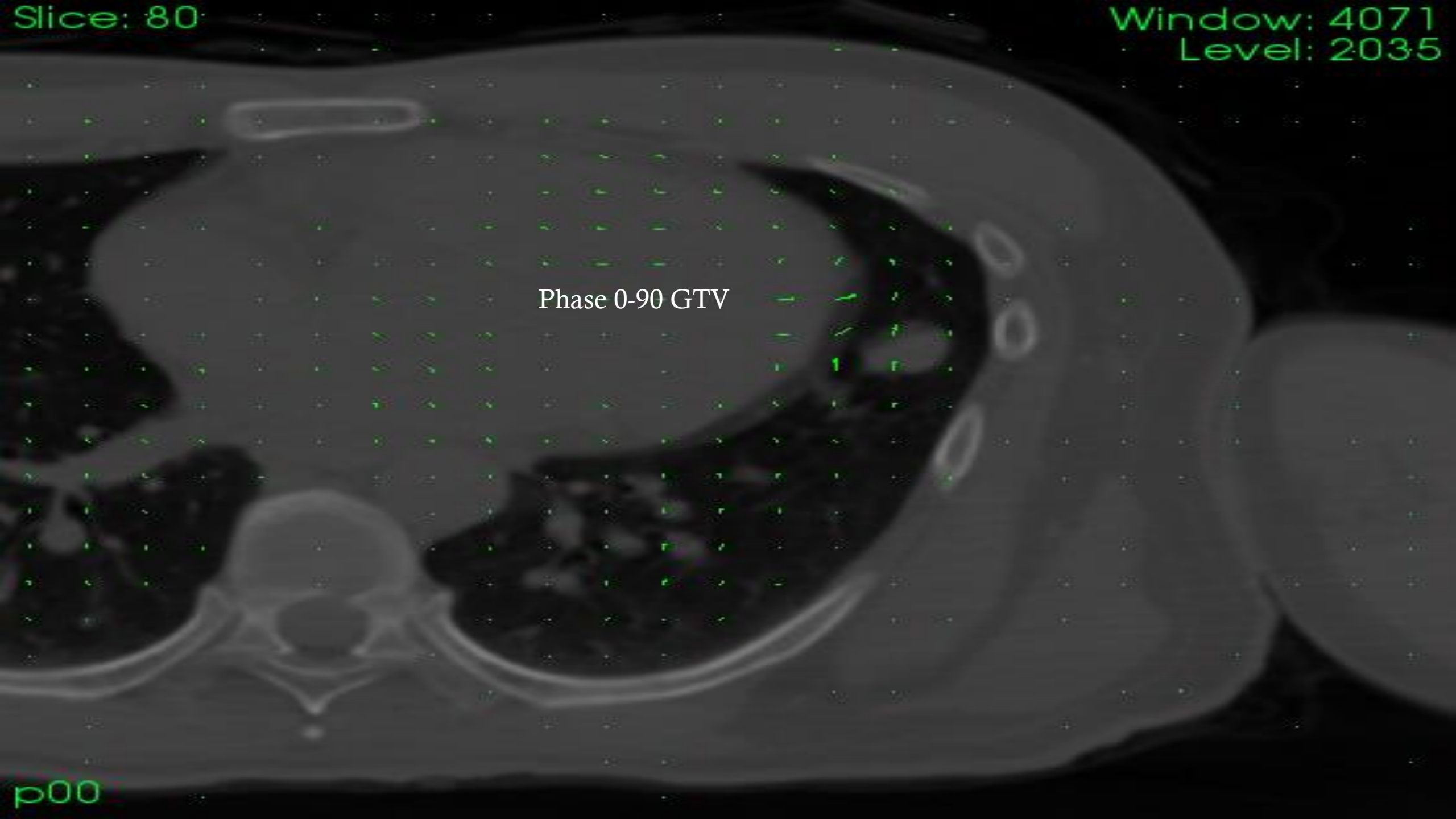
Patient 1 Phase 0-90 GTV and
Fids

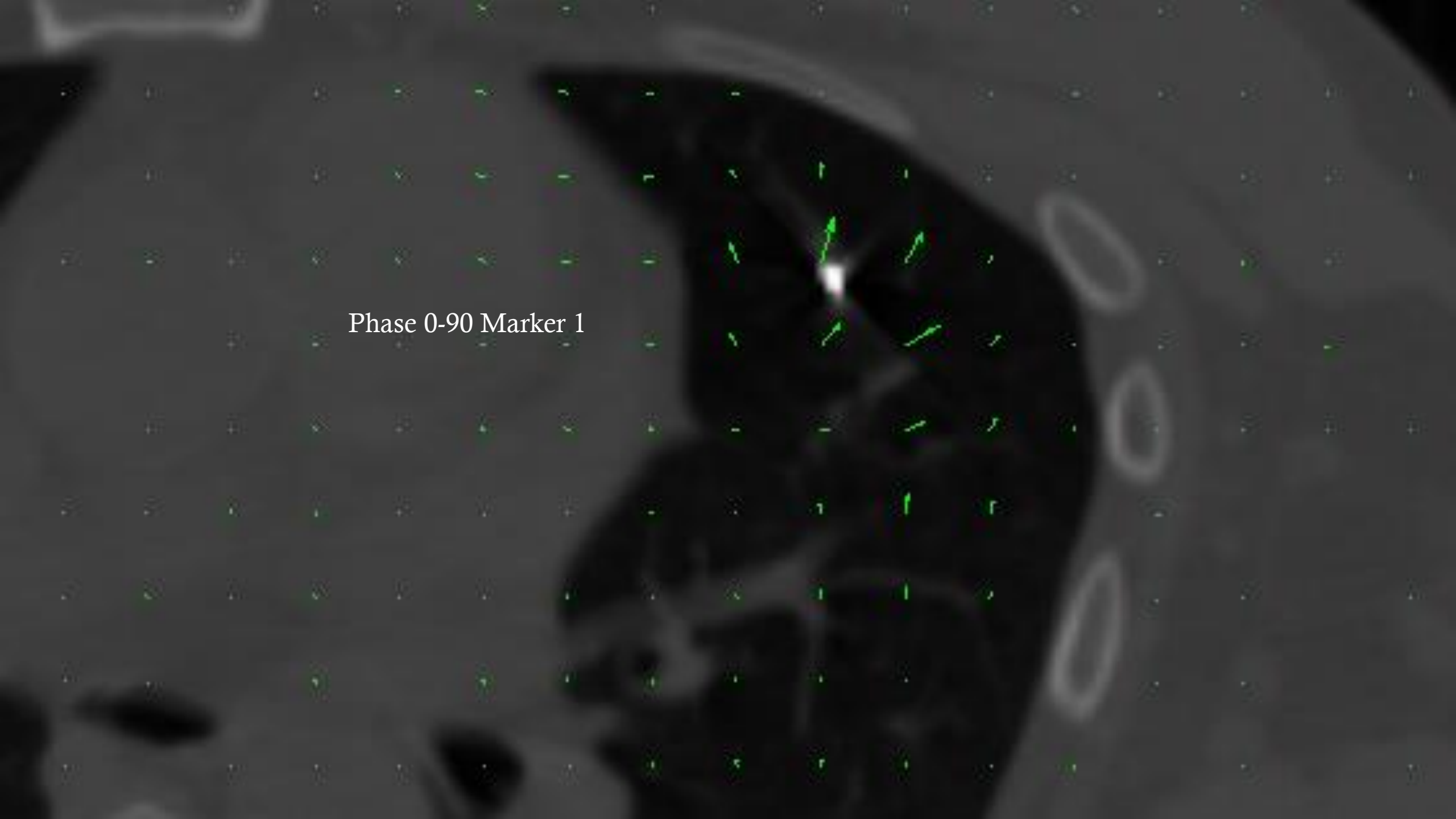
Slice: 80

Window: 4071
Level: 2035

Phase 0-90 GTV

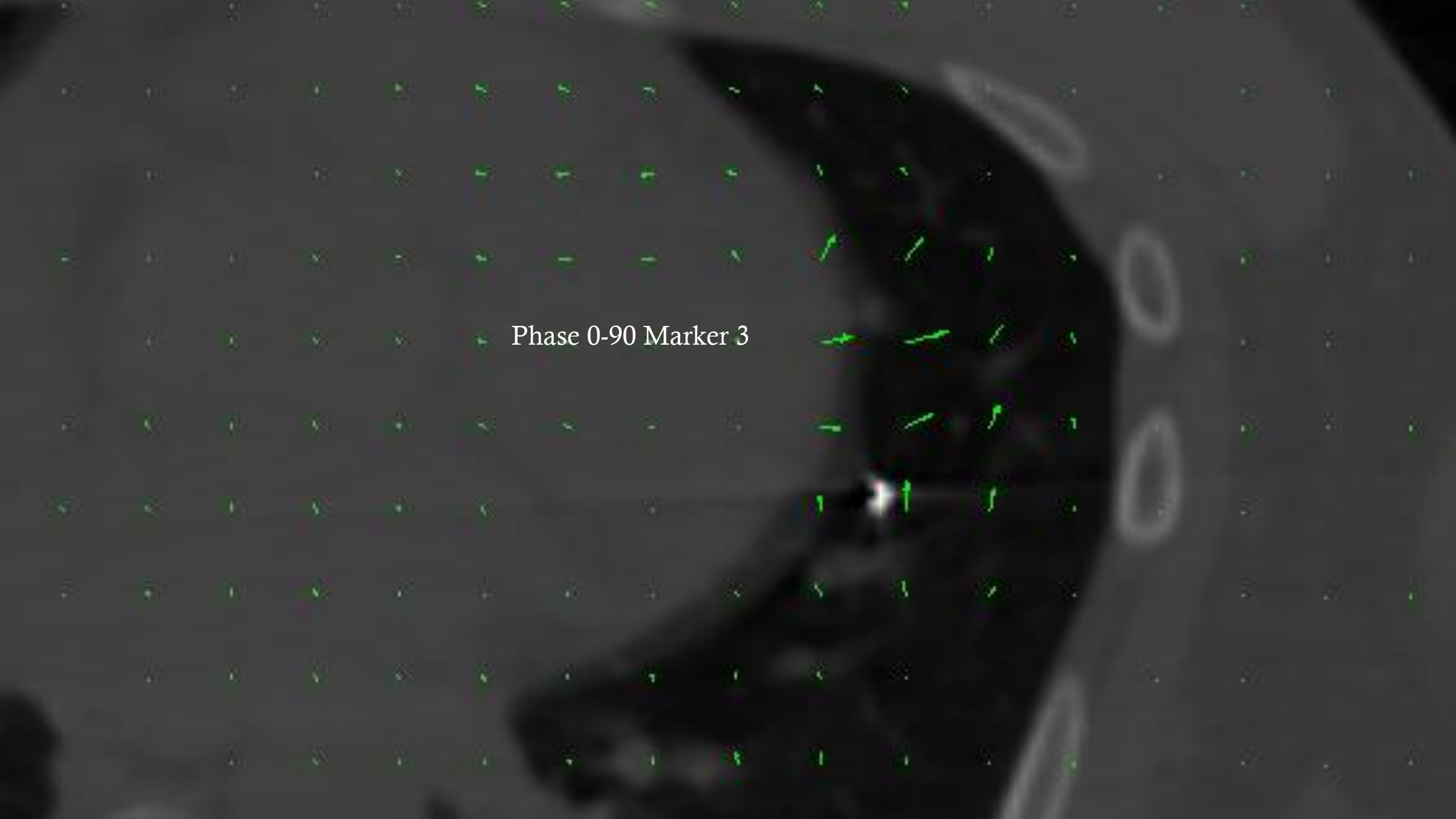
p00





Phase 0-90 Marker 1

Phase 0-90 Marker 2



Phase 0-90 Marker 3



Phase 0-90 Marker 4

Conclusions

- ◆ Looking at the change in distances it would appear that fid1 and fid3 are the best choice for tracking using a cutoff of .3 cm from the Max-Min row
- ◆ From the images it would also appear that fid1 and fid3 are good choices for tracking
- ◆ More patient data needs to be looked at to try and find a trend as to why these fids were good and not fid2 or fid4

Future

- ◆ Look at other patients to see if they fit this same trend
- ◆ Look at lower lung and upper lung patients separately as they will probably follow different trends
- ◆ If no trend is found to generalize the ideal placements, then 4-D CT images should be taken before fid placement to identify ideal spots for each patient (Personalized Patient Planning)

Sources

- ◆ **A simple algorithm to assess patient suitability for Calypso-seed implantation for four-dimensional prostate localization**

Randall J. Kimple,^{1a} Eric M. Wallen,^{2,3} Raj Pruthi,^{2,3} Lawrence B. Marks,^{1,3}

- ◆ **Synchrony- CyberKnife Respiratory Compensation Technology**

Cihat Ozhasoglu PhD., Cheng B. Saw PhD., Hungcheng Chen M.S., Steven Burton M.D., Krishna Komanduri PhD., Ning J. Yue PhD., Saiful M. Huq PhD. and Dwight E. Heron M.D.

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Questions?