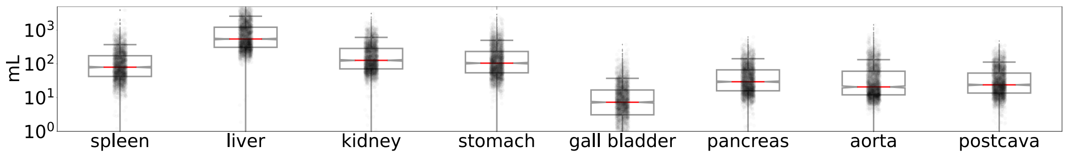
Appendix

A Implementation Details

Our AbdomenAtlas-8K includes three different AI architectures: Swin UNETR, U-Net, and nnU-Net. Swin UNETR and U-Net are trained on 2,100 CT volumes from 16 partially labeled public abdominal datasets (details in Figure 1). We use the Adam optimizer with an initial learning rate of $1e$-4, which is dynamically adjusted based on the combined dice and BCE losses. The weight decay is set to $1e$-5. nnU-Net is trained on 47 CT volumes from the BTCV [46] dataset. We utilize the SGD optimizer with an initial learning rate of $1e$-2 and a weight decay of $3e$-5. The AI architectures are trained on portal venous CT volumes. Eight NVIDIA RTX Quadro 8000 GPUs are used, and the batch size is 4 per GPU. The training process takes approximately 40 hours and the testing process takes around 12 hours.

B Datasets and Permissions

We will only disseminate the annotations of the CT volumes separately, and users will retrieve the original CT volumes, if needed, from the original sources (websites). Everything we intend to create and license-out will be in separate files, and no modifications are necessary to the original CT volumes. The source and permissions are elaborated in Table 3. We have consulted with the lawyers at Johns Hopkins University, confirming the permissions of distributing the annotations based on the license of each dataset.

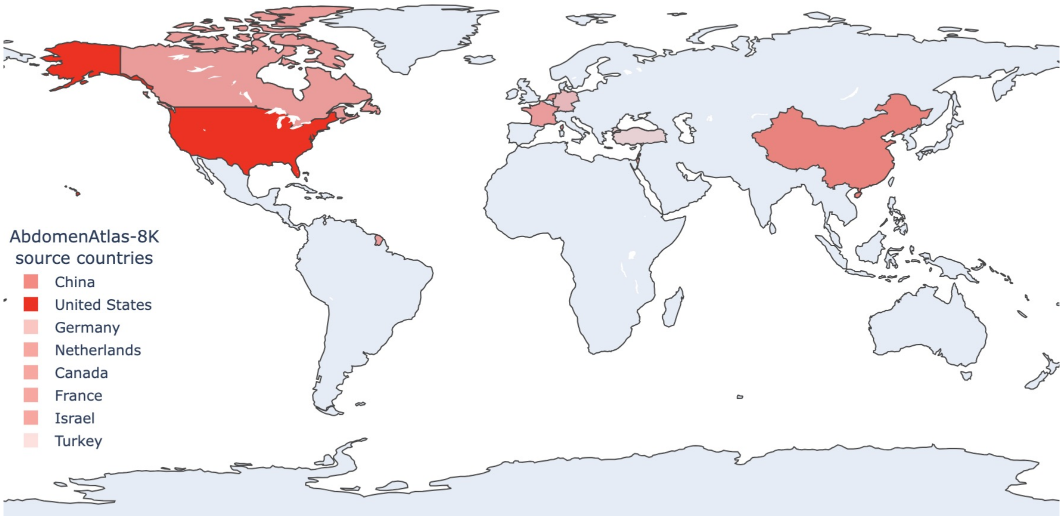


Dataset	Spleen	Liver	Kidney	Stomach
Multi-Atlas_Labeling	251.2 (211.0-401.7)	2331.4 (1743.9-2587.2)	466.3 (316.8-597.5)	431.9 (308.6-633.4)
TCIA_Pancreas-CT	224.3 (166.2-272.3)	1402.2 (1214.8-1687.3)	308.8 (276.9-372.3)	311.1 (228.3-398.5)
CHAOS	170.9 (118.4-234.2)	977.0 (896.0-1216.0)	212.0 (157.6-251.0)	130.1 (95.0-227.2)
LiTS	116.1 (69.6-193.1)	931.8 (573.5-1312.5)	206.9 (111.4-314.5)	142.7 (74.2-253.5)
KiTS	96.1 (54.6-202.0)	640.9 (421.4-1467.2)	186.8 (118.7-354.2)	107.3 (62.4-255.9)
WORD	178.1 (137.1-234.8)	1213.1 (1064.2-1406.9)	313.2 (267.1-361.0)	390.8 (251.5-518.9)
AbdomenCT-1K	54.2 (33.1-94.4)	364.3(255.8-689.2)	89.8 (61.6-154.7)	72.2 (41.8-133.2)
AMOS	268.6 (154.8-436.6)	1977.8 (1165.2-3127.8)	466.9 (276.4-723.1)	402.8 (226.2-748.2)
Decathlon	57.5 (35.7-105.4)	409.6 (262.8-671.7)	86.1 (55.2-140.6)	77.5 (48.5-137.6)
CT-ORG	245.0 (148.0-423.7)	2136.8 (1182.0-3108.4)	421.0 (230.2-727.6)	317.8 (151.2-565.3)
AbdomenCT-12organ	261.9 (199.9-383.5)	2111.0 (1890.2-2373.1)	523.6 (460.7-616.5)	414.8(276.3-561.0)
AbdomenAtlas-8K	79.6 (42.2-173.9)	544.4 (308.8-1216.0)	126.7 (70.8-285.9)	104.8 (54.2-232.4)

Dataset	Gall Bladder	Pancreas	Aorta	Postcava
Multi-Atlas_Labeling	23.8 (14.0-43.4)	108.0 (71.5-136.5)	100.7 (73.0-149.0)	105.5 (71.3-141.1)
TCIA_Pancreas-CT	21.0 (13.8-30.6)	68.9 (52.9-81.4)	42.1 (31.7-51.6)	69.8 (60.6-81.4)
CHAOS	11.7 (8.7-16.9)	58.1 (44.89-77.6)	17.8 (15.1-28.4)	46.1 (36.7-54.6)
LiTS	8.6 (2.6-16.9)	44.6 (27.2-69.9)	43.7 (19.8-80.5)	32.3 (13.1-63.0)
KiTS	8.8 (4.0-17.6)	36.8 (22.7-84.6)	28.8 (19.2-68.6)	28.3 (19.7-57.2)
WORD	11.6 (6.6-19.3)	83.1 (66.9-95.9)	83.4 (68.2-104.0)	54.1 (40.2-69.6)
AbdomenCT-1K	5.5 (2.6-11.9)	19.9 (13.0-35.7)	13.3 (9.7-24.4)	17.9(12.1-28.6)
AMOS	32.4 (19.0-60.4)	105.3 (64.9-171.4)	163.9 (88.9-215.3)	89.9 (71.1-142.7)
Decathlon	5.1 (2.0-10.0)	20.3 (13.1-37.5)	15.5 (10.9-24.5)	17.8 (11.3-29.2)
CT-ORG	17.3 (5.8-37.9)	96.9 (51.1-163.1)	95.0 (45.8-175.7)	68.9 (29.1-139.8)
AbdomenCT-12organ	31.6 (23.6-53.2)	116.3 (87.3-165.7)	66.9 (55.9-78.4)	103.3 (90.2-139.3)
AbdomenAtlas-8K	7.3 (3.1-16.8)	29.5 (15.9-66.3)	20.7 (12.1-60.5)	23.9 (13.6-53.3)

Figure 9: **The comparisons of volume distribution between public datasets and our dataset.** The values, expressed in mL, represent the median of the corresponding organ in the dataset, with the 25th and 75th percentiles indicated in parentheses.

Table 3: **The information for an assembly of datasets.** After summarizing the existing public datasets, we found that a combination of these datasets is fairly large (a total of 8,000 CT volumes and many more are coming over the years). The main challenge, however, is the absence of comprehensive annotations. In fact, scaling up annotations is much harder than scaling up CT volumes due to the limited time of expert radiologists. The existing labels of the public datasets are partial and incomplete, e.g., LiTS only had labels for the liver and liver tumors, and KiTS only had labels for the kidneys and kidney tumors. Our AbdomenAtlas-8K offered detailed annotations for all eight organs within each CT volume. With this, our contribution is significant.



Dataset	# of organs	# of volumes	# of centers	source countries	license	# of volumes in AbdomenAtlas-8K
1. Pancreas-CT [74]	1	82	1	US	CC BY 3.0	42
2. LiTS [7]	1	201	7	DE, NL, CA, FR, IL	CC BY-SA 4.0	131
3. KiTS [30]	1	300	1	US	CC BY-NC-SA 4.0	300
4. AbdomenCT-1K [55]	4	1,112	12	DE, NL, CA, FR, IL, US, CN	CC BY-NC-SA	1000
5. CT-ORG [72]	5	140	8	DE, NL, CA, FR, IL, US	CC BY 3.0	140
6. CHAOS [86]	4	40	1	TR	CC BY-SA 4.0	20
7-11. MSD CT Tasks [1]	9	947	1	US	CC BY-SA 4.0	945
12. BTCV [46]	12	50	1	US	CC BY 4.0	47
13. AMOS22 [40]	15	500	2	CN	CC BY-NC-SA	200
14. WORD [51]	16	150	1	CN	GNU GPL 3.0	120
15. FLARE'23	13	4,000	30	-	CC BY-NC-ND 4.0	2200
16. AbdomenCT-12organ [54]	12	50	-	-	CC BY-NC-SA	50
17. AATTCT-IDS	-	300	1	CN	-	-
18. CTSpine1K	-	1,005	-	-	CC-BY-NC-SA	-
19. Abdominal Trauma Det.	-	3,147	23	-	-	-
20. TotalSegmentator [89]	104	1,204	1	CH	CC BY 4.0	-
21. JHH (*private*) [92]	20	5,282	1	US	JHU	-

US: United States DE: Germany NL: Netherlands CA: Canada FR: France IL: Israel
CN: China TR: Turkey CH: Switzerland

Table 4: **The annotation time.** We employed two trained annotators to produce full annotations for the eight organs and recorded the average time needed for each organ. Both annotators have over 3-year experience in radiological image analysis.

Organs	Annotator #1	Annotator #2	Average
Spleen	30 min	28 min	29 min
Right Kidney	26 min	28 min	27 min
Left Kidney	23 min	25 min	24 min
Gall Bladder	11 min	10 min	10 min
Liver	40 min	40 min	40 min
Stomach	32 min	32 min	32 min
Aorta	22 min	20 min	21 min
Postcava (IVC)	27 min	30 min	28 min
Pancreas	19 min	19 min	19 min

Table 5: **Label quality improvement along the active learning procedure.** Assessing label quality is integral to ensure that the iterative training process is harnessing the most informative samples and that the revised labels are improved in quality. In doing so, we executed an external validation by leveraging a distinct dataset (JHH) separate from the active learning pool. Specifically, we trained AI models on the dataset at different stages: (1) before revising, (2) after revising Step #1, and (3) after revising Step #2. Subsequently, these three AI models were evaluated on the unseen JHH dataset. We randomly sampled 1,000 CT volumes from JHH and computed the mean DSC scores (mDSC) and normalized surface dice (mNSD) with a tolerance of 1mm for eight organs. After label revisions, both mDSC and mNSD showed an increase, demonstrating the effectiveness of the revised organ labels. Furthermore, we highlighted the two most significantly revised classes at each step in blue. For these organs, such as the aorta and postcava, AI models exhibited a marked improvement, jumping from 72.3% to 83.7% and 76.1% to 78.6%, respectively. Conversely, the segmentation performance for other classes saw only a slight uptick. This can be attributed to two key reasons: firstly, certain organs underwent minimal revisions at given steps, and secondly, some segmentation outcomes had already reached an apex of performance, exemplified by scores like DSC exceeding 90%.

Organ	Before revising		After revising Step #1		After revising Step #2	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	94.0 ± 7.6	71.6 ± 10.5	94.1 ± 7.2	71.8 ± 11.5	94.7 ± 5.5	74.8 ± 9.5
Right Kidney	91.9 ± 8.0	64.8 ± 10.0	92.1 ± 7.0	65.0 ± 10.1	92.5 ± 7.0	64.7 ± 7.7
Left Kidney	90.8 ± 8.7	65.3 ± 10.1	91.0 ± 7.9	66.2 ± 10.1	91.5 ± 7.4	64.9 ± 9.8
Gall Bladder	82.4 ± 14.3	59.2 ± 17.2	79.8 ± 15.9	54.3 ± 17.6	81.7 ± 12.4	55.6 ± 15.1
Liver	95.5 ± 6.2	64.3 ± 9.5	95.7 ± 4.9	63.9 ± 9.2	95.8 ± 4.4	62.8 ± 8.2
Stomach	91.5 ± 8.0	52.7 ± 10.3	91.9 ± 6.8	53.9 ± 10.2	92.4 ± 5.6	53.0 ± 8.8
Aorta	72.3 ± 12.1	55.6 ± 11.3	82.9 ± 10.2	63.8 ± 11.5	83.7± 8.8	64.2 ± 9.8
Postcava (IVC)	76.1 ± 12.0	52.3 ± 11.0	77.2 ± 11.0	63.6 ± 10.7	78.6± 10.1	54.5 ± 9.5
Pancreas	79.4 ± 12.4	51.5 ± 10.1	80.1 ± 11.0	52.6 ± 9.9	79.2± 12.4	51.6 ± 9.3
Average	86.0 ± 9.9	59.7 ± 11.1	87.2 ± 9.1	60.6 ± 11.2	87.8± 8.2	60.7 ± 9.7

Table 6: **Assessing AI generalizability to multiple novel datasets.** On the left panel, the AI was trained on 16 partially labeled datasets; on the right panel, the AI was trained on the subset of AbdomenAtlas-8K. Note that the subset of AbdomenAtlas-8K has the same number of CT volumes (5,195), but their annotations are more comprehensive than 16 public datasets. We evaluated the segmentation performance of the two AI models on three unseen datasets with different sample sizes (N), i.e., FLARE'23 [53] ($N = 300$), TotalSegmentator [89] ($N = 1,204$) and JHH [92] ($N = 5,282$). The performance is measured by mean DSC scores (mDSC) and mean normalized surface dice (mNSD) with a tolerance of 1mm. The results showed that when pre-training the AI model using AbdomenAtlas-8K, the average mDSC and mNSD scores improved. This suggests that AbdomenAtlas-8K has higher quality compared to partially labeled abdominal datasets.

FLARE'23 [53]	Trained on 16 partially labeled datasets		Trained on AbdomenAtlas-8K	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	96.1 ± 1.9	82.0 ± 16.4	96.4 ± 1.9****	84.7 ± 16.6****
Right Kidney	94.1 ± 6.7	81.5 ± 12.2	96.3 ± 1.9***	80.0 ± 14.1**
Left Kidney	93.9 ± 9.2	81.3 ± 12.7	93.1 ± 9.7$^{\mathrm{ns}}$	79.5 ± 14.6****
Gall Bladder	85.1 ± 5.0	50.5 ± 16.3	86.0 ± 3.9***	57.2 ± 13.0****
Liver	97.3 ± 1.2	78.7 ± 15.8	96.8 ± 2.0****	76.6 ± 14.9***
Stomach	91.8 ± 5.0	49.2 ± 16.4	91.5 ± 6.3$^{\mathrm{ns}}$	50.0 ± 17.3$^{\mathrm{ns}}$
Aorta	83.7 ± 14.7	72.0 ± 18.4	81.8 ± 17.8$^{\mathrm{ns}}$	73.4 ± 16.7$^{\mathrm{ns}}$
Postcava (IVC)	85.7 ± 6.3	67.9 ± 8.8	86.3 ± 6.6$^{\mathrm{ns}}$	70.2 ± 7.8**
Pancreas	85.3 ± 7.3	63.6 ± 15.2	85.5 ± 6.6$^{\mathrm{ns}}$	64.9 ± 12.5*
Average	90.3 ± 6.4	69.6 ± 14.7	90.4 ± 8.2	70.7 ± 14.1

TotalSegmentator [89]	Trained on 16 partially labeled datasets		Trained on AbdomenAtlas-8K	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	93.2 ± 11.0	59.4 ± 11.7	94.8 ± 8.4****	65.0 ± 12.3****
Right Kidney	91.2 ± 10.5	55.6± 13.9	91.8 ± 9.8**	57.5 ± 13.2***
Left Kidney	89.4 ± 14.2	58.7 ± 13.6	90.4 ± 12.7***	59.9 ± 13.3***
Gall Bladder	82.2 ± 15.5	45.2 ± 11.9	82.9 ± 15.9*	48.3 ± 12.6****
Liver	94.0 ± 10.0	53.1 ± 10.5	94.6 ± 9.3$^{\mathrm{ns}}$	54.4 ± 10.8*
Stomach	82.8 ± 17.4	43.6 ± 11.9	84.2 ± 18.0**	46.8 ± 12.5****
Aorta	72.1 ± 19.9	47.9 ± 13.0	75.7 ± 19.5****	53.5 ± 14.2****
Postcava (IVC)	73.7 ± 18.9	47.5 ± 14.2	74.7 ± 18.7**	50.2 ± 15.3****
Pancreas	80.6 ± 15.4	40.9 ± 10.3	82.4 ± 15.7***	46.5 ± 10.8****
Average	84.4 ± 14.8	50.2 ± 12.3	85.7 ± 14.2	53.6 ± 12.8

JHH [92]	Trained on 16 partially labeled datasets		Trained on AbdomenAtlas-8K	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	94.7 ± 1.8	72.0 ± 8.5	95.0 ± 1.5*	74.4 ± 8.4****
Right Kidney	92.2 ± 5.2	65.2 ± 9.3	92.2 ± 5.0$^{\mathrm{ns}}$	64.7 ± 8.9**
Left Kidney	91.7 ± 1.8	65.7 ± 9.0	91.6 ± 1.8$^{\mathrm{ns}}$	65.1 ± 9.3**
Gall Bladder	82.6 ± 12.6	60.8 ± 15.4	83.8 ± 10.5**	60.1 ± 15.8*
Liver	95.1 ± 7.7	66.0 ± 8.8	95.1 ± 7.7$^{\mathrm{ns}}$	66.2 ± 8.6$^{\mathrm{ns}}$
Stomach	91.6 ± 6.5	53.1 ± 9.8	92.4 ± 6.2**	55.7 ± 9.7****
Aorta	72.1 ± 10.2	55.5 ± 10.1	74.2 ± 10.5****	57.5 ± 10.3**
Postcava (IVC)	77.2 ± 11.0	54.9 ± 9.5	77.7 ± 10.9*	57.5 ± 10.3**
Pancreas	78.8 ± 12.4	52.3 ± 8.1	79.3 ± 11.3***	55.2 ± 8.8****
Average	86.2 ± 7.7	60.6 ± 9.8	86.8 ± 7.3	61.8 ± 9.9

$^{\mathrm{ns}}\ P > 0.05$ $^{*}\ P \leq 0.05$ $^{**}\ P \leq 0.01$ $^{***}\ P \leq 0.001$ $^{****}\ P \leq 0.0001$

Table 7: **Generalization of AI models trained on AbdomenAtlas-8K.** We directly applied AI trained on AbdomenAtlas-8K (public) to JHH (unseen, private) and compared its performance with AI trained on JHH.

SwinUNETR [84]	Trained on JHH (private)		Trained on AbdomenAtlas-8K (public)	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	92.7 ± 12.2	76.7 ± 16.6	94.2 ± 4.7	73.1 ± 10.6
Right Kidney	92.6 ± 10.4	80.5 ± 11.6	90.8 ± 11.6	64.8 ± 10.9
Left Kidney	91.8 ± 9.2	78.8 ± 11.4	91.0 ± 4.3	65.3 ± 9.7
Gall Bladder	74.5 ± 23.9	54.1 ± 24.0	81.9 ± 13.4	57.2 ± 17.5
Liver	96.2 ± 1.1	69.5 ± 8.6	96.1 ± 1.0	65.2 ± 8.0
Stomach	91.7 ± 7.8	57.8 ± 14.4	93.1 ± 2.6	56.5 ± 10.1
Aorta†	87.6 ± 7.6	80.5 ± 11.7	73.1 ± 12.0	58.0 ± 12.7
Postcava (IVC)	70.4 ± 18.0	51.2 ± 17.2	77.9 ± 10.3	54.6 ± 10.5
Pancreas	65.8 ± 23.2	49.3 ± 17.4	81.1 ± 7.7	52.5 ± 8.1
Average	84.8 ± 12.6	66.5 ± 14.8	86.5 ± 7.5	60.8 ± 10.9

UNETR [28]	Trained on JHH (private)		Trained on AbdomenAtlas-8K (public)	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	89.9 ± 8.2	62.3 ± 18.6	94.0 ± 4.6	72.2 ± 11.1
Right Kidney	79.3 ± 15.2	58.7 ± 16.4	92.0 ± 4.2	63.3 ± 8.7
Left Kidney	83.6 ± 13.4	63.2 ± 14.8	91.5 ± 2.2	64.2 ± 9.6
Gall Bladder	72.4 ± 17.2	50.3 ± 15.8	81.3 ± 12.1	55.9 ± 16.7
Liver	93.4 ± 3.7	55.7 ± 12.8	96.0 ± 0.9	64.2 ± 7.8
Stomach	84.9 ± 10.0	38.8 ± 9.8	92.9 ± 2.6	53.1 ± 9.5
Aorta†	83.9 ± 9.3	71.6 ± 14.1	74.0 ± 12.6	57.8 ± 12.8
Postcava (IVC)	58.3 ± 20.1	41.2 ± 13.0	76.2 ± 11.1	52.3 ± 10.1
Pancreas	62.1 ± 19.7	43.2 ± 11.6	81.2 ± 7.9	52.6 ± 7.5
Average	78.6 ± 13.0	53.9 ± 14.1	86.6 ± 6.5	59.5 ± 10.4

U-Net [73]	Trained on JHH (private)		Trained on AbdomenAtlas-8K (public)	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	90.0 ± 12.5	72.0 ± 17.9	94.7 ± 2.8	74.0 ± 9.8
Right Kidney	92.3 ± 7.3	79.4 ± 11.2	91.8 ± 6.2	63.5 ± 9.2
Left Kidney	89.7 ± 10.4	74.4 ± 14.1	91.5 ± 2.6	65.7 ± 9.5
Gall Bladder	76.3 ± 17.7	56.0 ± 20.0	82.8 ± 11.2	58.5 ± 14.7
Liver	95.1 ± 2.4	63.7 ± 11.5	96.1 ± 0.9	64.2 ± 7.9
Stomach	90.8 ± 6.3	53.1 ± 13.4	93.2 ± 2.9	56.0 ± 9.8
Aorta†	84.6 ± 12.4	76.2 ± 14.7	74.3 ± 11.1	57.4 ± 12.4
Postcava (IVC)	73.0 ± 14.3	50.5 ± 17.4	78.2 ± 10.1	55.1 ± 10.5
Pancreas	71.2 ± 17.6	52.6 ± 12.8	82.7 ± 6.0	54.2 ± 8.0
Average	84.8 ± 11.2	64.2 ± 14.8	87.3 ± 6.0	61.0 ± 10.2

SegResNet [12]	Trained on JHH (private)		Trained on AbdomenAtlas-8K (public)	
	mDSC (%)	mNSD (%)	mDSC (%)	mNSD (%)
Spleen	95.2 ± 2.3	78.8 ± 9.5	94.6 ± 2.8	74.1 ± 9.8
Right Kidney	93.9 ± 6.5	80.3 ± 8.7	92.0 ± 5.9	65.5 ± 8.0
Left Kidney	92.7 ± 5.8	78.2 ± 8.7	91.8 ± 1.6	65.7 ± 7.9
Gall Bladder	80.4 ± 13.0	55.7 ± 16.4	82.8 ± 11.0	58.2 ± 16.3
Liver	90.2 ± 2.9	58.1 ± 7.5	95.8 ± 1.4	63.4 ± 8.3
Stomach	92.8 ± 5.1	55.2 ± 12.3	93.3 ± 2.9	55.6 ± 9.4
Aorta†	85.4 ± 6.9	75.2 ± 11.5	73.9 ± 12.2	55.5 ± 13.1
Postcava (IVC)	75.4 ± 9.8	45.5 ± 13.4	77.2 ± 10.6	53.2 ± 10.2
Pancreas	82.6 ± 6.8	56.9 ± 9.7	81.5 ± 6.5	52.6 ± 7.8
Average	87.6 ± 6.6	64.9 ± 10.9	87.0 ± 6.1	60.4 ± 10.1

† During the training process using AbdomenAtlas-8K, the ground truth of **Aorta** exhibits variation across different public datasets, resulting in the AI's inability to learn as anticipated. Conversely, when training on the JHH dataset, the annotation protocol of **Aorta** remains relatively consistent.

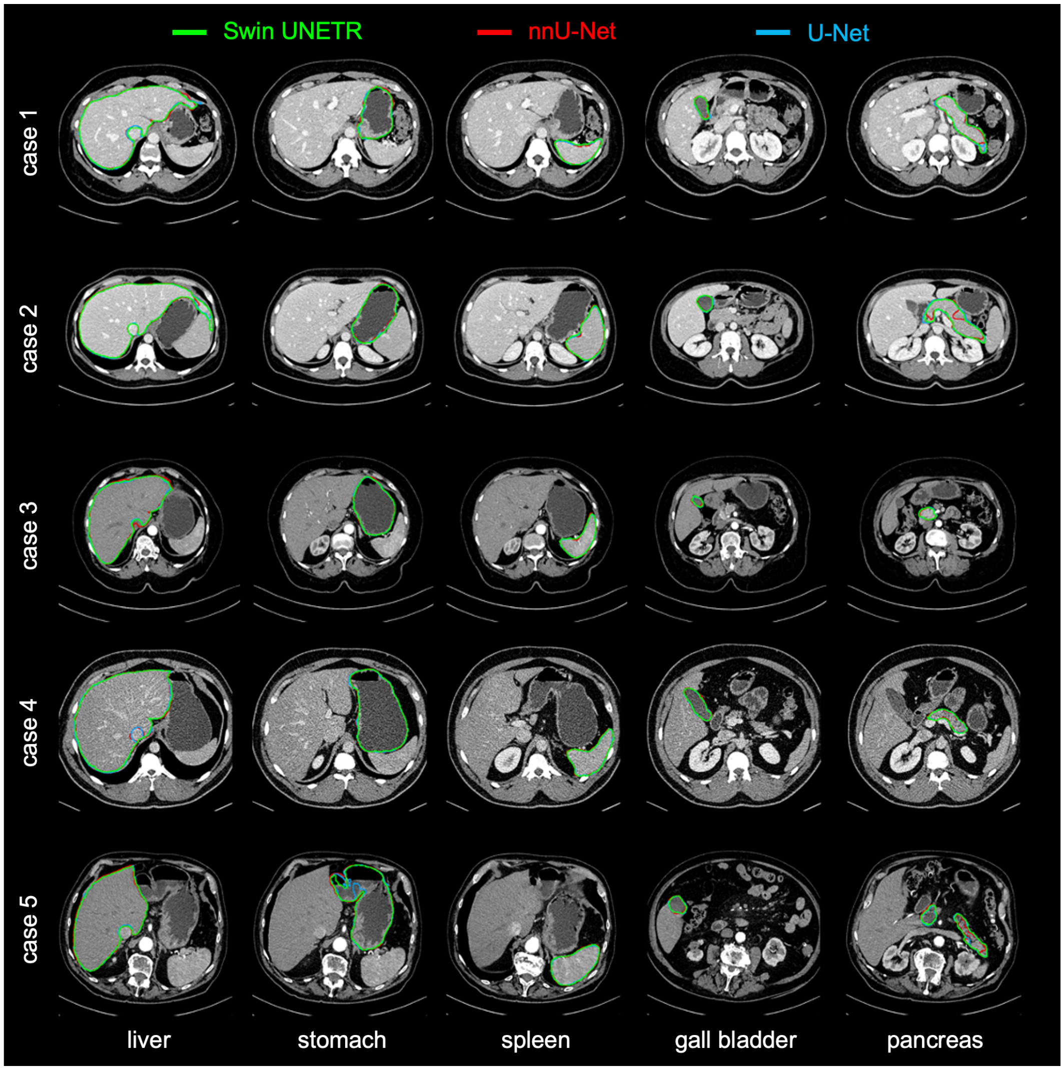


Figure 10: [Better viewed in color and zoomed in for details] **Variance in model predictions.** Our AbdomenAtlas-8K comprises an ensemble of three distinct segmentation architectures, thereby obviating the potential influence of architectural bias. As such, our AbdomenAtlas-8K stands out for its robustness and objectivity.

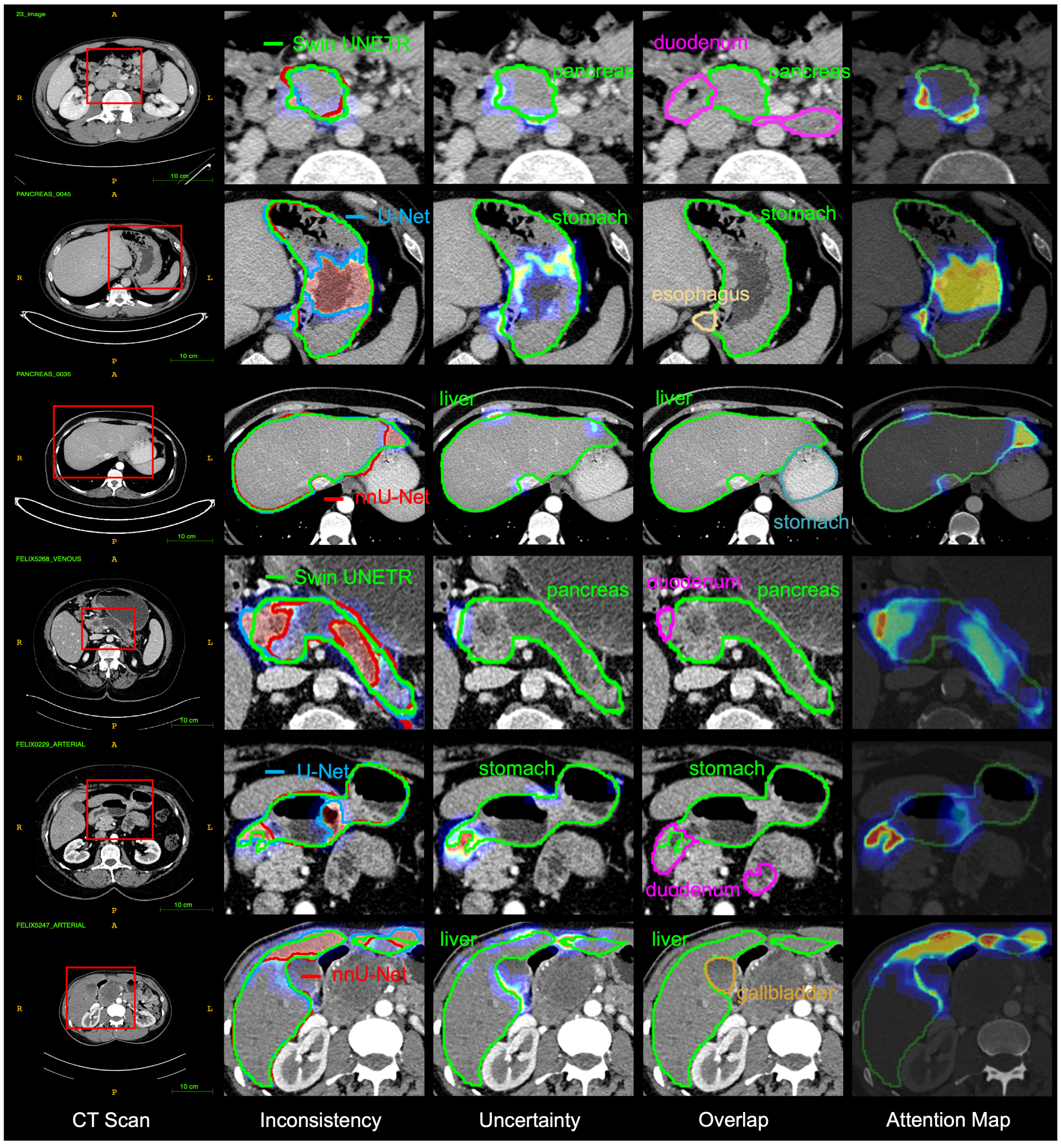


Figure 11: **Examples of attention map generation.** The attention map helps our annotator quickly and effectively locate regions with a high risk of prediction errors.

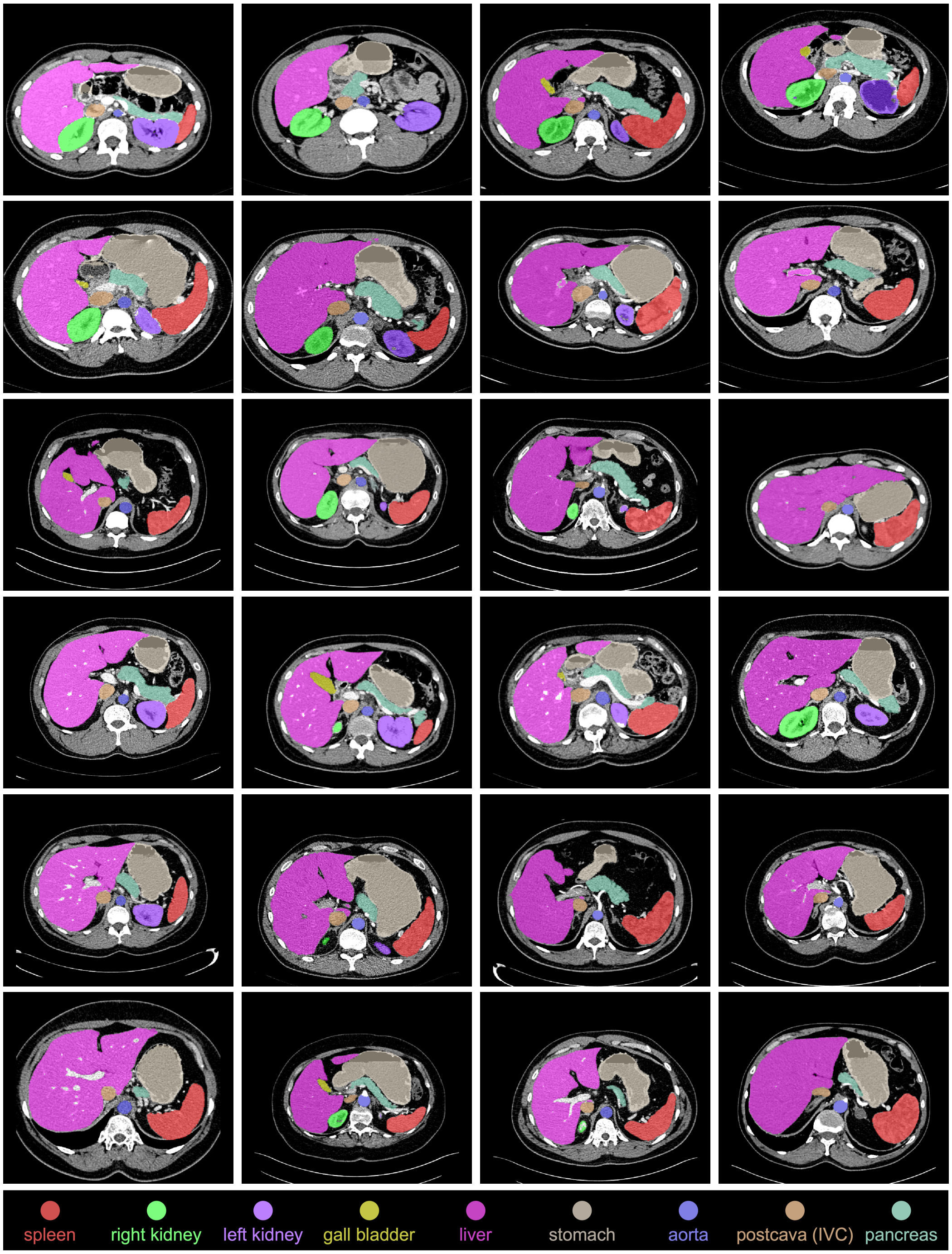


Figure 12: [Watch the animations by clicking them, better viewed with Acrobat/Foxit Reader] **Example annotated slices from AbdomenAtlas-8K**. AbdomenAtlas-8K includes annotations for eight organs, treating the left and right kidneys as a single organ.