

# Connectivity-Preserving Losses for 3D Coronary Artery Segmentation

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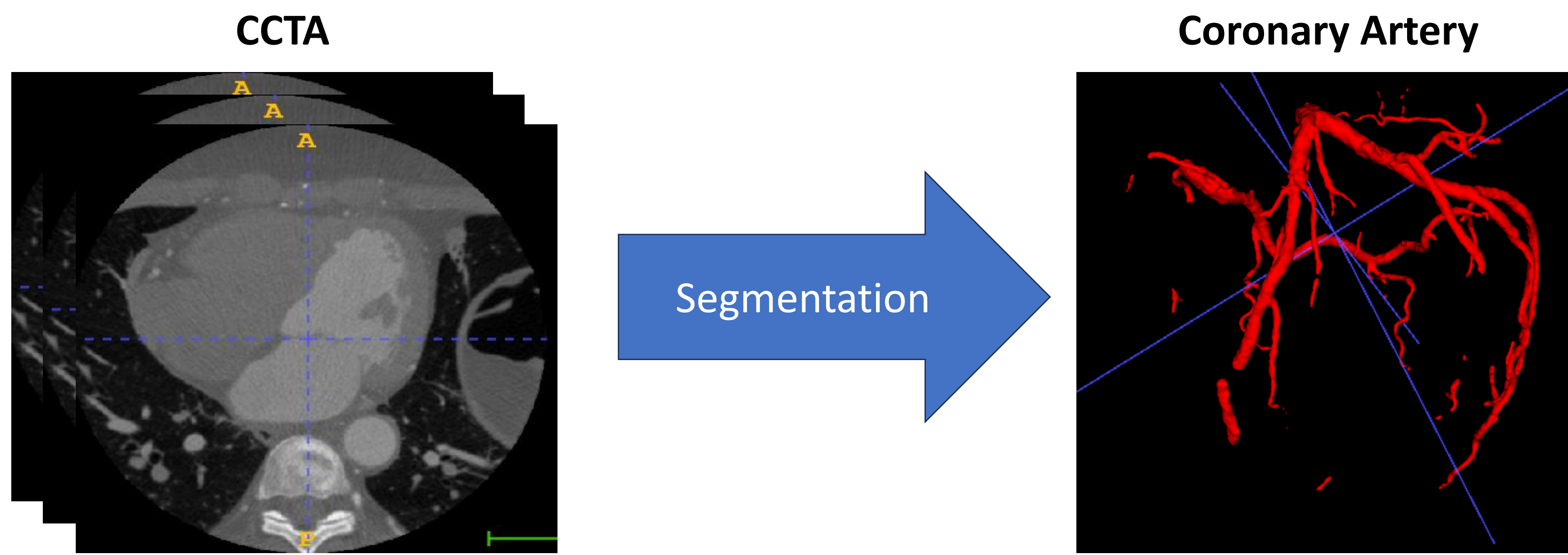


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## 1. The Connectivity Problem in Coronary Artery Segmentation



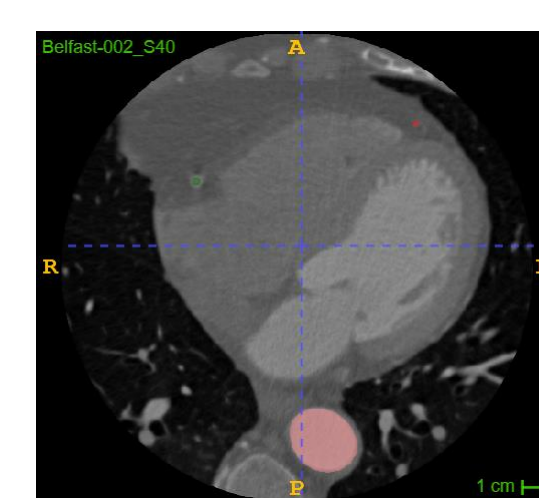
### Motivation and Research Question

- Connectivity of segmentations is important for downstream tasks
- Existing approaches address connectivity but rely on complex multi-staged pipelines
- Errors potentially accumulate and propagate across stages, making correction difficult
- Connectivity-preserving losses exist, but their efficacy for coronary artery trees remains to be established

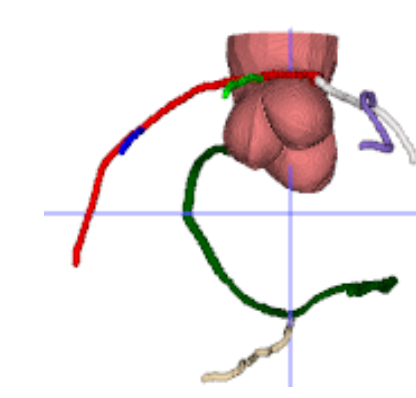
What are the benefits and challenges of integrating **connectivity-preserving losses** into a **standard architecture** such as **nnU-Net** for coronary artery tree segmentation compared to using **generic losses**?

### Hypotheses for Issues with Baseline Methods

- ✗ No sufficiently publicly fully annotated data cohort available
- ✗ Dimension of coronary arteries at edge of CT imaging resolution
- ✗ Highly variable topology makes integrating prior shape knowledge challenging
- ✗ Generic losses under-penalize disconnected or thin segments



Voxel Masks



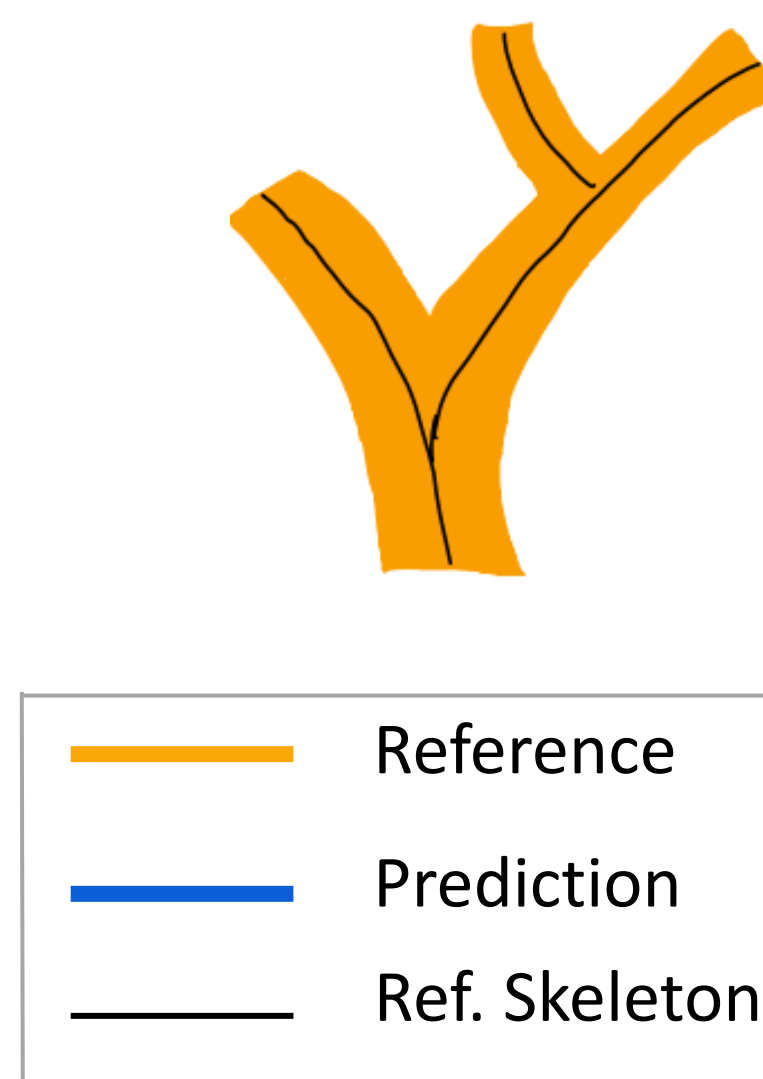
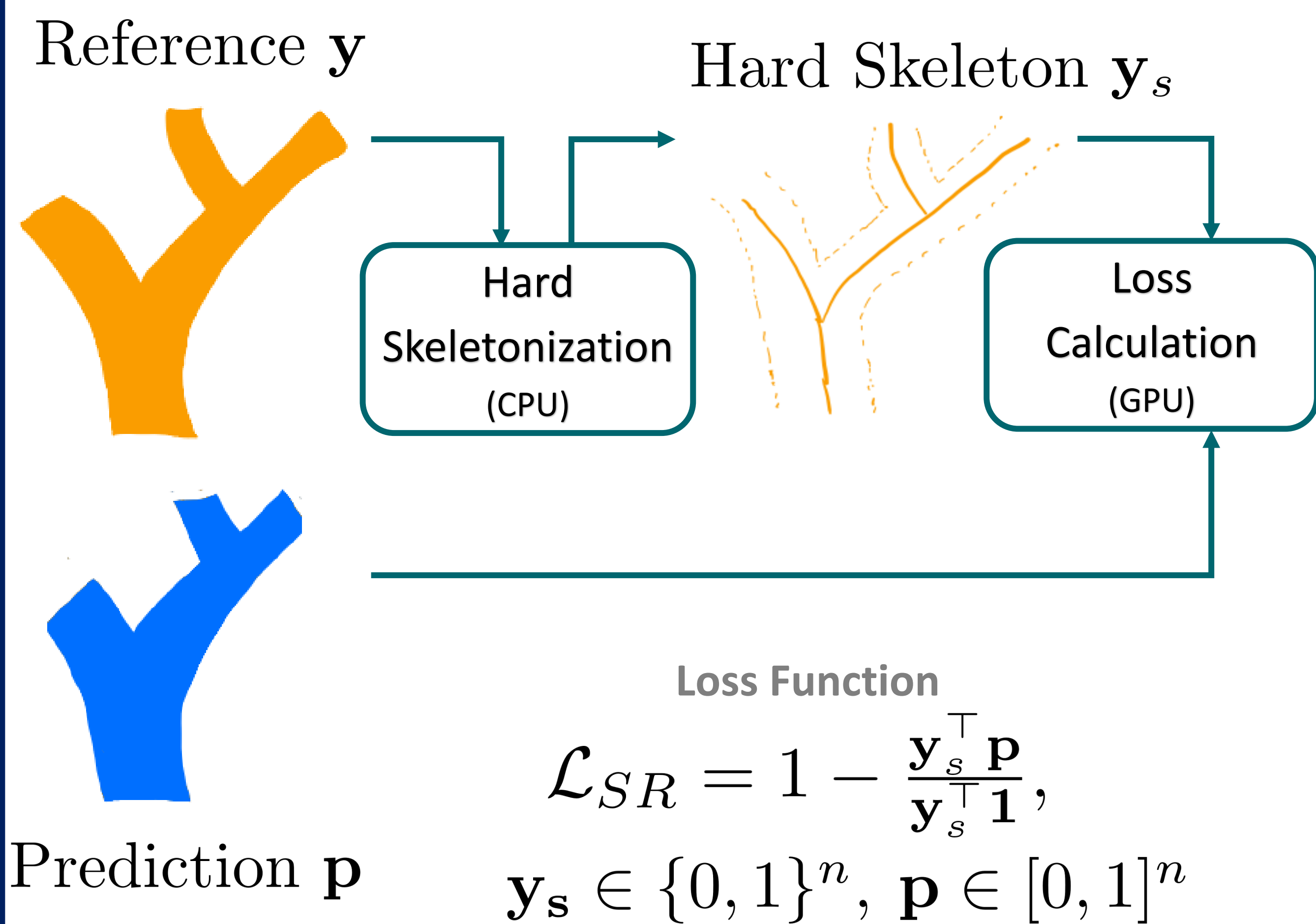
Rendered Volumes

### Dataset

	ASOCA	In-House
Amount	40	58
Diseased	20	38
No stenosis	20	20

## 2. Preserving Vessel Connectivity

### Skeleton Recall (SR) Loss [1]



Metric Score Interpretation:

- 1 : no penalization
- <1 : penalization
- : desired behaviour
- : undesired behaviour

### Comparison of DICE vs. SR Loss under Typical Failure Modes

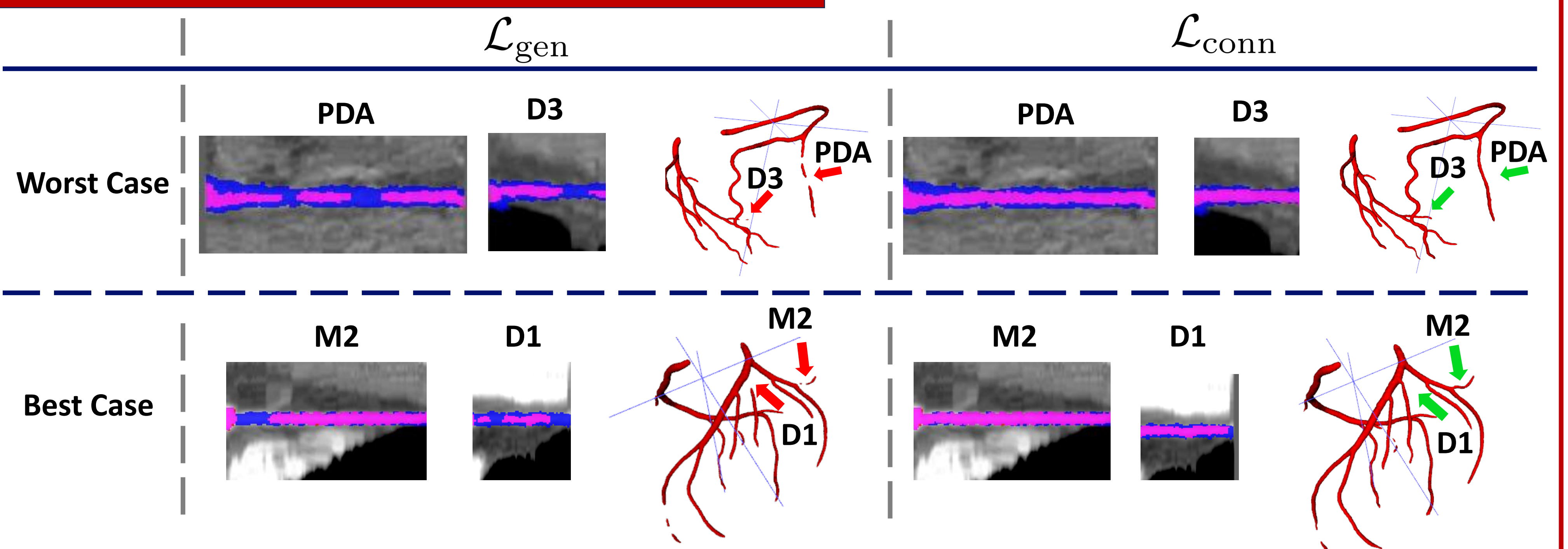
Failure Mode	DICE	SR
Perfect Match	1	1
Thickness	<1	1
Over-completeness	<1	1
Connectivity	≈1	<1

## 3. Impact of Connectivity-Preserving Loss

$$\mathcal{L}_{gen} = \mathcal{L}_{Dice} + \mathcal{L}_{CE}$$

$$\mathcal{L}_{conn} = \mathcal{L}_{generic} + 1 \cdot \mathcal{L}_{SR}$$

Metric	$\mathcal{L}_{gen}$	$\mathcal{L}_{conn}$
Dice	79.11 [74.19, 81.46]	77.99 [74.40, 81.38]
clDice	87.58 [84.46, 90.78]	86.71 [82.91, 89.14]
$\epsilon$ Dice	94.17 [91.77, 95.92]	93.58 [91.43, 95.24]
clTPR	89.89 [84.49, 95.41]	93.86 [90.54, 97.60]
TP $\beta_0$ E	2 [1, 3]	1 [0, 2]
GC	1 [0, 2]	1 [0, 1]



## 4. Conclusion: Significantly Improved Connectivity

Criteria	Connectivity Improvement	No overlap drop	No computational overhead	Easy to implement	Architecture agnostic
$\mathcal{L}_{conn}$	✓	✓	✓	✓	✓

## 5. References & Contact

[1] Y. Kirchhoff et al., "Skeleton recall loss for connectivity conserving and resource efficient segmentation of thin tubular structures," in ECCV 2024.

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