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Comparaison de fonctions de coût pour la détection automatique de fil guide sur des images fluoroscopiques de Cholangiopancréatographie Rétrograde Endoscopique

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Comparison of Loss Functions for Guidewire Automatic Detection on a Limited Dataset of Fluoroscopic Images for Endoscopic Retrograde CholangioPancreatography

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MEDICAL CONTEXT

Endoscopic Retrograde CholangioPancreatography (ERCP)

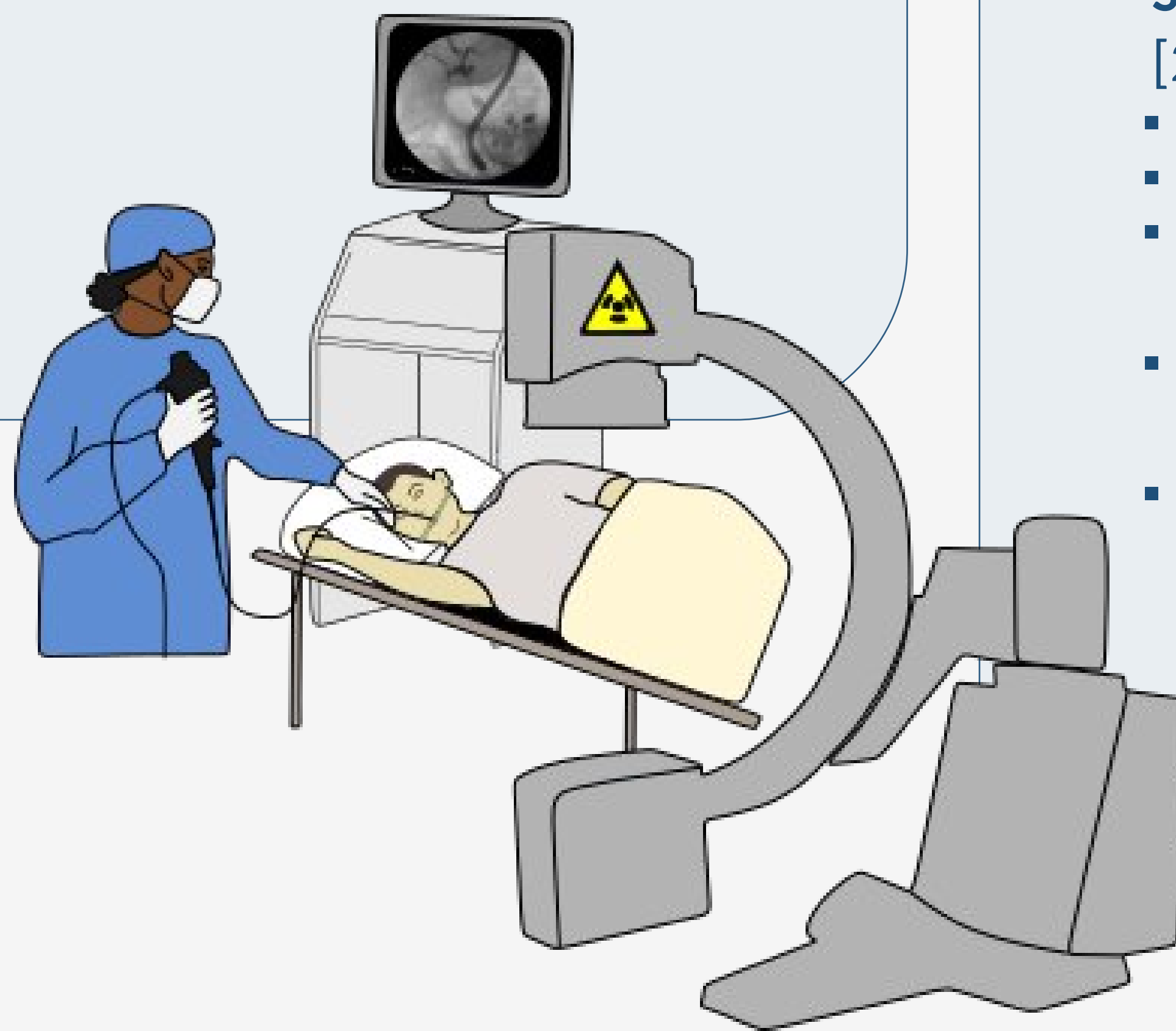
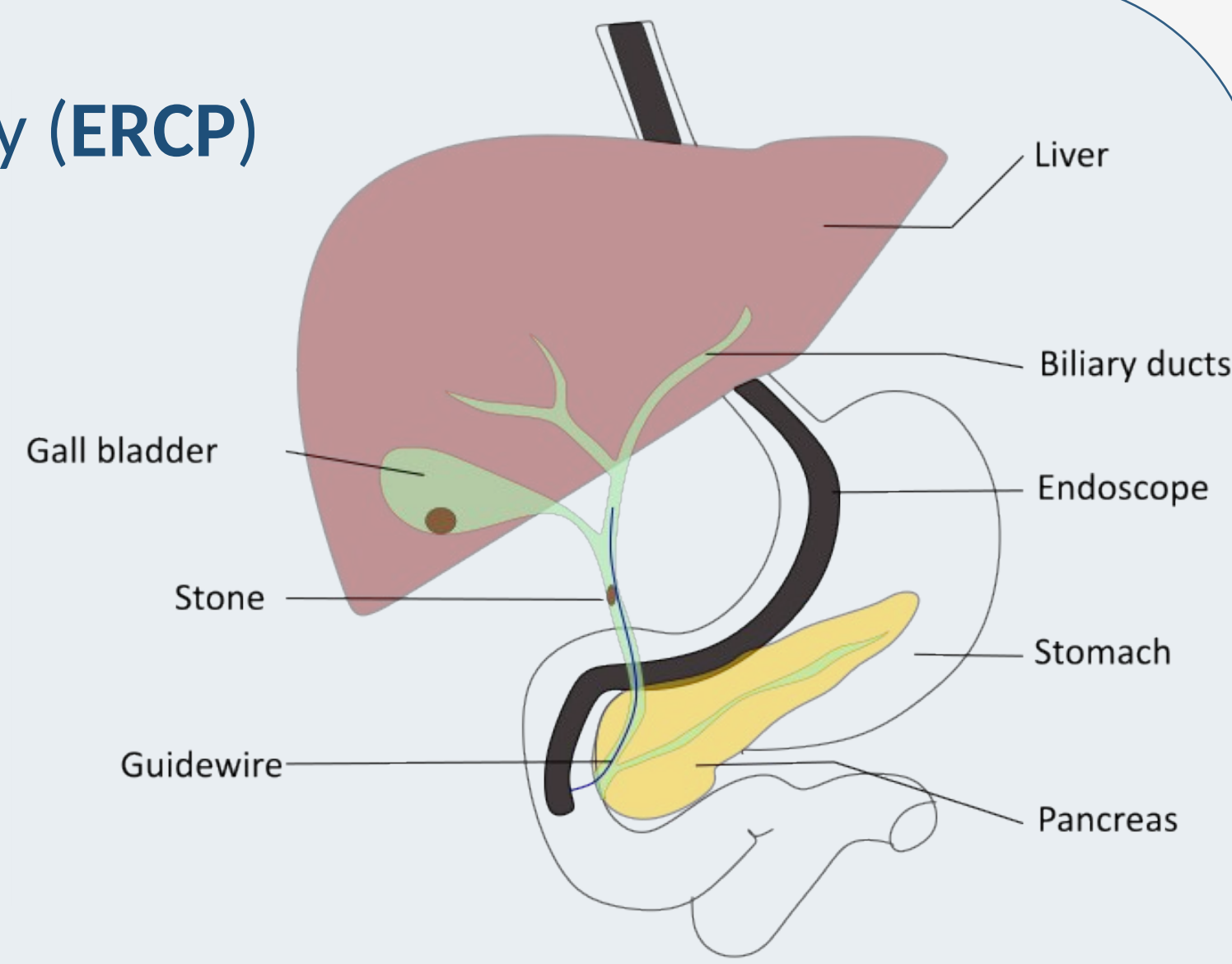
- Draining of the bile ducts
- Minimally invasive procedure

Problems

- High inter-patient anatomical variability
- Loss of 3D information with 2D X-ray
- Contrast agent increases the risk of cholangitis

State of the art

- None in ERCP
- Similar field: Endovascular (different images)
- U-Net paired with another method



METHODS

2 Datasets :

- Saint-Antoine (SA)
- Henri Mondor (HM)

| Dataset | Image Size | Total nb of images | Train | Validation | Test |
|---------|-------------|--------------------|-------|------------|------|
| SA | 1024 x 1024 | 47 | 31 | 6 | 10 |
| HM | 1536 x 1536 | 73 | 50 | 13 | 10 |

- Baseline: nnU-Net [1]
- Study of different loss functions with U-Net [2]
 - Dice
 - Dice + Cross Entropy
 - Tversky [3]
 - Weight differently false positives and false negatives
 - Dice + Focal [4]
 - Adapted for class imbalance
 - Dice + Vessel [5]
 - Adapted for segmentation of thin and elongated structures

Training

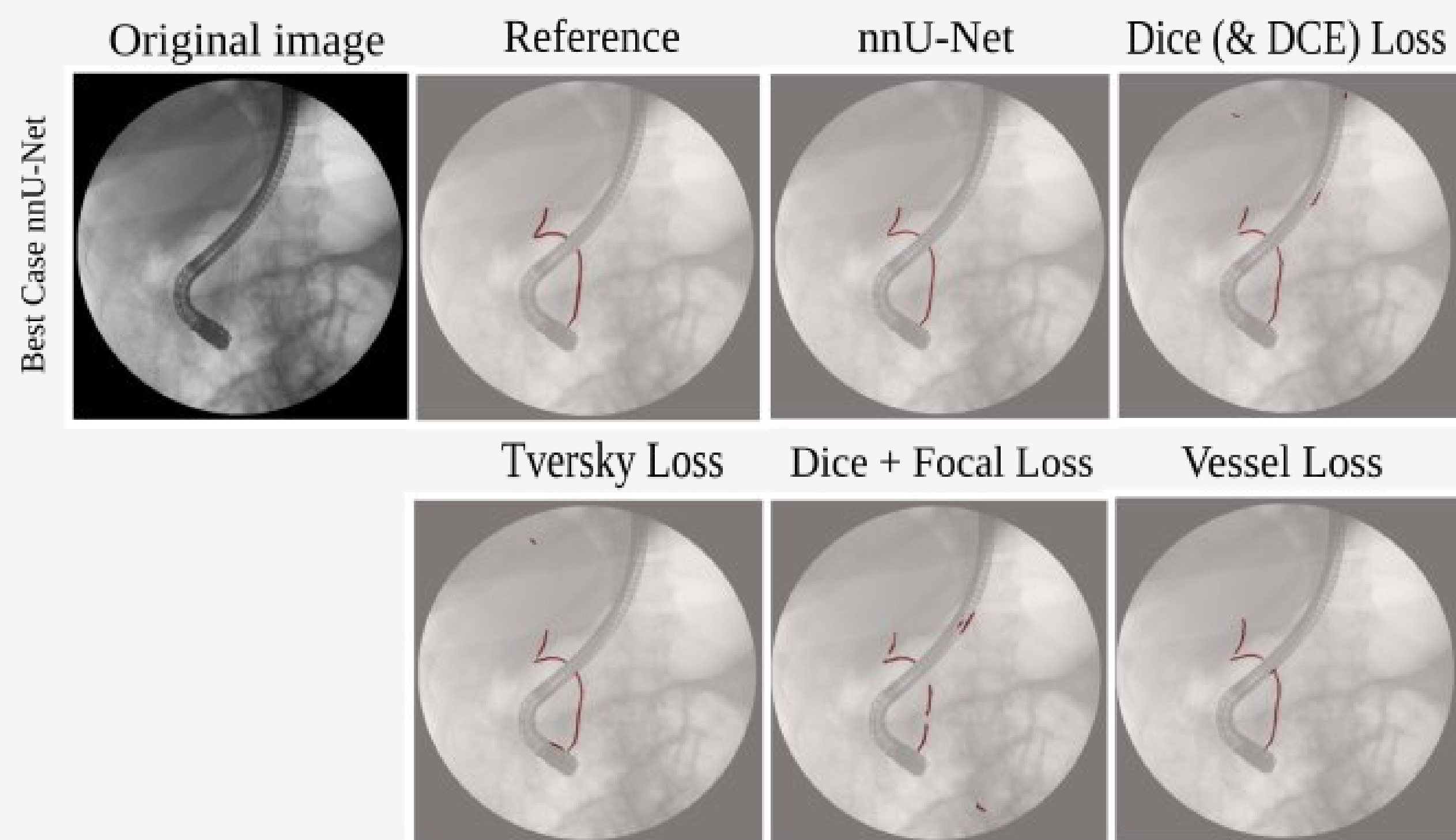
- 3-fold cross-validation
- SA dataset, 500 epochs
- HM dataset pretrained on SA

OBJECTIVES

To segment the guidewire on 2D X-ray fluoroscopy with a limited dataset with varied loss functions

RESULTS

Saint-Antoine Dataset

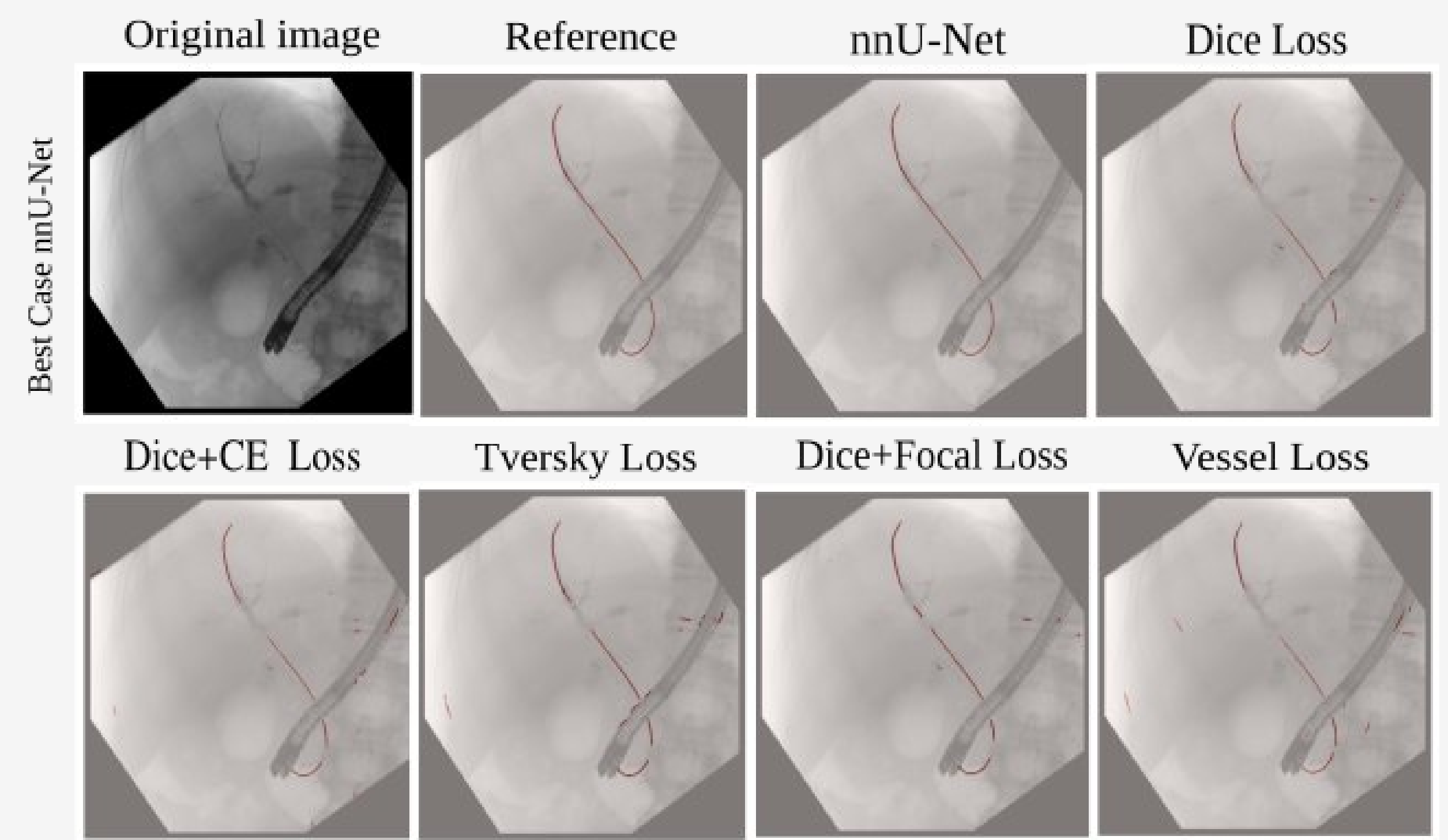


| METHOD | DICE | CIDice | TVERSKY | MCC | HD | Diff CC |
|----------------|-------------|-------------|-------------|-------------|-----------|---------|
| nnU-Net [1] | 0.78 ± 0.04 | 0.94 ± 0.05 | 0.74 ± 0.05 | 0.89 ± 0.02 | 25 ± 28 | 1 |
| Dice/Dice + CE | 0.59 ± 0.06 | 0.69 ± 0.09 | 0.57 ± 0.04 | 0.80 ± 0.03 | 336 ± 107 | 6 |
| Tversky | 0.65 ± 0.03 | 0.76 ± 0.03 | 0.61 ± 0.03 | 0.83 ± 0.01 | 233 ± 45 | 3 |
| Dice + Focal | 0.66 ± 0.03 | 0.74 ± 0.01 | 0.64 ± 0.02 | 0.83 ± 0.01 | 271 ± 48 | 4 |
| Dice + Vessel | 0.61 ± 0.04 | 0.72 ± 0.05 | 0.57 ± 0.03 | 0.81 ± 0.02 | 242 ± 71 | 4 |

For nnU-Net: Training time = 33 hours & Inference time = 6.2s/ image

For any U-Net with specific loss function: Training time = 3 hours & Inference time = 0.69s/ image

Henri Mondor Dataset



| METHOD | DICE | CIDice | TVERSKY | MCC | HD | Diff CC |
|---------------|-------------|-------------|-------------|-------------|-----------|---------|
| nnU-Net [1] | 0.79 ± 0.05 | 0.90 ± 0.05 | 0.79 ± 0.05 | 0.89 ± 0.03 | 92 ± 215 | 2 |
| Dice | 0.64 ± 0.04 | 0.72 ± 0.06 | 0.60 ± 0.08 | 0.83 ± 0.02 | 408 ± 5 | 6 |
| Dice + CE | 0.65 ± 0.01 | 0.75 ± 0.04 | 0.63 ± 0.02 | 0.82 ± 0.01 | 625 ± 183 | 7 |
| Tversky | 0.58 ± 0.01 | 0.70 ± 0.05 | 0.58 ± 0.02 | 0.79 ± 0.02 | 619 ± 43 | 8 |
| Dice + Focal | 0.62 ± 0.03 | 0.70 ± 0.03 | 0.60 ± 0.04 | 0.81 ± 0.01 | 376 ± 40 | 6 |
| Dice + Vessel | 0.61 ± 0.01 | 0.69 ± 0.01 | 0.59 ± 0.01 | 0.81 ± 0.01 | 582 ± 72 | 8 |

For nnU-Net: Training time = 52 hours & Inference time = 9.4 s/ image

For any U-Net with specific loss function: Training time = 4.5 hours & Inference time = 0.98 s/ image

CONCLUSION & CLINICAL APPLICATION

- Simple and well known method
- Comparison of multiple loss functions
- Reduce training and inference time by 10
- Result of segmentation usable for 2D/3D fusion to predict in which bile duct the guidewire is and improve navigation



References

[1] Isensee, *Nature Methods*, 2020 [2] Ronneberger, *MICCAI*, 2015 [3] Salehi, *MICCAI*, 2017 [4] Lin, *ICCV*, 2017 [5] La Barbera, *Medical Image Analysis*, 2023