Convolutional Neural Net Transformer (CNNT) for free-breathing real-time cine imaging

A novel architecture for real-time cine imaging at higher accelerations

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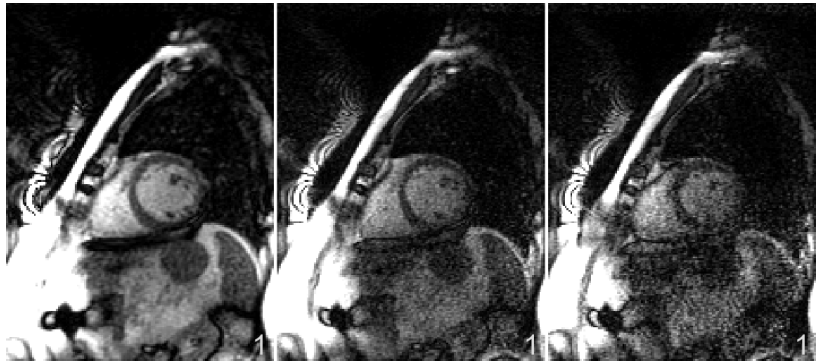
Declaration of Interests

- **No conflicts to declare**

Background: Task

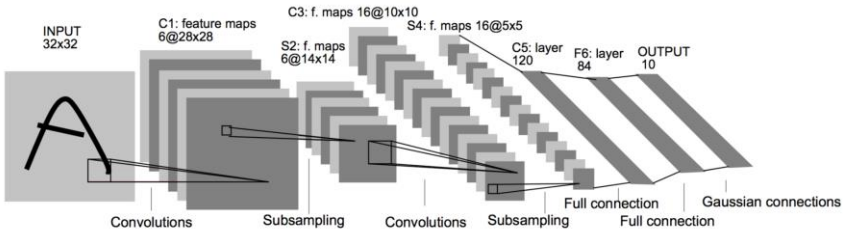
- Real-time cine imaging
  - Does not require breath-holding
  - Can be used in the presence of irregular heartbeats
- To maintain good temporal and spatial resolution, higher acceleration (4x,5x,6x parallel imaging) is required

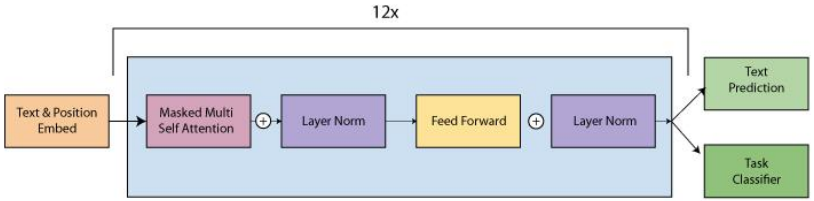


Background: CNN + Transformers

- **Convolution Neural Nets**
  - Commonly used for 2D data (images)
  - Efficient with parameters
  - Good in reading spatial dependencies
  - Limited learning of temporal relations

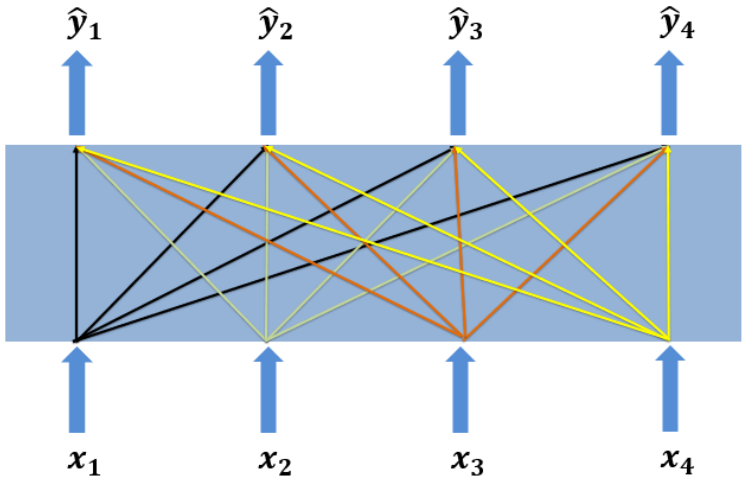
- **Transformers**
  - Commonly used with sequence data
  - Can capture long range temporal dependencies
  - Uses attention mechanism for faster training across time





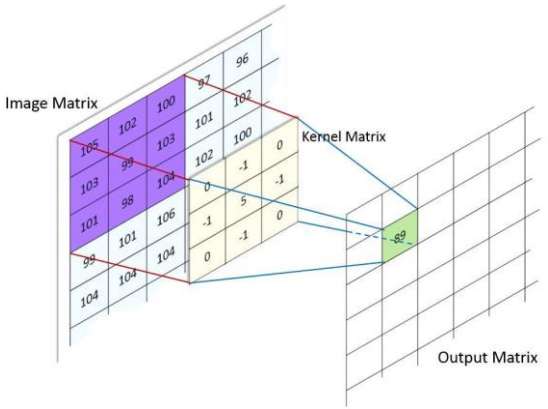
Attention in transformers

- **Baseline and most SotA transformers use linear layers**
  - To map inputs to learnable matrices (Key, Query and Value)



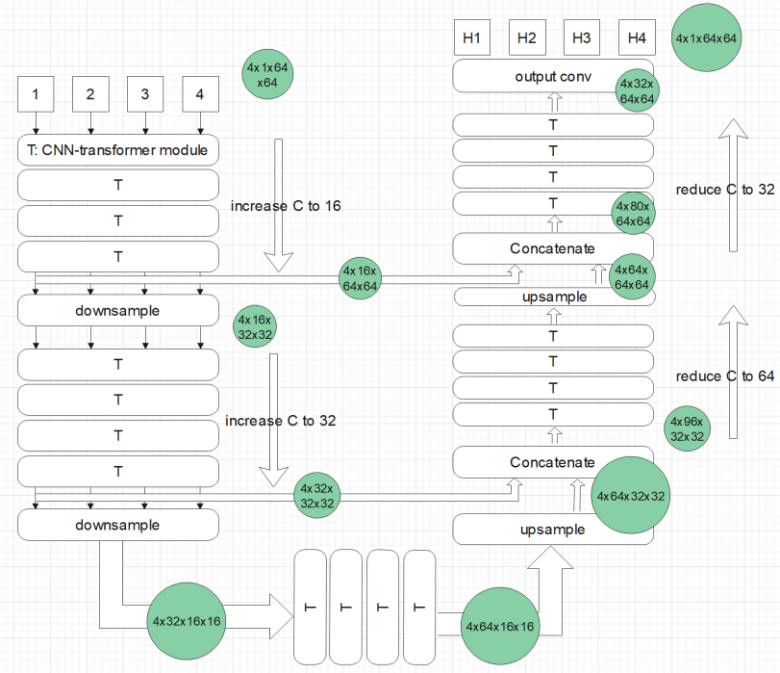
Linear to Conv attention

- **We propose: replace linear layer mappings to convolution layers instead**
  - Heavily reduces the effective parameters
  - Makes use of learning spatial correlations as CNNs
  - Can control the number of channels
  - CNNT layer (Convolutional Neural Network Transformer layer)

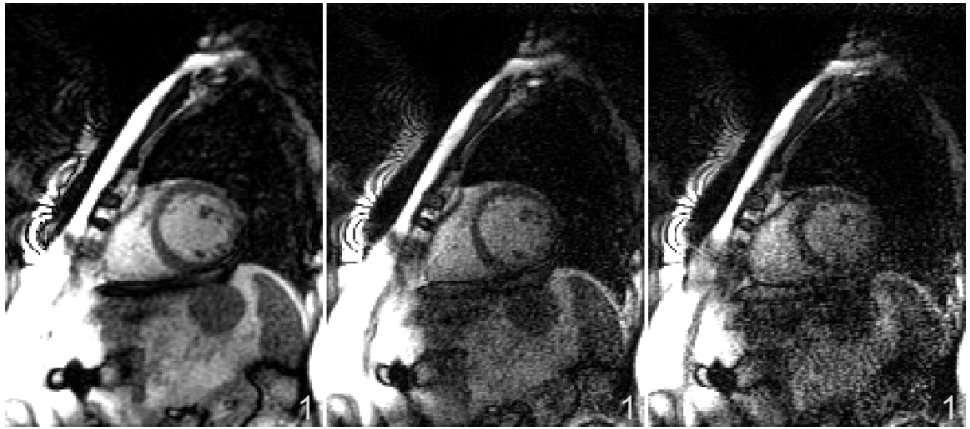


CNNT Unet

- **Unets have proven to work well in medical imaging**
  - Use up/down sampling to control spatial resolution
  - Skip connections for long-term gradient flow
- **Stack CNNTs per block**
  - Takes 2D+T
  - Outputs 2D+T
  - Variable sized inputs



Data acquisition



- FOV 360×270mm2, flip angle 50°
- R4 acceleration
  - Matrix size: 160x90
  - Temporal resolution: 40ms
- R5 acceleration
  - Matrix size: 192x108
  - Temporal resolution: 42ms
- R6 acceleration
  - Matrix size: 192x108
  - Temporal resolution: 35ms

Raw data

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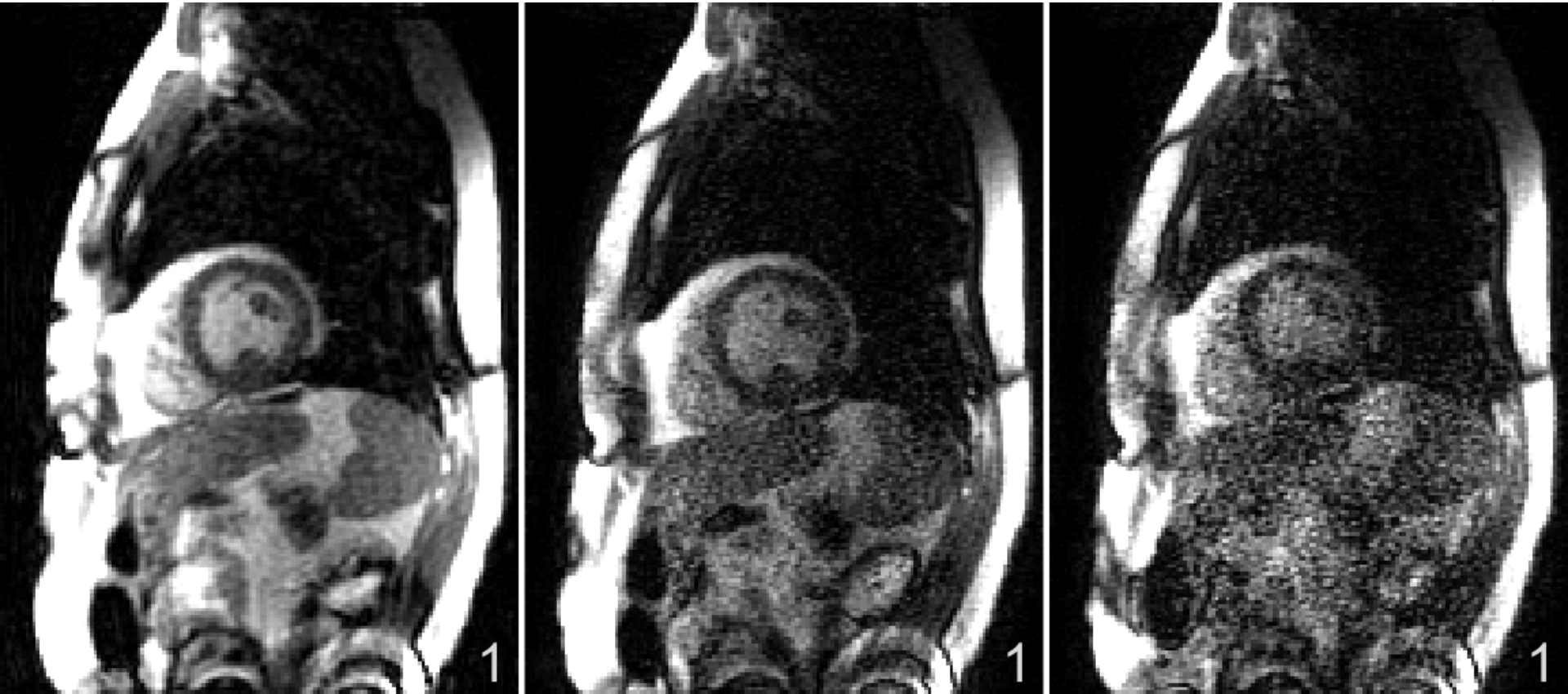

Result: CNNT Unet

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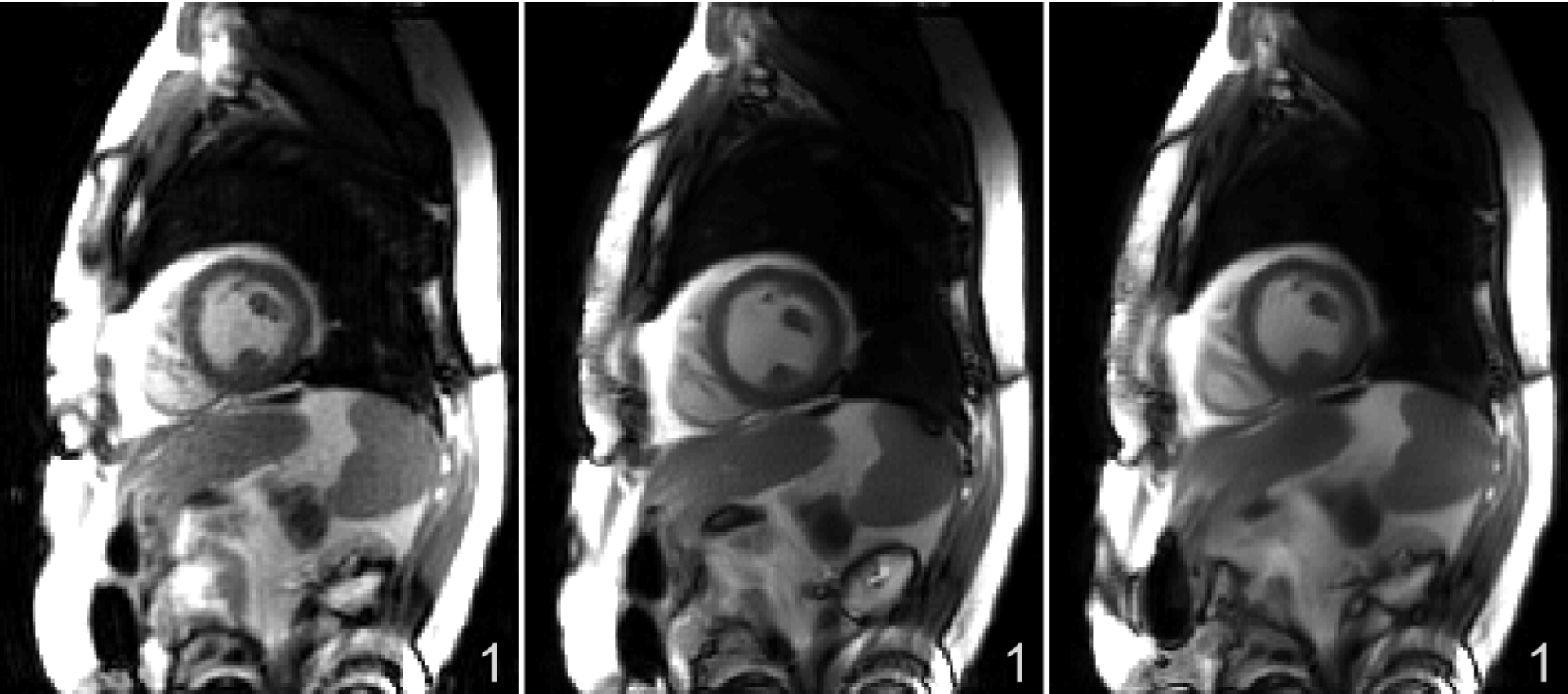

Result: 2D Unet

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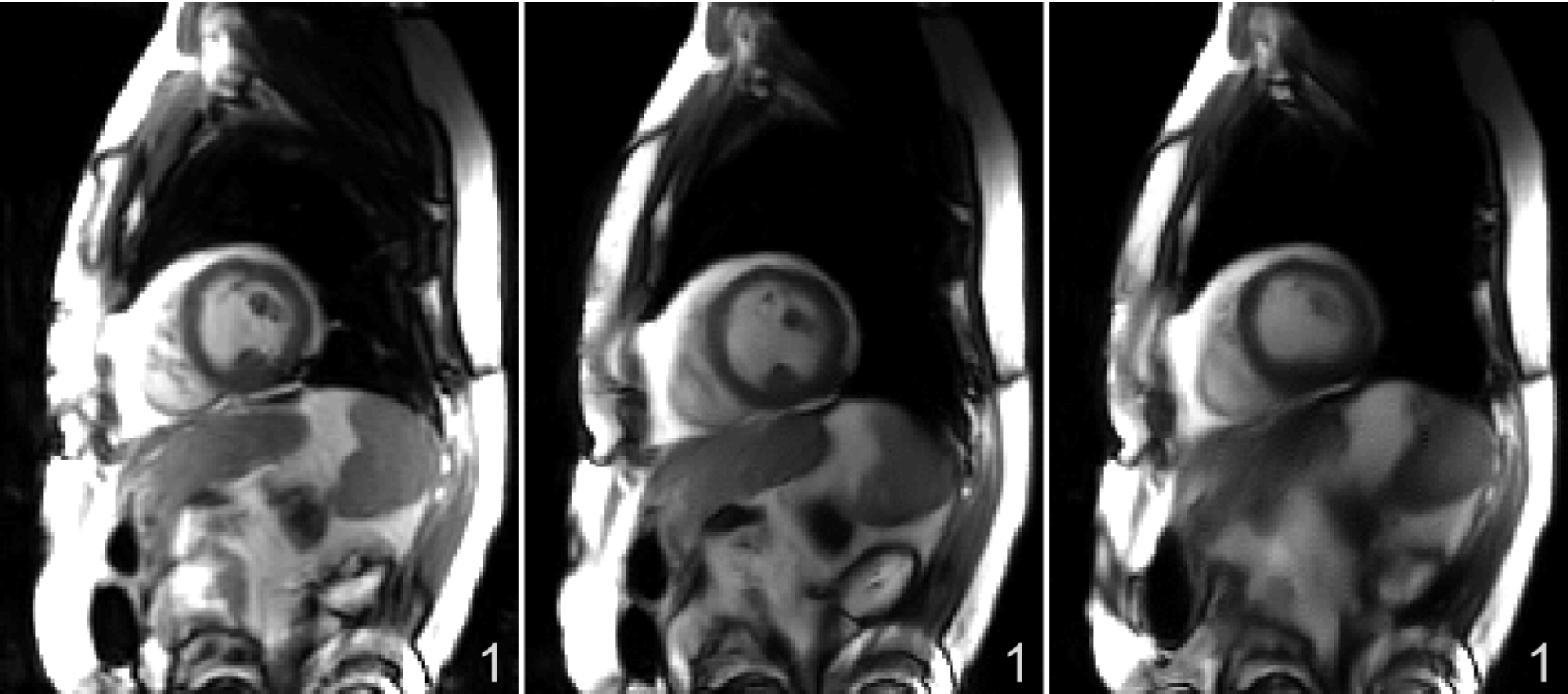
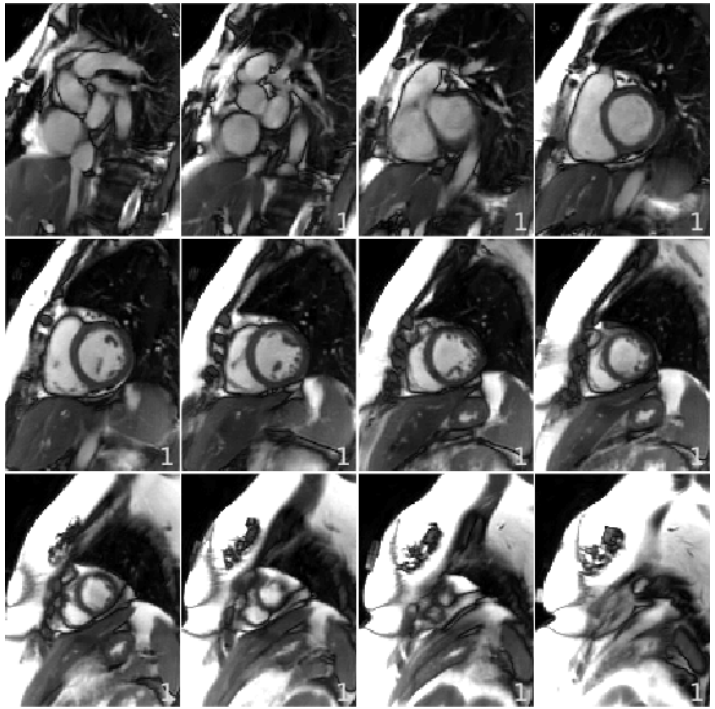


Results

- **Comparison between standard TGRAPPA and CNNT for N=10 patients on Regions of Interest of Blood and Myocardium**

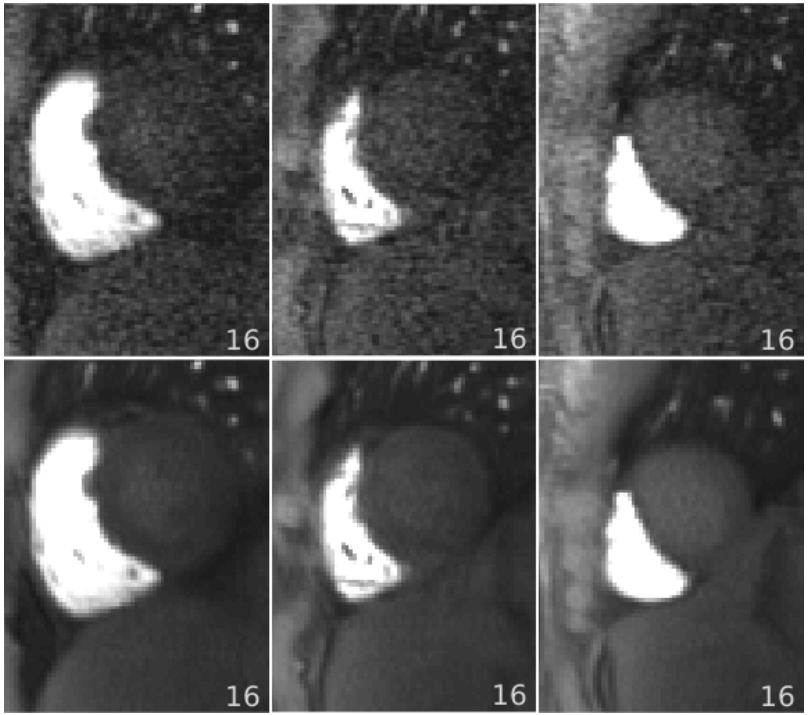
Signal-to-noise ratio	R4		R5		R6	
	TGRAPPA	CNNT	TGRAPPA	CNNT	TGRAPPA	CNNT
Blood	32.4±10.7	54.9±16.0	13.1±4.97	43.9±12.7	8.60±3.08	31.9±8.84
% increase from TGRAPPA	-	**170 %**	-	**335%**	-	**371%**
Myocardium	13.4±4.77	44.9±11.7	5.41±1.91	34.3±8.43	3.49±1.21	28.9±6.44
% increase from TGRAPPA	-	**335 %**	-	**634%**	-	**828%**
p-value	<1e-5 for both blood and myocardium		<1e-5		<1e-5	

Results: RetroCine



- Retro-gated BSSPF Cine
- 30ms temporal resolution
- R=4 acceleration
- Matrix size 256x144, FOV 360x270mm2
- 3s breath-hold per slice

Results: High Resolution Perfusion



- Free-breathing perfusion
- 1.5T scanner
- Spatial resolution 256x144
- FOV 360x270m2
- R=4 acceleration

Conclusion

- **We propose a novel architect: Convolution Neural Network Transformer (CNNT)**
- **CNNT Unet outperforms current practices by a significant margin in the image enhancement task**
- **Suitable for temporal CMR imaging**
- **Opens doors for improvements in other imaging applications**
  - RetroCine, Perfusion, T1/T2 mapping, Flow imaging etc.