Med-SeAM: Medical Context Aware Self-Supervised Learning Framework for Anomaly Classification in Knee MRI

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INTRODUCTION

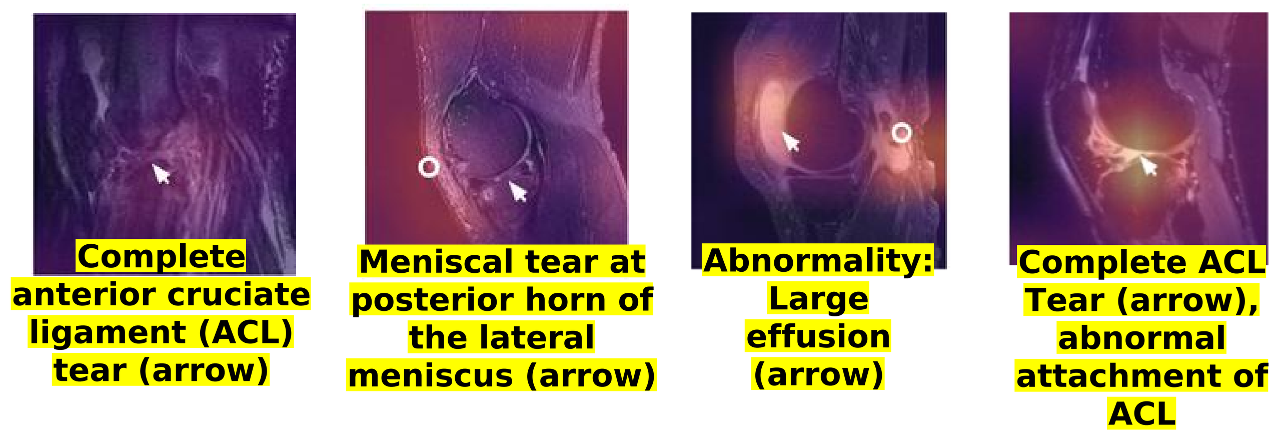
The prevalence of meniscal tears is 12% to 14%, while the occurrence of ACL tears is 4% to 6% annually.

CHALLENGES

1. **Obtaining high-quality slice labels for diagnosing disorders from MRI volumes is challenging in medical settings.**

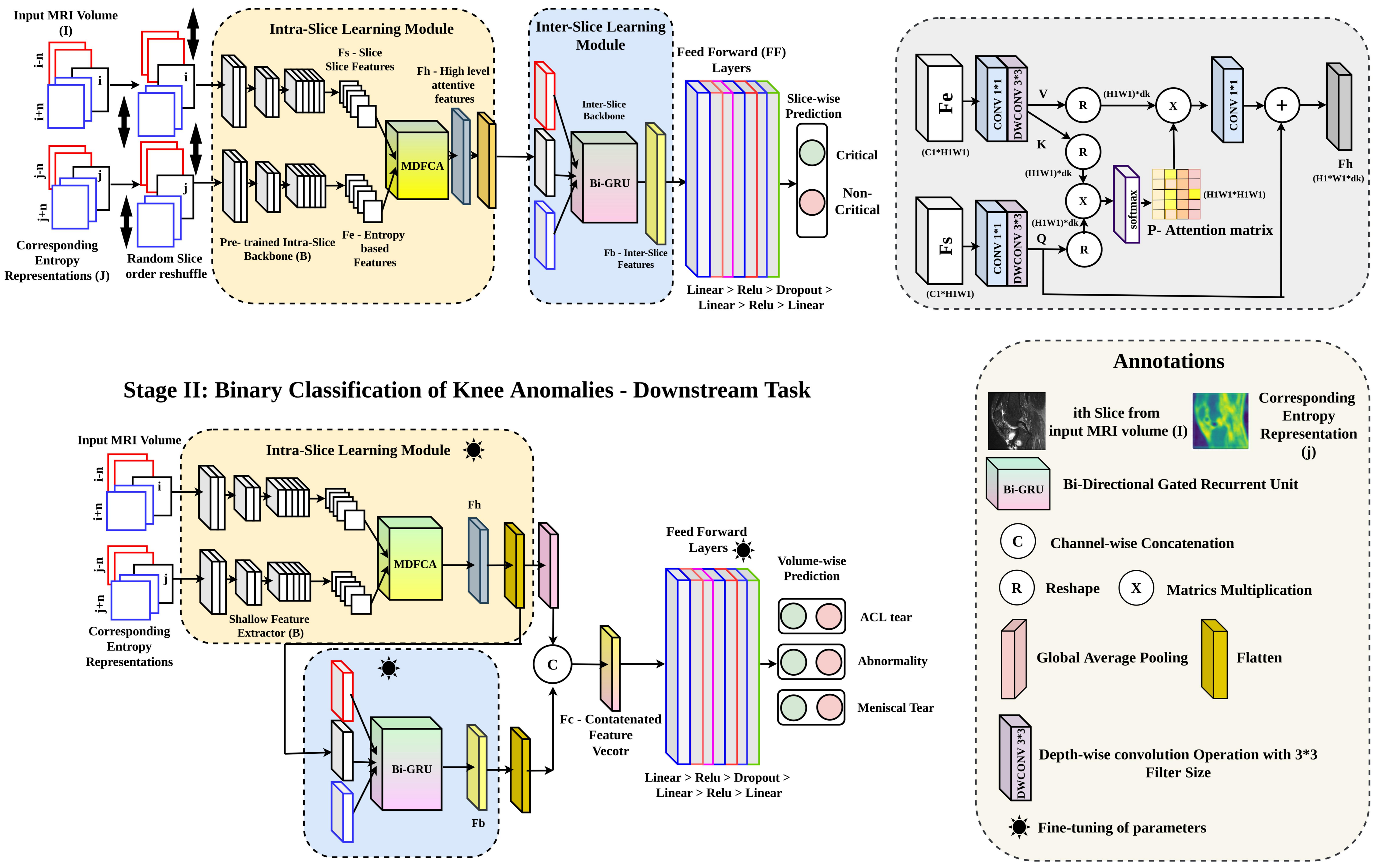
2. **Current self-supervised methods rely on simplistic label assignments for pretext tasks.**

3. **Medical imaging poses challenges for deep learning due to grayscale nature, non-differential spatial context, and small ROIs relative to image dimensions.**



PROPOSED SCHEME

Figure 1: Schematic of proposed Med-SeAM framework



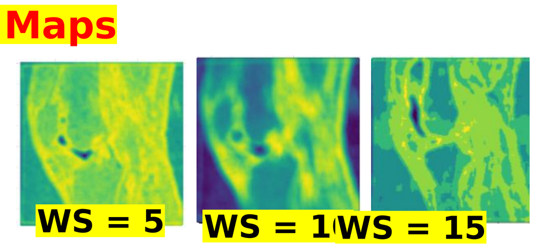
CONTRIBUTIONS

Key Strategy of the Dual Stage Proposed Med-SeAM: To learn intra- and inter-slice contexts from MRI volume in sequential manner.

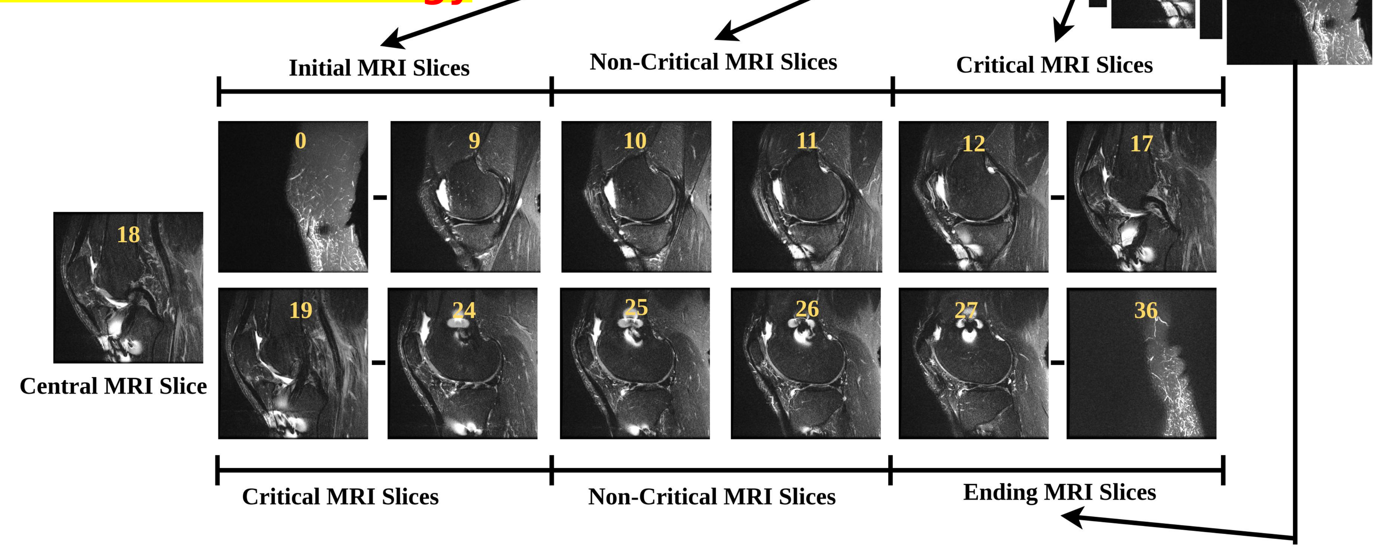
Principal idea of Novel Disease Context Learning (DCL) as pretext task is to classify the critical and non-critical MRI slices based on anatomical location and its clinical relavance in disease.

Objective of Proposed Multi-Domain Feature Cross Attention (MDFCA) module is to contemplate the cross attention between the MRI slices and its entropy counterpart.

Entropy Maps



Slice Selection Strategy

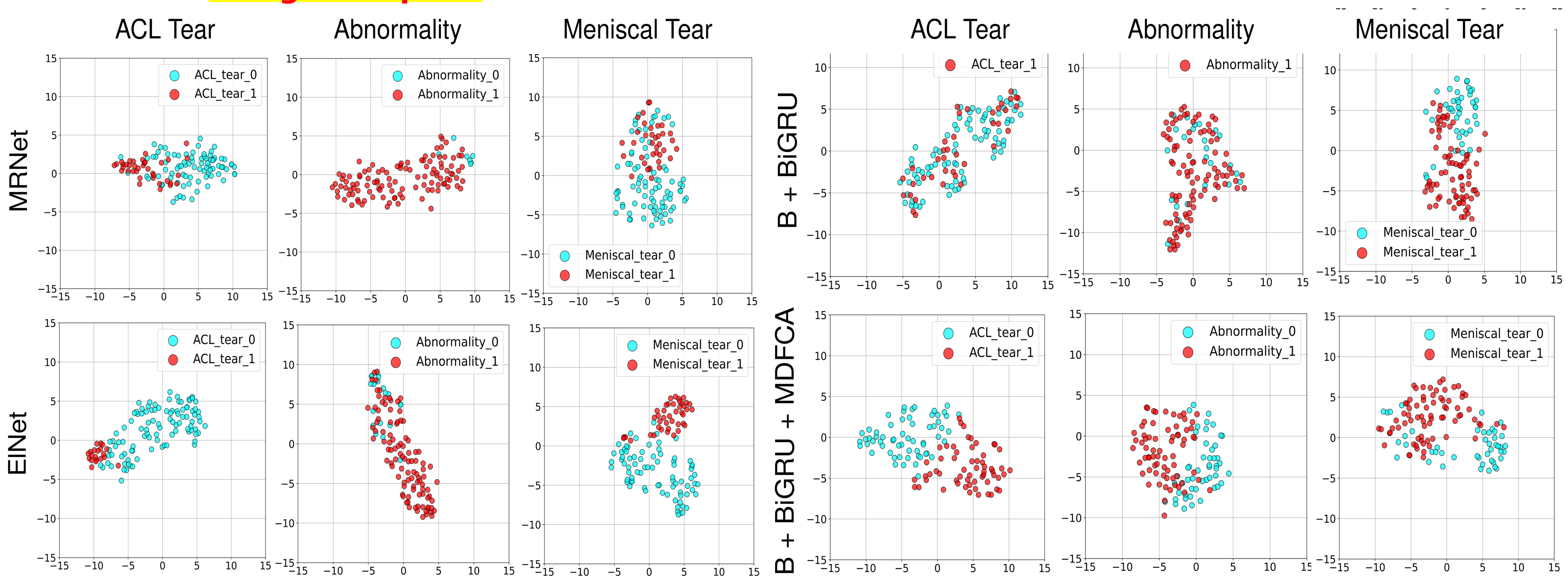


EXPERIMENTAL RESULTS

Table 1: Comparison of the proposed Med-SeAM framework with SOTA

Type	Architecture	Accuracy	Sensitivity/Specificity	AUC
ACL tear	MRNet [1]	0.791	0.703 / 0.863	0.872
Abnormality		0.858	0.957 / 0.486	0.921
Meniscus Tear		0.683	0.615 / 0.750	0.740
ACL tear	EINet [2]	0.750	0.500 / 0.954	0.807
Abnormality		0.783	0.949 / 0.660	0.802
Meniscus Tear		0.700	0.712 / 0.576	0.716
ACL tear	SKID [3]	0.691	0.111 / 0.988	0.825
Abnormality		0.825	0.979 / 0.240	0.883
Meniscus Tear		0.675	0.753 / 0.471	0.760
ACL tear	Proposed Model (w/o SSL)	0.692	0.674 / 0.760	0.717
Abnormality		0.810	0.890 / 0.687	0.816
Meniscus Tear		0.642	0.766 / 0.587	0.753
ACL tear	Proposed Model	0.767	0.776 / 0.704	0.837
Abnormality		0.875	0.926 / 0.683	0.803
Meniscus Tear		0.742	0.760 / 0.680	0.719

Figure 2: Comparison of the proposed Med-SeAM framework with SOTA using tSNE plots

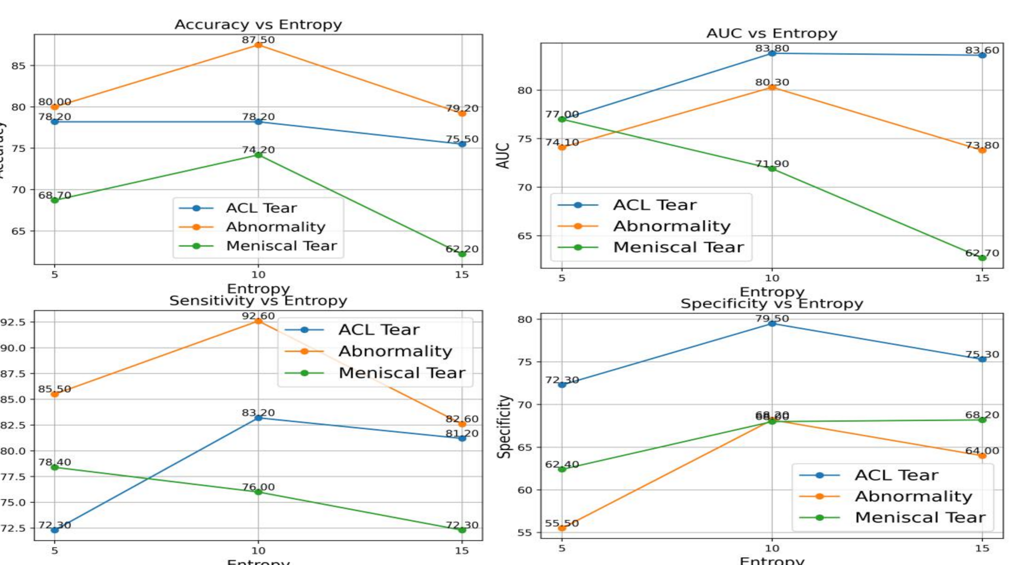


ABLATIONS

Table 2: Effect of proposed DCL Pretext Task

Architecture	ACL Tear	Abnormality	Meniscal Tear
SimCLR [11]	0.618 / 0.688	0.722 / 0.649	0.603 / 0.654
MoCoV2 [12]	0.449 / 0.390	0.727 / 0.690	0.547 / 0.610
SKID [3]	0.691 / 0.825	0.825 / 0.883	0.641 / 0.760
Context-aware SSL [13]	0.751/ 0.913	0.855 / 0.855	0.671/ 0.788
Proposed Model	0.767/ 0.837	0.875 / 0.803	0.742/ 0.719

Figure 3: Effect of Entropy window sizes



CONCLUSION

The Med-SeAM framework is found to improve classification performance of abnormality by 10.61% in accuracy and 3.5% in sensitivity, while for meniscal tear, the improvement is about 2.06% in accuracy compared to SOTA.

The Med-SeAM outperforms Context-Aware SSL [13] by 2.13% in average accuracy for detecting knee anomalies. This significant improvement stems from integrating domain knowledge, leveraging the spatial consistency and minimal dynamic changes in medical images.

The proposed DCL pretext task can be effectively applied to volume-based data, even in the absence of explicit slice labels.

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SELECTED REFERENCES

[1] Nicholas Bien et al. 2018. Deep-learning-assisted diagnosis for knee magnetic resonance imaging: development and retrospective validation of MRNet. PLoS medicine 15, 11 (2018), e1002699

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