Diagnosis for Tubal Patency with Contrast Medium in Hysterosalpingography Images Using Asymmetric Contrastive Learning

Asymmetric Contrastive Learning을 이용한 자궁난관조영술 영상에서의 조영제를 통한 난관 개통 진단

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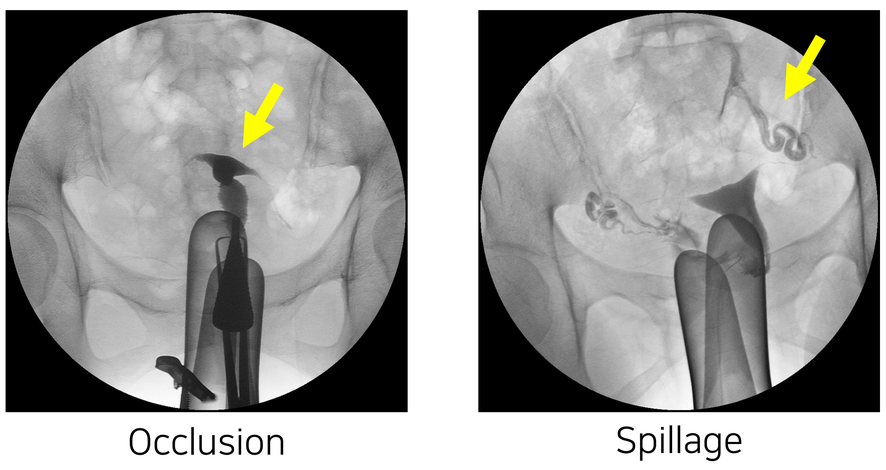
Background

- The number of infertility patients is steadily increasing worldwide due to rising age at marriage, lifestyle changes, and various social factors.
- In 85% of infertility cases, the cause can be identified, with tubal infertility being one of the significant factors.
- In tertiary hospitals, the interpretation of Hysterosalpingography (HSG) images is performed by radiology specialists. However, in general infertility clinics, the requesting gynecologists often perform the readings themselves, which can lead to a relatively inaccurate and time-consuming.
- Accurate and fast interpretation of HSG images based on deep learning approach can be helpful for determining effective treatment plans for patients.

Contributions

- We demonstrate the pioneering feasibility of a deep learning approach to classify contrast medium spillage into uterine tubes in X-ray-based HSG images.
- We demonstrate that the 2-stage learning method with Supervised Contrastive learning improves the ability to discriminate spillage in uterine tubes.
- We confirm the effectiveness of using Supervised Contrastive Loss and Asymmetric Loss on the HSG dataset with imbalanced distributions.

Methods



Occlusion Spillage

Figure 1. Hysterosalpingography images used for learning

- The dataset was collected by retrospectively reviewing cases in which HSG was performed for infertility examination at Seoul National University Bundang Hospital from June 2003 to May 2023 (IRB No. B-2307-839-102).
- Each case's uterine tubal spillage status was labeled as binary (Occlusion, Spillage) by a reproductive endocrinologist. The labeled dataset is imbalanced, with 75% of the cases being classified as spillage and 25% as occlusion.

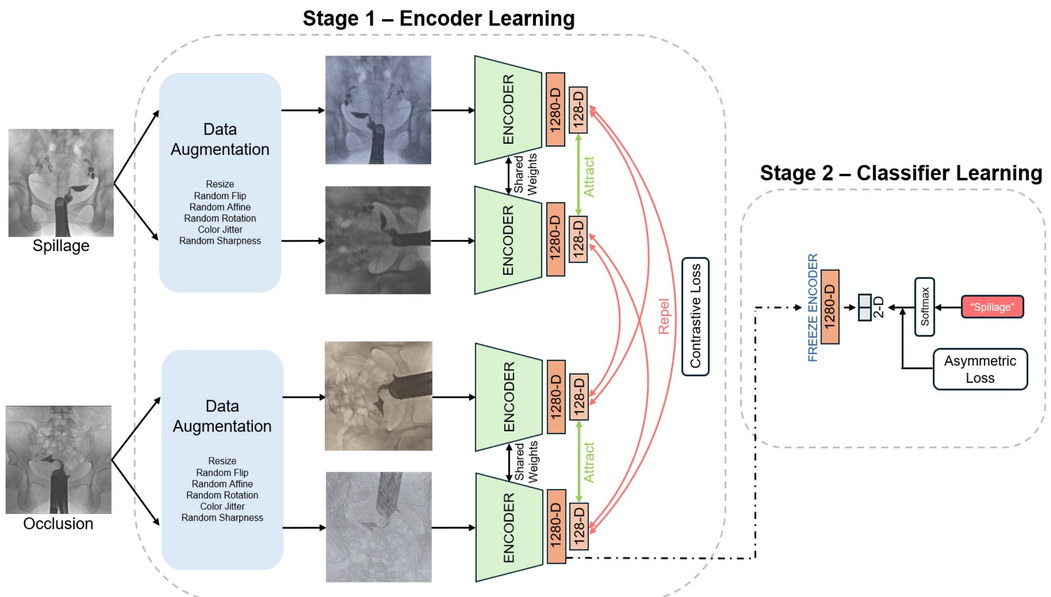


Figure 2. An overview of the proposed method

- Based on Representation Learning, the encoder and classifier are separated into distinct stages.
- In Stage 1, using Supervised Contrastive Loss, these embedding vectors are trained to place samples belonging to other classes further apart.
- In Stage 2, the encoder trained in Stage 1 is frozen, and only the classifier is trained. In this process, Asymmetric Loss, is applied to help more effective classification in datasets where spillage and occlusion samples are imbalanced.

Experiments

Methods	Accuracy (%)	Precision	Recall	F1	AUPRC
CE	84.388 ± 2.223	0.813 ± 0.107	0.508 ± 0.029	0.623 ± 0.037	0.761 ± 0.100
Focal	85.564 ± 1.593	0.750 ± 0.023	0.650 ± 0.087	0.695 ± 0.049	0.758 ± 0.025
ASL	85.564 ± 0.967	**0.832 ± 0.105**	0.558 ± 0.063	0.663 ± 0.020	**0.827 ± 0.048**
SupCon+CE	86.709 ± 2.282	0.792 ± 0.112	**0.675 ± 0.090**	0.720 ± 0.032	0.766 ± 0.038
SupCon+Focal	87.342 ± 1.675	0.820 ± 0.008	0.641 ± 0.095	0.717 ± 0.050	0.776 ± 0.045
SupCon+ASL	**87.764 ± 0.731**	0.827 ± 0.057	0.650 ± 0.066	**0.724 ± 0.030**	0.769 ± 0.036

Table 1. Results on comparing each methods

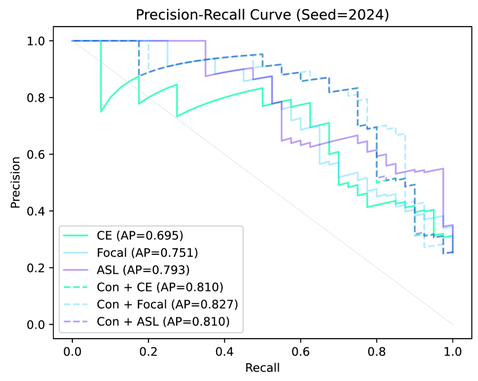


Figure 3. Results on comparing each methods with PR CURVE

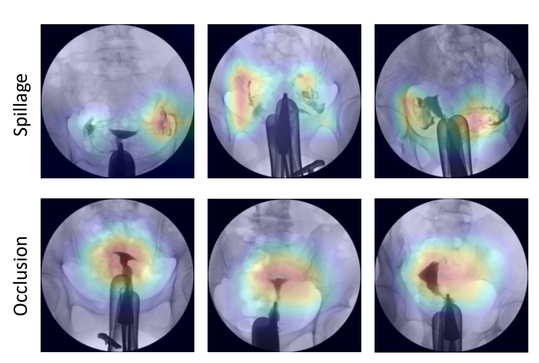


Figure 4. Visualization with Grad-CAM

- To compare the effects of Supervised Contrastive Loss on each stage separately with the effects of Asymmetric Loss, we conducted experiments using six different methods: training with Cross Entropy Loss, Focal Loss, and Asymmetric Loss in a single-stage approach, and using a 2-stage approach with Supervised Contrastive Loss combined with Cross Entropy Loss, Focal Loss, and Asymmetric Loss.

Conclusion

- When contrast medium spillage is observed in both uterine tubes, it can be confirmed that both sides are well focused in Grad-CAM.
- In these evaluations, the method combining Supervised Contrastive Loss and Asymmetric Loss achieved the highest performance in accuracy and F1 score, and the second-best performance in precision and recall.
- This approach showed effectiveness in identifying uterine tubal spillage in HSG images and demonstrates its clinical applicability.

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