One-Shot Traumatic Brain Segmentation with Adversarial Training and Uncertainty Rectification

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RESEARCH BACKGROUND

- Brain segmentation on the consciousness-related brain ROIs of patients with severe traumatic brain injuries (sTBI) is essential for clinical treatment;
- The presence of brain trauma significantly affects the effectiveness of brain segmentation methods designed for healthy brains;
- The collection of both sTBI brain MR scans and their brain region labels is demanding and costive;
- We propose a novel one-shot traumatic segmentation method, with adversarial training and uncertainty rectification.

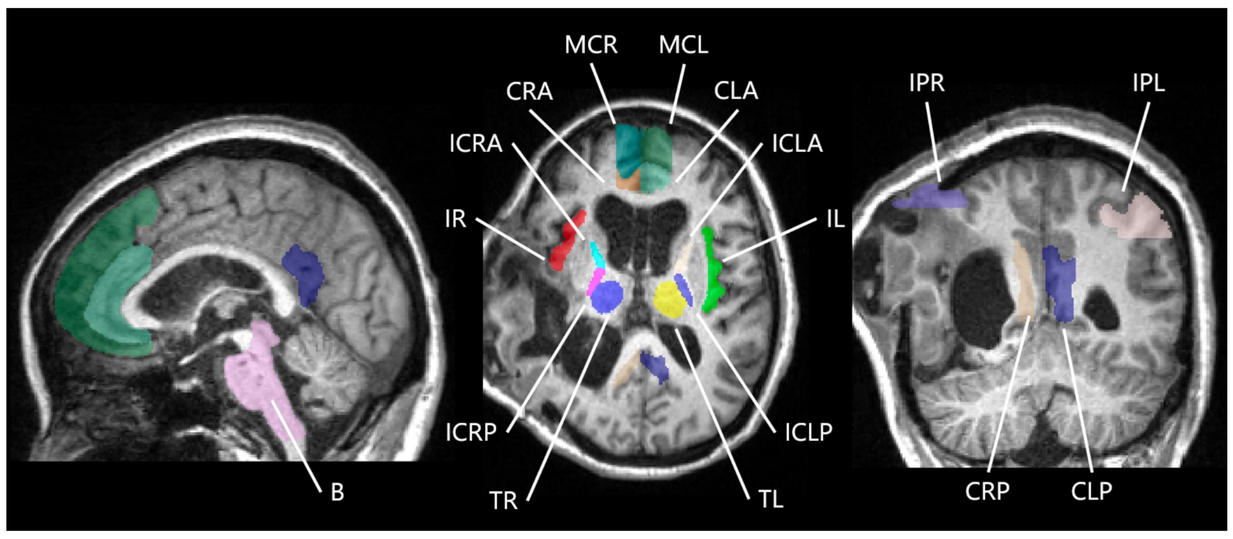

Fig. 1. Illustration of the MR scan and consciousness-related brain ROIs of a sTBI patient.

METHOD

① Overview

- Compared with previous alternatives, we introduce adversarial training to improve the diversity of atlas augmentation and the robustness of segmentation, and uncertainty rectification which alleviates potential label errors.

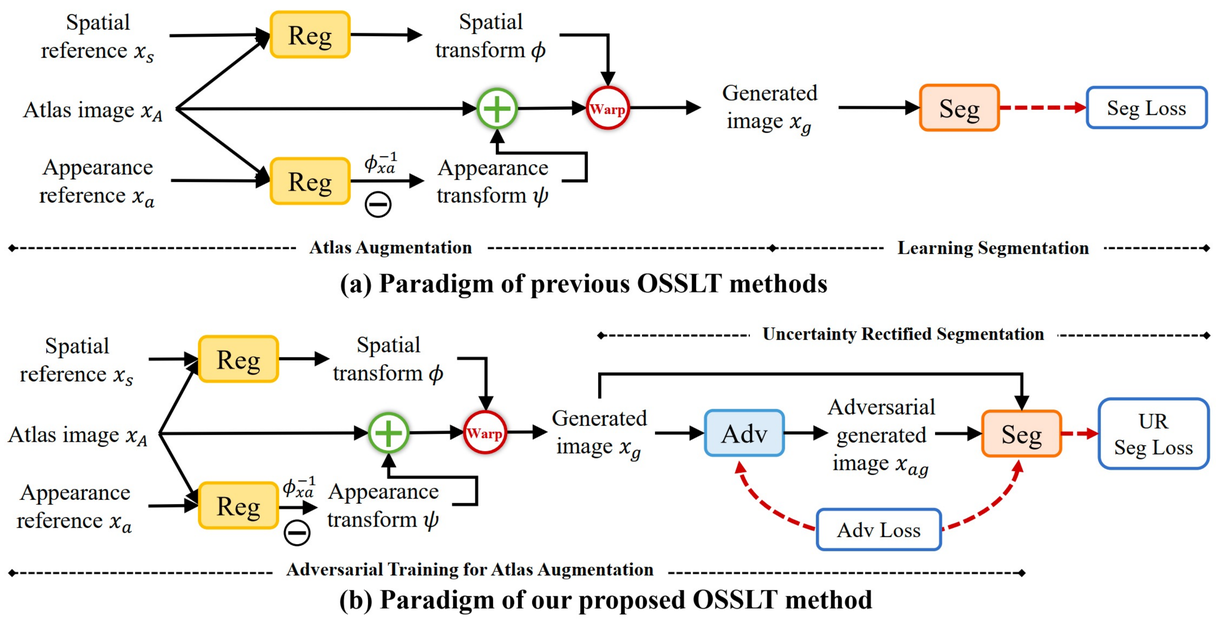

Fig. 2. Comparison of our one-shot traumatic brain segmentation method with previous attempts.

② Adversarial training for data augmentation

- The adversarial network and the segmentation network is trained in an adversarial manner;
- The adversarial network is trained to maximize the segmentation difference before and after applying adversarial augmentation;
- The segmentation network is trained to minimize the segmentation difference under the adversarial perturbations.

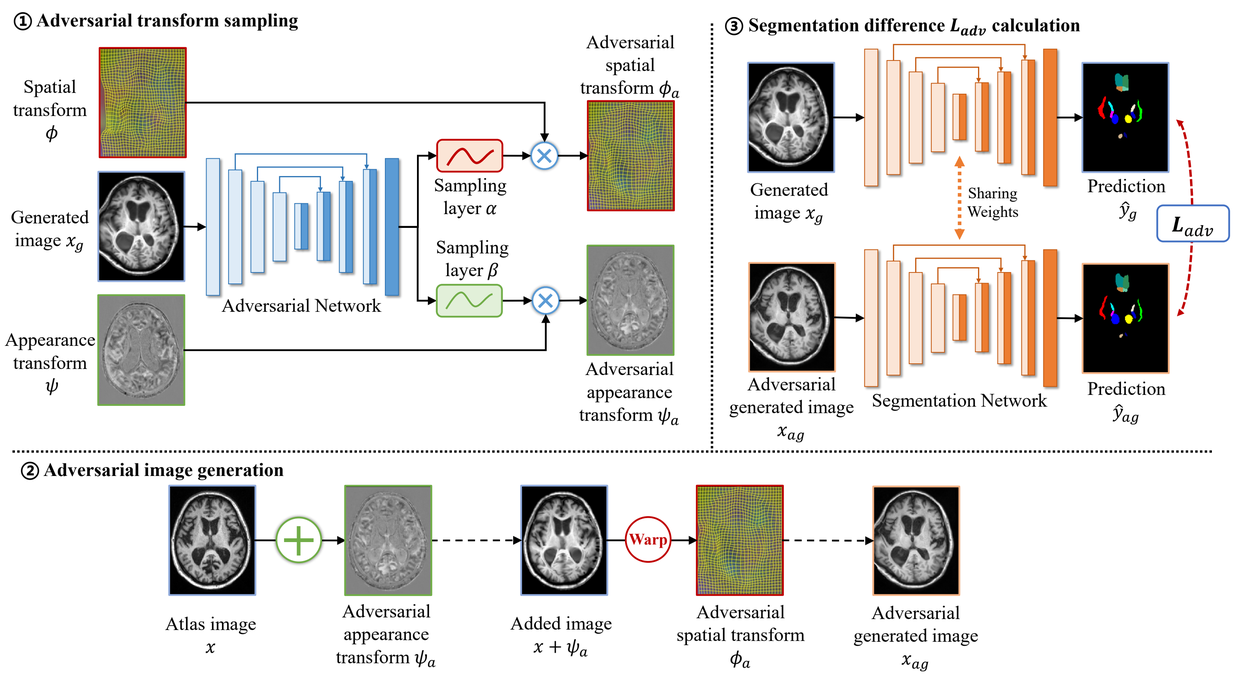

Fig. 3. The diagram of proposed adversarial training.

③ Uncertainty rectification to surpass label errors

- Abnormalities in sTBI brains can bring label errors during data augmentation;
- Spatial deformed atlas image is fed to segmentation network as a spatial reference;
- The segmentation difference of spatial deformed atlases and synthesized sTBI images indicates the potential regions where labels may err.
- A spatial-weighted segmentation loss is utilized to reduce the effects of potential label errors.

RESULTS

Proposed one-shot method outperforms other one-shot alternatives.

	IR	IL	TR	TL	ICRA	ICRP
Brainstorm	46.2±21.9	43.2±21.3	**66.7±18.1**	57.1±7.3	46.8±11.7	34.5±21.0
LT-Net	45.4±24.6	52.4±21.0	59.5±17.9	58.3±10.4	47.0±19.7	42.6±17.3
DeepAtlas	50.3±25.4	44.2±27.0	56.4±16.1	57.5±8.7	50.4±13.8	38.8±18.7
Proposed	**52.6±24.8**	**54.4±22.9**	62.0±16.2	**58.4±10.2**	**51.1±16.6**	**44.2±17.5**
	ICLA	**ICLP**	**CRA**	**CRP**	**CLA**	**CLP**
Brainstorm	46.1±14.3	38.8±14.6	50.1±16.6	48.0±13.2	50.9±11.1	54.2±10.8
LT-Net	43.5±19.2	42.6±17.2	52.2±18.4	48.4±12.5	48.5±13.0	56.5±11.9
DeepAtlas	**53.8±15.6**	**46.2±16.9**	46.4±19.3	42.5±13.9	43.4±15.8	52.1±13.0
Proposed	53.0±16.7	44.7±18.1	**56.1±15.0**	**53.2±12.5**	**51.7±12.9**	**60.8±11.1**
	MCR	**MCL**	**IPL**	**IPR**	**B**	***Overall***
Brainstorm	52.5±18.7	57.9±11.9	50.1±17.1	52.2±16.5	86.4±4.3	51.9±19.0
LT-Net	56.1±20.1	59.2±12.3	43.0±15.4	53.5±18.2	87.0±6.2	52.7±19.6
DeepAtlas	55.9±17.9	54.6±13.2	**54.6±13.2**	50.8±15.3	88.9±4.0	51.5±19.8
Proposed	**61.0±16.9**	**61.1±11.1**	48.1±18.9	**53.7±17.0**	**90.1±4.2**	**56.3±18.8**

Table 1. Brain segmentation performance comparison with state-of-the-art methods on selected brain ROIs.

CONCLUSION

We propose a novel one-shot traumatic brain segmentation method with adversarial training and uncertainty rectification to improve the augmentation diversity and alleviate the issue of potential label errors. Our method has great potential to benefit brain analysis and clinical healthcare of sTBI patients.