A fully-automated convolutional neural network with deep supervision approach for haemorrhage segmentation and volume quantification in CT scans

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Purpose: (426 characters)
To aid more effective management of haemorrhagic stroke \cite{1,2}, we developed a fully automated method applying convoluted neural network with deep supervision (CNN-DS) \cite{3,4} for improved haematoma segmentation and volume quantification in computed tomography (CT) images. The main objectives are to generate the CNN-DS method and to evaluate its performance while making comparisons to previously established machine learning (ML) methods.

Materials & Methods: (836 characters)
Non-contrast whole-brain CT scans of 55 patients with haemorrhagic stroke were retrieved from clinical database from three hospitals in Fraser Health, British Columbia, Canada. The CT scan of each patient was standardized to 64 slices of 128 x 128 pixels, and annotated independently by experienced raters, to generate a binary classification of hematoma vs. normal brain tissue. For each voxel, the class label with majority-voting was used as the reference standard. The dataset was split into training (n=45) and testing (n=10) subsets. Applying the training set, the CNN-DS method was built based on U-Net architecture with deep supervision. The accuracy and efficiency of the CNN-DS method were examined using the testing set and compared with the random forests based PItcHPERFeCT\cite{5} and patch-wise U-Net deep neural networks methods.

Results: (639 characters)
The CNN-DS method for hematoma quantification in the training set had a Dice coefficient score of 0.82\textpm0.06 at an average running time of 0.59\textpm0.02 seconds (s). The testing set revealed a Dice coefficient of 0.83\textpm0.07 and precision of 0.84\textpm0.09, superior to the other methods. The of 0.82\textpm0.08 recall rate with CNN-DS method was greater than patch-wise U-Net (0.76), while
PltchPERFeCT showed a higher recall (0.98) at a high cost of processing time, considerably slower than CNN-DS (1412±150s vs 0.74±0.07s). Kappa coefficients for interrater agreement rate did not differ statistically between the “human-human” and “method-human” pairs.

**Conclusion:** (333 characters)
The CNN-DS method developed in this study demonstrated human-level performance in segmenting and quantifying hematoma, signifying substantial improvements over the previously established methods. The result warrants further research in realizing the potential of the CNN-DS method for more effective stroke assessment and management.