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LETTER TO THE EDITOR

Temporal subtraction of computed tomography images improves detectability of bone metastases by radiology residents

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Abstract

Objective Temporal subtraction of CT (TS) images improves detection of newly developed bone metastases (BM). We sought to determine whether TS improves detection of BM by radiology residents as well.

Methods We performed an observer study using a previously reported dataset, consisting of 60 oncology patients, each with previous and current CT images. TS images were calculated using in-house software. Four residents independently interpreted twice the 60 sets of CT images, without and with TS. They identified BM by marking suspicious lesions likely to be BM. Lesion-based sensitivity and number of false positives per patient were calculated. Figure-of-merit (FOM) was calculated. Detectability of BM, with and without TS, was compared between radiology residents and board-certified radiologists, as published previously.

Results FOM of residents significantly improved by implementing TS (p value < 0.0001). Lesion-based sensitivity, false positives per patients, and FOM were 40.8%, 0.121, and 0.657, respectively, without TS, and 58.1%, 0.0958, and 0.796, respectively, with TS. These findings were comparable with the previously published values for board-certified radiologists without TS (58.0%, 0.19, and 0.758, respectively).

Conclusion The detectability of BM by residents improved markedly by implementing TS and reached that of board-certified radiologists without TS.

Key Points

- *Detectability of bone metastases on CT by residents improved significantly when using temporal subtraction of CT (TS).*
- *Detections by residents with TS and board-certified radiologists without TS were comparable.*
- *TS is useful for residents as it is for board-certified radiologists.*

Keywords Tomography · X-Ray computed · Bone neoplasms · Internship and residency

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Abbreviations and acronyms

BM Newly developed bone metastases
CT Computed tomography
FOM Figure-of-merit
TS Temporal subtraction of CT

Introduction

Early and accurate detection of bone metastases during oncological follow-up is a critical task, and CT is the primary modality in these patients. However, the detection of bone metastases with CT is challenging with the risk of missing potentially dangerous lesions.

Temporal subtraction of CT (TS) images improves the performance of board-certified radiologists in the detection of new bone lesions [1–4]. The TS scheme has improved since its inception [1, 3], making it possible to enhance bone metastasis visualization. For example, artifact reduction was improved between the two studies [1, 3]. Because interpretation of TS images requires sufficient comprehension of the characteristics of TS, the efficacy of TS is not apparent for residents.

The purpose of the current study was to assess if residents using TS improved their performance in the detection of newly developed bone metastases in a practical clinical situation, and to compare with that of board-certified radiologists.

Materials and methods

Dataset

An observer study was performed using the same dataset as in a prior publication [1], which consisted of 60 datasets each containing previous and current CT images. The inclusion criteria for patients, the patient characteristics, and detail of CT scan from the prior publication [1] are shown in Supplementary Material.

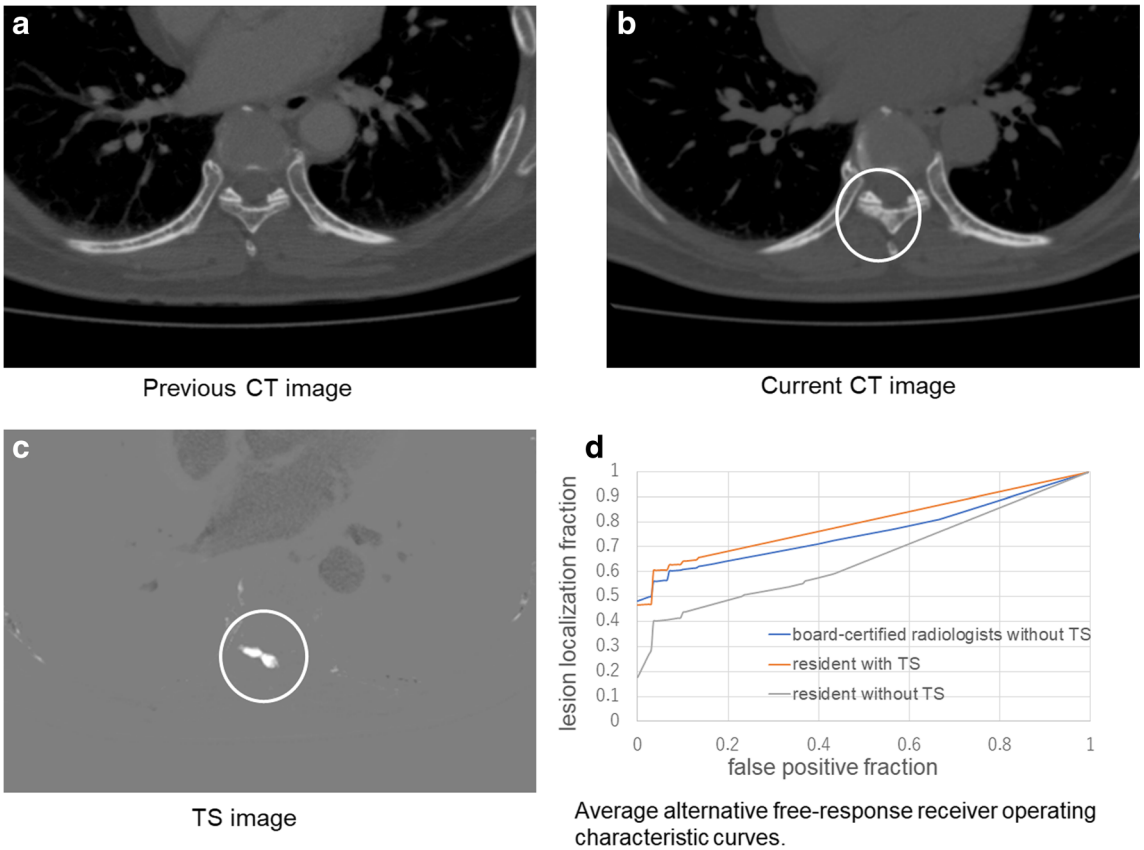

Fig. 1 TS image and average alternative free-response receiver operating characteristic curves: (**a**) Previous CT image (axial); (**b**) current CT image (axial); (**c**) TS image (axial); (**d**) average alternative free-response receiver operating characteristic curves. The TS image is generated by nonlinear registration and subsequently by subtraction. The white circle represents bone metastasis. Although it is difficult to pinpoint the metastasis on the current CT image, it is relatively easy to detect the metastasis on the TS image. In general, area under the alternative free-response receiver operating characteristic curve is equivalent to FOM. The average FOM of residents without TS, residents with TS, and board-certified radiologists without TS are 0.657, 0.796, and 0.758, respectively. The average FOM for residents with TS was higher than that of residents without TS; this was statistically significantly different ($p < 0.0001$). Computed tomography (CT), temporal subtraction of CT (TS), figure-of-merit (FOM)

TS method

TS images were obtained by subtraction of two different sets of torso CT images (previous CT images and current CT image) to enhance the temporal changes between the two sets. The detail of TS method is shown in Supplementary Material.

Observer study

Four residents independently interpreted the 60 sets of CT images without and with TS, twice with a 30-day interval. The four residents were asked to identify bone metastasis by marking locations with the likelihood of bone metastasis. Reading time was recorded.

Statistical analysis

Jackknife free-response receiver operating characteristic analysis was employed to evaluate the residents' performance [1, 3, 5, 6], create an alternative free-response receiver operating characteristic curve, and calculate figure-of-merit (FOM) values. In addition, the lesion-based sensitivity, number of false positives per patient, patient-based sensitivity, and patient-based specificity were also calculated. We set the threshold likelihood level for the diagnosis of metastasis as 50%.

Results

An illustrative example of bone metastasis on TS images is shown in Fig. 1a–c.

The details of FOM, lesion-based sensitivity, false positive per patients, patient-based sensitivity, patient-based specificity, and reading time for the four residents are shown in Supplementary Material. Results of board-certified radiologists without TS are also shown in Supplementary Material, as published in a previous study [1].

The average alternative free-response receiver operating characteristic curves of all four residents and board-certified radiologists are shown in Fig. 1d. The average FOM improved very significantly, from 0.657 ± 0.064 (range 0.576–0.711) without TS to 0.796 ± 0.047 (range 0.756–0.852) with TS ($p < 0.0001$). The lesion-based sensitivity, false positives per patient, patient-based sensitivity, and patient-based specificity were as follows: 40.8 ± 1.05%, 0.121 ± 0.0343, 58.3 ± 1.17%, and 96.7 ± 4.71%, respectively, without TS; and 58.1 ± 6.81%, 0.0958 ± 0.0285, 75.0 ± 7.90%, and 95.8 ± 1.67%, respectively, with TS. The lesion-based sensitivity, patient-based sensitivity, and false positives per patient were improved by TS.

The reading time was 234 ± 58.7 s without TS, and 229 ± 55.3 s with TS; thus, the reading time was roughly similar with or without TS.

Discussion

Both lesion-based and patient-based sensitivities improved markedly when residents used TS. In addition, the FOM of residents with TS reached that of board-certified radiologists without TS, which was reported in a previous study [1]. The FOM of residents without and with TS were 0.657 and 0.796, respectively, in the current study, and that of board-certified radiologists without TS was 0.758 in the previous study [1]. The false positives per patient for residents with TS tended to be better than that without TS. The reading time of residents with TS was comparable to that without TS. These results showed that the residents' performance clearly improved by adopting TS.

The previous study [1] compared detectability of bone metastasis for radiologists without TS and with TS and concluded that TS was potentially useful for the detection of bone metastases by board-certified radiologists. Based on the previous [1] and current studies, TS is useful not only for board-certified radiologists, but also for residents.

Per patient false positive for residents using TS was lower than without TS in the current study. We speculate that the residents could reliably exclude stable benign lesions with TS. This helps avoid erroneous detection of subtle signs, which is a risk when asked to read CT within a limited time frame, as in daily clinical practice.

The sensitivity, specificity, and false-positive rate per case improved with the implementation of TS, and there was no reading time penalty. These results suggest that the usefulness of implementing TS was superior to its adverse effect. Benign lesions, such as Schmorl nodes, old traumatic lesions, degenerated lesions, and old compression fractures, are generally stable. However, TS was highly sensitive to temporal changes in these benign lesions, according to the previous study [3]. Consequently, temporal changes in benign lesions can be theoretically misinterpreted as bone metastasis, which leads to increase in the false positives. However, our results show that false positives did not increase in the current study.

There were several limitations in our study. First, this study was a retrospective and single-center study. All cases in our study were recruited from our clinical database. Second, the bone lesions were not confirmed by histology. In the clinical setting, it is rare to perform a biopsy to obtain histological confirmation of bone metastases when a primary lesion is evident. Third, we did not evaluate the result of board-certified radiologists who participated in the previous study [5] with TS images generated by the TS scheme of the current study.

Conclusion

The performance of residents in detecting bone metastases depicted in torso CT images improved markedly with TS,

and was comparable with that of board-certified radiologists without TS.

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Compliance with ethical standards

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Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Study subjects or cohorts overlap For 60 subjects in our study, there is overlap between our study and the previous study (ref. [1]). The purpose of our study (detectability of residents) is totally different from that of the previous study (detectability of board-certified radiologists).

Methodology
- retrospective
- diagnostic or prognostic study
- performed at one institution

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