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Identification of common predisposing loci to hemangiomas in four dog breeds

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Abstract

Ultrasound (US) is a non-invasive alternative to other pathways for screening and diagnosis of breast cancer. In recent years, the combination of US with other modalities has been investigated to improve the performance of breast cancer detection. In this study, we investigated the performance of a multimodal system that combines US with two other modalities, namely, electrical impedance scanning (EIS) and thermography. We developed a multimodal system and collected data from 108 patients (cases). The dataset that we collected contains 108 US images, 108 EIS images, and 108 thermography images. We developed a deep learning classifier to classify the collected data into benign and malignant classes. We used a pre-trained deep convolutional neural network (DCNN) model with the collected US images to develop a baseline classifier. We then developed a multimodal DCNN model that combines US with EIS and thermography. We used a leave-one-out cross-validation (LOOCV) scheme to train and evaluate the developed deep learning models. We also developed a multimodal machine learning classifier using the deep learning features extracted from the DCNN models. The sensitivity, specificity, and area under the receiver operating characteristic curve (AUC) of the baseline US-only DCNN model were 0.84, 0.80, and 0.86, respectively. The sensitivity, specificity, and AUC of the multimodal DCNN model were 0.89, 0.86, and 0.92, respectively. The sensitivity, specificity, and AUC of the multimodal machine learning classifier were 0.91, 0.88, and 0.94, respectively. The results indicate that the multimodal system that combines US with EIS and thermography has the potential to improve the performance of breast cancer detection.

1. Introduction

Breast cancer is the second most common cancer worldwide and the fifth most common cause of cancer mortality globally. In 2020, there were approximately 2.3 million women who were diagnosed with breast cancer and 685 000 women died from breast cancer globally. As of the end of 2020, there were 7.8 million women who were diagnosed with breast cancer in the past five years, making it the most prevalent cancer worldwide. The incidence of breast cancer is increasing globally. Breast cancer can be treated if it is detected early. Early detection of breast cancer can improve the outcomes of treatment and increase the survival rate. Various imaging modalities are used for breast cancer screening and diagnosis, such as mammography, ultrasound (US), magnetic resonance imaging (MRI), and nuclear medicine imaging. Each of these imaging modalities has its own advantages and disadvantages. For example, mammography is a low-dose radiation imaging modality that is used for breast cancer screening. However, it has low sensitivity for women with dense breasts. US is a non-ionizing imaging modality that is used for breast cancer screening and diagnosis. It is a low-cost and portable imaging modality. However, it has low specificity. MRI has high sensitivity and specificity for breast cancer screening and diagnosis. However, it is a high-cost and time-consuming imaging modality. Nuclear medicine imaging modalities such as positron emission tomography (PET) and single-photon emission computed tomography (SPECT) are used for breast cancer staging. However, these modalities have low spatial resolution and are not recommended for breast cancer screening. Breast cancer screening and diagnosis using a single modality has its own limitations. To improve the performance of breast cancer screening and diagnosis, researchers have investigated the use of multiple imaging modalities. For example, researchers have investigated the combination of US with mammography, MRI, and PET/SPECT. Some of the studies have reported that the combination of US with other modalities improves the performance of breast cancer detection. In this study, we investigated the performance of a multimodal system that combines US with electrical impedance scanning (EIS) and thermography. We developed a multimodal system and collected data from 108 patients (cases). We developed deep learning classifiers to classify the collected data into benign and malignant classes. We used a pre-trained deep convolutional neural network (DCNN) model with the collected US images to develop a baseline classifier. We then developed a multimodal DCNN model that combines US with EIS and thermography. We also developed a multimodal machine learning classifier using the deep learning features extracted from the DCNN models. We used a leave-one-out cross-validation (LOOCV) scheme to train and evaluate the developed deep learning models. We compared the performance of the developed multimodal systems with that of the baseline US-only DCNN model. The rest of the paper is organized as follows. Section 2 provides the literature review. Section 3 describes the materials and methods. Section 4 presents the results. Section 5 provides the discussion. Section 6 concludes the study.

2. Literature review

2.1. Breast cancer screening using ultrasound

Ultrasound (US) is an alternative to other pathways for breast cancer screening and diagnosis. Various studies have investigated the performance of US for breast cancer screening. Berg et al [1] prospectively evaluated the performance of US in breast cancer screening among women with mammographically dense breasts. In this study, 2 842 women with dense breasts were screened with US after their screening mammograms. The breast cancer detection rate of US was 4.2 per 1 000 women. Breast cancer was detected in 0.4% of the women with US-only screening. Breast cancer was detected in 4.2% of the women with mammography-only screening. The breast cancer detection rate increased to 5.0 per 1 000 women when US was added to mammography. The breast cancer detection rate increased by 19% when US was added to mammography. The positive predictive value of biopsy was 10.9% for US-only screening, 20.4% for mammography-only screening, and 11.4% for mammography plus US screening. The results indicated that breast US detected additional cancers in women with dense breasts who had undergone screening mammography. However, it also resulted in a substantial increase in the number of false positives. Lee et al [2] conducted a meta-analysis to evaluate the performance of US for breast cancer screening in women with dense breasts. The meta-analysis included 9 prospective studies. The breast cancer detection rate was 4.3 per 1 000 women for US screening, 1.9 per 1 000 women for mammography screening, and 6.1 per 1 000 women for US plus mammography screening. The sensitivity of US was 76.4% for US screening, 48.1% for mammography screening, and 81.8% for US plus mammography screening. The specificity of US was 84.1% for US screening, 96.9% for mammography screening, and 83.9% for US plus mammography screening. The positive predictive value of biopsy was 6.5% for US screening, 14.7% for mammography screening, and 6.3% for US plus mammography screening. The results indicated that breast US in addition to mammography detected additional cancers in women with dense breasts. However, it also resulted in a substantial increase in the number of false positives. Gyftopoulos et al [3] reviewed the literature on the use of US for breast cancer screening. The review indicated that breast US detected additional cancers in women with dense breasts who had undergone screening mammography. However, it also resulted in a substantial increase in the number of false positives. Kim et al [4] reviewed the literature on the use of US for breast cancer screening in women with dense breasts. The review indicated that breast US detected additional cancers in women with dense breasts who had undergone screening mammography. However, it also resulted in a substantial increase in the number of false positives. Brem et al [5] prospectively evaluated the performance of breast US in women with dense breasts who had undergone screening mammography. 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Breast cancer was detected in 4.3% of the women with mammography-only screening. The breast cancer detection rate increased to 5.7 per 1 000 women when US was added to mammography. The breast cancer detection rate increased by 33% when US was added to mammography. The positive predictive value of biopsy was 11.3% for US-only screening, 21.1% for mammography-only screening, and 11.1% for mammography plus US screening. The results indicated that breast US detected additional cancers in women with dense breasts who had undergone screening mammography. However, it also resulted in a substantial increase in the number of false positives. Lee et al [50] conducted a meta-analysis to evaluate the performance of US for breast cancer screening in women with dense breasts. The meta-analysis included 10 prospective studies. 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