Light-based depth-sensing device with deep learning to measure spinal deformity: abridged secondary publication

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KEY MESSAGES

1. A light-based depth-sensing device with deep learning offers a rapid, non-invasive method for spine examination and has potential for integration into routine scoliosis screening for adolescents.
2. The device demonstrates promising performance in scoliosis assessment.
3. This screening tool may be beneficial in resource-constrained or remote regions such as those with a shortage of radiographic medical imaging devices or specialists.

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Introduction

Scoliosis is a three-dimensional spinal deformity, defined by a Cobb angle (ie, angle formed by the upper endplate of the uppermost tilted vertebra and lower endplate of the lowermost tilted vertebra in the structural curve) of >10° on standing plain radiographs.[1] Among scoliosis types (idiopathic, congenital, neuromuscular, and syndromic), adolescent idiopathic scoliosis (AIS) is most common in the paediatric population. In Hong Kong, the prevalences of AIS are 2.2% in boys and 4.8% in girls.[2,3] Untreated cases can rapidly progress during the pubertal growth spurt, causing body disfigurement, cardiopulmonary compromise, and back pain.[4,5] Additionally, spinal degeneration may damage surrounding muscles, ligaments, and joint structures, thereby exacerbating pain and causing additional physical limitations. Early detection and intervention to prevent curve progression are therefore essential. Clinical screening and diagnosis currently require physical and radiographic examinations, which are subjective or associated with radiation exposure. We developed and validated a radiation-free portable device that uses light-based depth-sensing and deep-learning technologies to analyse AIS via landmark detection and image synthesis.

Methods

Consecutive patients with AIS who were treated in two scoliosis clinics in Hong Kong between 1 November 2021 and 31 March 2023 were recruited. Patients were excluded if they had psychological and/or systematic neural disorders that could affect compliance and/or mobility. For each participant, a red-green-blue depth image of the nude back was captured using our light-based depth-sensing device (Fig). Manually labelled landmarks and alignment parameters identified by our spine surgeons were considered the ground truth. Images from training and internal validation cohorts (n=1936) were used to develop the deep learning models. The model was then prospectively validated on another cohort (n=302) from Hong Kong with similar demographics. We evaluated the model's accuracy in detecting anatomical landmarks on the nude back and its performance in synthesising radiograph-comparable images (RCIs). These RCIs contain sufficient anatomical information to quantify disease severity and identify curve type.

Results

Our model consistently demonstrated high accuracy in predicting anatomical landmarks on the nude back, with a mean Euclidian and Manhattan distance error of <4 pixels. Using radiographic assessments by spine specialists as the ground truth, the synthesised RCIs achieved a sensitivity of >0.909 and a negative predictive value of >0.933 for AIS severity classification; the corresponding values for curve type classification were 0.974 and 0.908. Estimated Cobb angles from the synthesised RCIs were strongly correlated with ground truth angles (R^2=0.984, P<0.001).

Discussion

The light-based depth-sensing device with deep learning offers a rapid, non-invasive method for

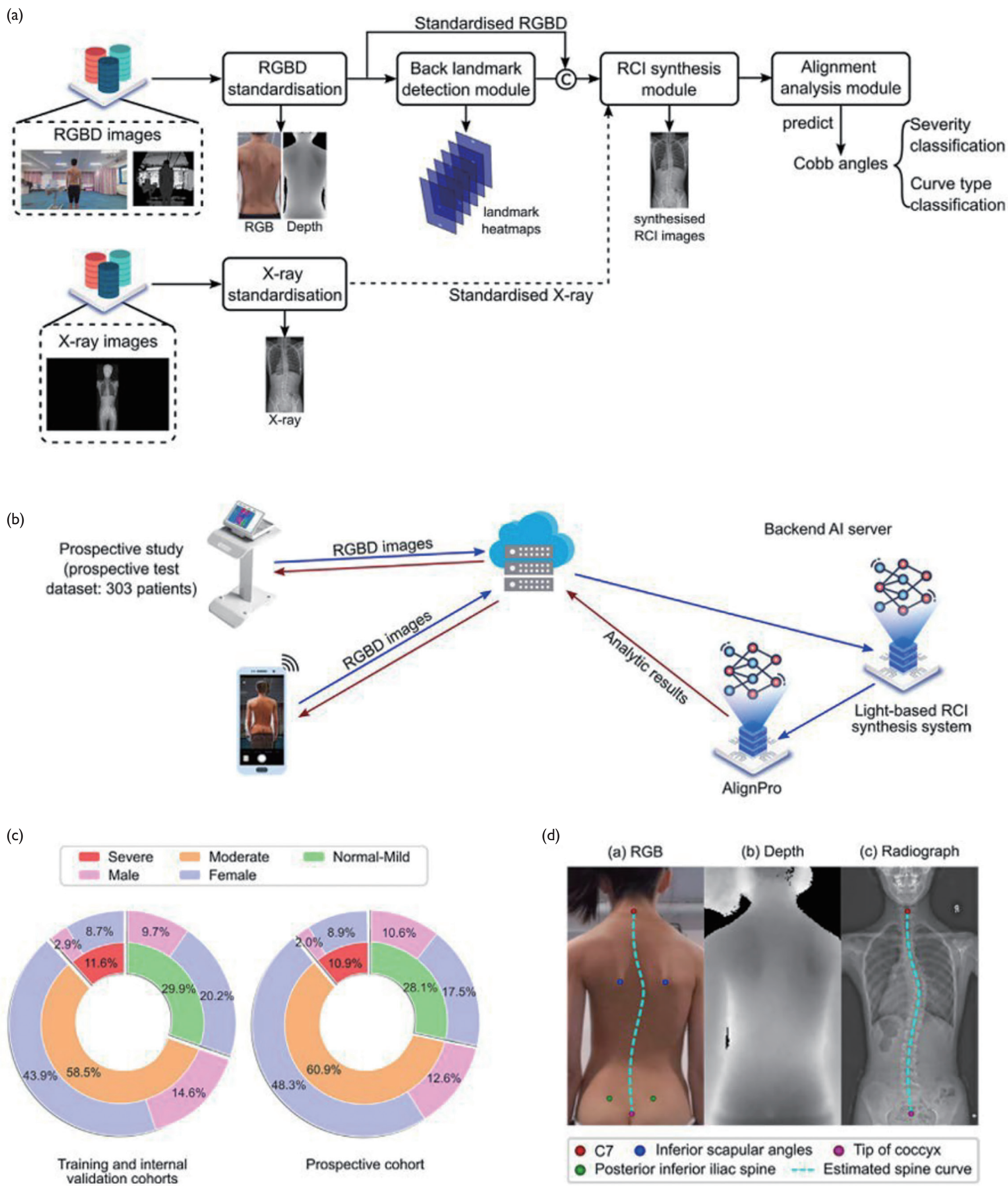

FIG. (a) The workflow of the light-based radiograph-comparable image (RCI) synthesis system, which comprises a red-green-blue depth (RGBD) and radiograph standardisation module, a back landmark detection module, a landmark-guided RCI synthesis module, and a quantitative alignment analysis module. The first module uses rule-based and adaptive algorithms to standardise images, whereas the other three modules use deep learning techniques. (b) RGBD images captured with a smartphone and our equipment are transmitted to a cloud data centre for analysis by the backend artificial intelligence server that hosts the light-based RCI synthesis and AlignPro system. Results are then transmitted back to the smartphone and equipment for display. (c) Pie charts showing proportions of different severity levels and sexes in all participants. (d) Examples of an RGB image, a depth image, and a corresponding radiograph spine examination and has potential for integration into routine scoliosis screening for adolescents. The device demonstrates promising performance in scoliosis assessment. This screening tool may be beneficial in resource-constrained or remote regions such as those with a shortage of radiographic medical imaging devices or specialists. International multicentre trials are needed to assess the effects of demographic variables such as body mass index and skin colour, and to enhance device reliability before clinical use.

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Disclosure

The results of this research have been previously published in:

1. Meng N, Wong KYK, Zhao M, Cheung JP, Zhang T. Radiograph-comparable image synthesis for spine alignment analysis using deep learning with prospective clinical validation. eClinicalMedicine 2023;61:102050.

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