Computer-aided Diagnostic Systems for Osteoporotic Vertebral Fracture Detection: Opportunities and Challenges

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In the current issue of JBMR, Nithin Kolanu and colleagues evaluate a computer-aided diagnostic (CAD) system designed to identify osteoporotic vertebral fractures (VFs) visualised opportunistically from CT images. The system, developed by Zebra Medical Vision (Shefayim, Israel; www.zebra-med.com), extracts a virtual sagittal section visualising the spinal mid-plane and identifies VFs using machine learning algorithms. It outputs the probability that the volume contains a VF, and a heat map indicating the probable locations of VFs in the sagittal image. In a single-site study involving thoracic CT scans from 1696 patients with a VF prevalence of 24%, the system achieved a sensitivity, specificity and accuracy of 54%, 92% and 83%, respectively.

Osteoporosis is under-diagnosed and under-treated in clinical practice (1). While VFs are the most common osteoporotic fracture, they can be clinically "silent" despite being a crucial early clinical manifestation of the disease. This creates a potential role for opportunistic assessment for VFs in clinical images acquired for other indications, with CT arguably presenting the most important target. A large and increasing number of procedures are performed and they frequently visualise part of the spine, offering the possibility of identifying a subset of the currently undiagnosed osteoporosis patients at little additional cost. However, current diagnosis rates for CT are significantly worse than other modalities; a recent, UK-wide audit found that VFs visualised opportunistically in CT images were accurately reported in only 26.2% of patients, and only 2.6% were referred for further management (2). The feasibility of improvement through existing radiology service provision is questionable. CT imaging activity has increased rapidly in recent years, rising by 110% between 2000 and 2016 in the US and by 69% in the UK NHS between 2012/13 and 2018/19 (3,4). In contrast, the NHS currently has a shortfall of 1,876 radiologists, 33% of posts, forecast to rise to 43% by 2024 and only 1% of trusts were able to meet their reporting requirements within contracted hours in 2019 (5). Similarly, the American Association of Medical Colleges has predicted a shortfall of between 17,100 and 41,900 physicians in specialities including radiology by 2033 (6).

CAD systems may provide a solution, with potential benefits for the patients in whom VFs are identified. However, identification of the fracture is only part of the jigsaw puzzle, and integration into existing clinical workflows presents considerable challenges. The current shortfall in radiologists militates against *any* solution that increases clinical workload. Kolanu et al. show that Zebra's CAD can identify images containing VFs, and highlight the probable location of the VF within the image, but the results are neither perfectly accurate nor complete. The radiologist cannot yet *rely* on the system without thoroughly assessing the sagittal reformats, which takes precious reporting time. The "elephant in the room" is that manual input from radiologists is still needed to confirm the diagnosis, identify the vertebral level, grade the severity of any fracture, and make recommendations for future management in line with local service provision in order to complete a radiology report that complies with clinical guidelines (7). [Compston2017]

Other CAD-based VF detection methods for clinical CT images are emerging, including those of Infervision (Beijing, China; global.infervision.com), O.N. Diagnostics (Berkeley, California; www.ondiagnostics.com), and Optasia Medical Ltd. (Manchester, UK; www.optasiamedical.com). Systems that estimate bone mineral density (BMD) from CT, such as CliniQCT (Mindways Inc, Austin, Texas; www.qct.com) or that combine BMD assessment with bone strength analysis, such as VirtuOst (O.N. Diagnostics, Berkley, California; ondiagnostics.com), are also available. In contrast to the Zebra and Infervision systems, Optasia Medical's ASPIRE™ operates as a tele-radiology service, out-sourcing the opportunistic reporting of VFs with an in-house radiologist confirming the diagnoses, thus removing workload from radiology departments. Nevertheless, these systems all have the potential to significantly increase the number of VFs identified, and thus impact downstream services, a factor which must be considered at the point of adoption.

CAD systems will have utility only if they can be incorporated into clinical workflows without imposing unrealistic burdens. This requires consideration of multiple issues and potential technological interventions, of which improved VF diagnostic rates are only one. Integration into existing radiology services must avoid increasing workload, and subsequent patient management must similarly avoid overwhelming the capacity of downstream services. CAD systems should therefore produce actionable radiology reports that minimise the requirement for manual input or further diagnostic testing. Computerised patient management systems that automate routine tasks, such as scheduling of patient contact and communications with primary care, might mitigate the impact of increased patient numbers. It is also important to remember the ultimate aim; VF detection has clinical utility only if it enables prevention of future fractures through appropriate prescription of medications to reduce fracture risk and high enough patient adherence with medication regimes. A retrospective study of Zebra's CAD system on a cohort of 48,227 patients found that fracture risk prediction using CT-based BMD estimation and VF detection was only slightly better than that provided by FRAX (www.shef.ac.uk/FRAX), which estimates fracture risk based on clinical factors, without BMD estimation (8).

CAD systems may have clinical utility, even without increasing diagnostic accuracy, if they automate fracture risk estimation while reducing clinical workload. However, careful attention to health economics is required. Studies have been performed for specific interventions, such as bisphosphonate drugs (9). However, these are insufficient to model the full impact of appropriate patient management and will underestimate patient benefit unless the full range standard interventions, such as falls risk assessments, are also considered. Finally, adherence and persistence for first-line osteoporosis drugs are relatively poor (9). Long-term patient support and monitoring are required to ensure persistence rates sufficient to reduce fracture risk. Simple technologies such as mobile telephone apps that facilitate communication between patients, clinicians and patient support groups could therefore be highly effective.

In conclusion, a future where patients can benefit from machine-learning based diagnostic systems in the diagnosis and management of osteoporosis seems increasingly likely. CAD systems with a high sensitivity and specificity for VFs are one facet of a completely novel clinical pathway, where technological support at multiple points will be required.

Conflicts of Interest

Dr. Bromiley has collaborated with Optasia Medical Ltd. on the development of the ASPIRE™ service, but has no financial interest in the company or service.

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