Editorial Commentary

Dynamic chest radiography: moving from basic research to clinical application

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We thank the editors of the *Journal of Thoracic Disease* for inviting us to provide editorial commentary on a paper by FitzMaurice *et al.* which was published earlier this year in *BMJ Open Respiratory Research* (1). In this study, FitzMaurice *et al.* investigated the ability to estimate lung volume subdivisions using dynamic chest radiography (DCR) in people with cystic fibrosis (pwCF) and demonstrated plausible correlations between whole-body plethysmographic lung volume subdivisions and DCR lung areas. Measuring the lung volume subdivisions in pwCF is important because several subdivisions contain information regarding early detection, disease progression, and treatment effects. However, pulmonary function tests (PFTs) require the use of mouthpieces, nose clips, face masks, or enclosed chambers that alter normal ventilation, and aerosol-generating maneuvers are hazardous to patients with transmissible respiratory infections. Thus, DCR could be a rapid, non-aerosol-generating, and physiological alternative for estimating lung-volume subdivisions. These results may be helpful in the era of the COVID-19 pandemic and in upcoming similar situations in the future. Therefore, DCR is an attractive option for such patients and situations. This study is a good first step toward clarifying the use of DCR in this context. This will hopefully lead to larger studies in the future to better define the role of DCR for pwCF.

In this study, a unique scanning protocol combining tidal and forced breathing was used to capture DCR images. This enabled the calculation of the projected lung area (PLA) at maximum inspiration, maximum expiration, end-tidal inspiration, and end-tidal expiration simultaneously and related them to pulmonary lung volume subdivisions measured by whole-body plethysmography. Most previous studies comparing PLAs and PFT adopted only forced breathing (2-4). Only two studies have investigated the relationship between PLAs and PFT using similar protocols, including tidal and forced breathing (5,6). However, because the PFT parameters did not include residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC) in these studies, a one-to-one correspondence between the lung volume subdivisions and PLAs was impossible. The concept that each PLA corresponds to a lung subdivision is of great interest and enables the estimation of lung volume subdivisions, including lung functional residual capacity, using DCR. Future research using a similar method for many pulmonary diseases may be interesting because measurements of TLC, FRC, and RV are significant for several pulmonary diseases such as severe chronic obstructive pulmonary disease (COPD)/asthma, interstitial pneumonia, and neuromuscular diseases. However, these measurements cannot be evaluated using routine spirometry. This study provides support for further research in this direction. Moreover, these parameters are of great interest for a deeper understanding of the respiratory pathophysiology. DCR does not require a mouthpiece or other adjuncts, therefore, it is more representative of physiological breathing than PFT. DCR system is composed

of a flat panel detector with a large field of view (FOV) that covers the entire lung and supports capturing sequential images, a pulsed X-ray generator, and dedicated analysis software. If these components have been installed, DCR can be performed in any general X-ray examination room. The adoption of DCR systems may lead to an increased ability to evaluate detailed lung function in clinics or small hospitals that have difficulty performing PFT owing to the absence of dedicated equipment and pulmonary function technologists. However, it should be noted that at least seven patients could not perform the optimal breathing maneuver (mainly incomplete passive expiration) and were excluded from the analysis. Measures such as reducing the frame rate and increasing the scan time while maintaining the radiation dose should be considered. Maximum achievable effective dose for a combined posteroanterior (PA) and lateral image series was 0.17 mSv in this study.

Flexibility in the scan direction is a significant advantage of DCR. However, it is unknown which directional scan is most suitable for analysis, and multidirectional image acquisition leads to increased radiation exposure. In this study, FitzMaurice *et al.* developed models to calculate lung volume subdivisions from DCR lung areas and found that the parameters derived from PA images alone correlated well with lung volumes in predicting lung volume subdivisions. Parameters derived from lateral images were removed during regression modeling (1). In contrast, Ueyama *et al.* reported that combining the lung field areas in the PA and lateral views in the calculation of lung volumes achieved a stronger correlation with PFT parameters (4). However, they also reported that the test–retest reliabilities of the DCR measurements at maximum expiration were lower than those at maximum inspiration. Although the reproducibility of the measurements was not investigated in the study by FitzMaurice *et al.*, similarly low reliabilities may occur during tidal inspiration and expiration when combining lateral images. Considering the challenges in lung-border tracing and the risk of increased radiation dose during the capture of lateral images, this issue warrants further future exploration. Moreover, the connections between DCR parameters and lung volume divisions in this study, while statistically significant, did not exhibit particularly strong associations. Hence, occasional disparities between DCR parameters and PFT results can be anticipated. To establish DCR as a suitable alternative for precisely determining lung volume subdivisions, additional technological innovations are desirable. As mentioned in this paper by FitzMaurice *et al.*, further evaluations of the functionalities of DCR, such as assessing lung density to gauge air content, could potentially be integrated into the lung-volume estimation model instead of adding lateral imaging.

DCR is a technically established but clinically new functional imaging technique for the chest. DCR is an attractive technology for the evaluation of various respiratory diseases owing to its many advantages in clinical practice, such as easy accessibility, position flexibility, low radiation dose, and the absence of a need for intravenous contrast agents or inhaled tracers. Therefore, this clinically useful method is rapidly being adopted worldwide, even though its introduction coincided with the onset of COVID-19 pandemic. Since the first description in the 2000s (7,8), many basic and translational studies on DCR have been conducted. DCR can be applied to the diaphragm and thoracic structural motion; PLA change, which was analyzed in this study; ventilation imaging; and airway imaging. PLA, defined as the area of the lung fields obtained using DCR, corresponds to pulmonary function. The concept of PLA was based on a previous study determining total lung capacity by chest radiograph (9). Several studies have shown an association between PLA, its temporal changes, and pulmonary function. PLA at maximum inspiration correlates well with forced vital capacity in healthy individuals and in those with respiratory disease (1-4,6,10). PLA measurements are also useful for evaluating the types of respiratory disorders, disease severity in COPD, and treatment effects in cystic fibrosis (2,3,5,11). PA PLA can be easily measured semi-automatically using a workstation, and its quantification is probable with reproducibility (5).

Additionally, DCR was originally invented for the assessment of not only dynamic lung or thoracic motion but also lung ventilation and perfusion (12). The interval change in the pixel value obtained from the PA view of successive DCR images is converted to a colored map using the concentration gradient method to visualize the ventilation of a particular respiratory phase. A previous animal-based study showed that changes in pixel values were different in an airway obstruction pig model (13). Clinically, the craniocaudal gradient of pixel value changes has been reported to be associated with the severity of COPD; a possible cause could be the effect of flow limitation in the lower lung fields (14). The interval change in the pixel value obtained during breath-holding provides information on lung perfusion. DCR-derived ventilation and perfusion metrics have been shown to correlate reasonably well with

nuclear medicine imaging findings (15,16), suggesting that DCR can provide useful information on pulmonary function. The efficacy of DCR perfusion has been reported in many pulmonary vascular diseases, including acute and chronic pulmonary embolisms (17-21). This method holds significant promise in the field of cardiovascular analysis and provides valuable information for clinical decision making.

Finally, a significant advantage of DCR is its ability to assess both ventilation- and perfusion-related information simultaneously with a small radiation dose. From the perspective of pulmonary pathophysiology, a ventilation/perfusion mismatch may be the key to elucidating cryptogenic dyspnea. To date, only one case of ventilation-perfusion (V/Q) mismatch has been demonstrated using DCR in a patient with ipsilateral pulmonary artery stenosis and persistent dyspnea (22). Combining ventilation and perfusion assessments using DCR may offer new perspectives and highlight new research avenues in this field (e.g., comparison between V/Q mismatch derived from DCR and the diffusing capacity of the lungs for carbon monoxide). To achieve this and enhance the utility of DCR, improvements in the accuracy of DCR analysis and the establishment of quantitative evaluation methods are required. Furthermore, DCR can obtain information regarding not only ventilation/perfusion but also chest structure and motion. Given the abundance of information derived from a single DCR scan, it may be helpful for many pulmonary diseases.

In summary, the study by FitzMaurice *et al.* is an interesting study that shows the possibility of using DCR as an adjunct to traditional methods of lung volume subdivision measurement. This study outlined a new path for the clinical utility of DCR. DCR is a simple and easily accessible modality with the potential to evaluate several pulmonary functions including lung volume, chest motion, ventilation, and perfusion. The stage of its activities is now transitioning from basic research to clinical applications. This novel technology may provide new insights into the lung pathophysiology and further possibilities for clinical applications.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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