Computed Tomography: The Better Pulmonologist?

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In 1971, the British engineer Godfrey Hounsfield finalised his developments at EMI (Electric and Musical Industries) which he had started in 1949 and examined the first human using computed tomography (CT) [1]. For the development of this technology, Hounsfield, along with the South African physicist Allan McLeod Cormack, who had published essential studies on the absorption of X-rays, received the Nobel Prize in Medicine in 1979.

The success story of CT started slowly: in 1972 the first commercial CT scanners were produced, but the technique was not routinely used. In the early days of CT, the use concentrated on the examination of the head. Initially the organ to be examined had to be placed in a water bath and slice thicknesses of 5–15 mm were acquired [2]. The X-ray tube was not able to rotate completely around the patient. Due to the connection cable, the rotation was limited and had to turn back again after recording a double layer. The applied X-ray dose often reached the permissible limits and the calculation of the images with the available high-performance calculators lasted many hours [3].

Some of these limitations could be overcome by the German physicist Willi A. Kalender in 1989 [3]. Due to the technical developments to spiral CT, the X-ray tube

and the detector system could now be moved around the patient continuously without the need for a cable connection. With the latest development, the triumph of the CT began, and more and more systems were installed worldwide.

Newer developments include multi-slice CT, sub-millimeter resolution, and subsecondary acquisition as well as iterative image reconstruction, which can reduce the radiation dose required for an examination by 60–70% with a better image quality. Further improvements are imminent. Due to these developments, CT soon became the imaging method number one in medicine [4].

In pneumology, CT has proven its value for many years. T (tumor) and N (nodal) staging in bronchial carcinoma was the primary domain of CT for years [5], but angio-CT is now also an integral part of the diagnosis of pulmonary emboli [6]. Worldwide, low-dose CT trials are ongoing to establish CT as the screening technology for lung cancer.

In obstructive lung disease, the technique is also more and more often used. In the current issue of *Respiration*, Kirby et al. [7] present a novel method of estimating small airway disease using inspiratory-to-expiratory CT scans. 470 participants from the population-based CanCOLD study were evaluated, and CT and pulmonary function

Fig. 1. Computed tomography (CT) inspiratory-to-expiratory Disease Probability Map (DPM) voxel classification. **a** The CT DPM depicts voxels classified as emphysema in red, gas trapping related to small airway disease in yellow, and normal in green. The first three images show the DPM for three separate axial slices (base to apex of the lung) and the fourth image shows the DPM for a central, coronal slice in a subject with chronic obstructive pulmonary disease. **b** VIDA's LungPrint™ of the continuous probability of gas trapping on the *x* axis versus the continuous probability of emphysema on the *y* axis for each registered inspiratory-to-

expiratory voxel pair in the lung of the same subject with chronic obstructive pulmonary disease as shown above. Voxels in the lower-left quadrant are classified as normal, voxels in the lower-right quadrant are classified as gas trapping, and voxels in the upper-right quadrant are classified as emphysema. **c** Low-attenuation cluster analysis of the emphysema and gas trapping lung voxels; the size of the sphere is proportional to the extent of spatial clustering of emphysema and gas trapping. **d, e** Percent of emphysema, gas trapping, and normal voxels in the lung according to anatomical location (**d**) and overall for the total lung (**e**).

measurements were acquired for all in full inspirations/full expirations. All CT images were registered and each voxel was classified as emphysema, gas trapping related to functional small airway disease (GasTrap). In their paper, the group was able to show that CT inspiration-to-expiration gas trapping measurements are significantly associated with pulmonary function and symptoms. In the Discussion, the limitations are discussed openly, as well as other hurdles within the study. However, we all can expect a rapid improvement of the use of CT in the diagnosis, treatment, and follow-up of obstructive lung diseases. In specific indications, such as lung volume reduction [8], a CT-based analysis is already the gold standard nowadays. The decision as to whether a patient is qualified for a volume reduction intervention is made by software-assisted analysis of the CT [9] (Fig. 1).

However, CT also plays an increasingly important role in other fields of lung diseases. The current guidelines and recommendations for the diagnosis and therapy of pulmonary fibrosis [10, 11] established CT as the major diagnostic test and as guidance for diagnostic and therapeutic decisions. Depending on the findings, further examination or an immediate treatment are recommended. In the case of obstructive pulmonary diseases, more and more CT examinations are arranged, and asthma also plays an increasing role in CT imaging. The question to be answered is whether bronchial wall thickening, hyperinflated areas, air trapping, and possible regional improvement after inhalation of bronchodilators can be tested well and effectively by CT examination [12].

Last but not least, the question arises as to whether CT can replace the most popular tool for the pneumologist,

the spirometry. Large American trials, which examine patients repeatedly over time, no longer offer lung function testing as part of the trials. The lung function parameters are calculated from the CT data sets. Various software solutions are available to work up the initial black-and-white images to obtain the necessary parameters [9].

Observing this development critically, we have to pay attention to our discipline with Argus eyes. Thus, imagine this scenario: the general practitioner refers an ex-smoker for a low-dose CT with the question: carcinoma yes/no? In addition to this information, the general practitioner receives all lung function parameters, clustering of possible emphysema, and a detailed description of possible fibrotic areas. The question that arises is: do we still need the lung specialist?

We believe that it is our task to familiarize the next generation of pneumologists sufficiently with the CT method and its interpretation. The importance of classical X-ray is diminishing. We have to learn and to teach how to read CT images independently or in an interdisciplinary context. We are fully aware that the specialist expertise is obviously superior to the imaging of lung diseases and the pure analysis of pixels and voxels, since ultimately individualized patient care is required. Nonetheless, CT remains one of our central imaging techniques and will certainly become more important in the coming years, but hopefully we can influence its further developments and uses.

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