Personalised CT scan protocols for the detection of pulmonary embolism

This thesis titled “Personalised CT Scan Protocols for the Detection of Pulmonary mbolism”, describes a systematic approach on how to individualise iodinated contrast media (CM) injection and computed tomography (CT) scan protocols in patients suspected for pulmonary emboli.

The first chapters of this thesis describe a stepwise approach for individualising CM injection and CT scan protocols, while the final chapter shows the robustness of these adaptations in a real world setting after using these protocols in clinical practice for an extended period of time.

Chapter 2 describes the evaluation of individually shaped CM delivery in CT pulmonary angiography (CTPA). This study showed an CM injection adjusted to patients’ body weight could reduce up to 51% CM, compared to a fixed protocol which was used before. Even under emergency conditions, diagnostic image quality was not compromised, and even improved.

Chapter 3 explored the simultaneous adjustment of CM delivery and scan parameters, tailored to patient characteristics. It was shown that combining automated tube voltage selection (ATVS) with CM tailored to both the patient’s body weight ánd the V setting, resulted in good image quality and homogeneous attenuation of the pulmonary arteries throughout the patient population. The mean injected CM volume in this study was 28 ± 6 mL which is a 69% reduction compared to the 90 mL one-size-fits-all protocol from **Chapter 2**. Mean radiation dose was low, between 1.3 and 2.2 mSv, owing to most patients being scanned at 70 or 80 kV as selected by ATVS, instead of the - at that moment- standard 100 or 120 kV.

The work from **Chapters 2 and 3** combined with the work of coworkers from our group has led to a simple rule-of-thumb: The 10-to-10 Rule. **Chapter 4** describes how to apply this simple rule when optimising either arterial or parenchymal CT scans. In short, for CT angiography one deducts 10% of the iodine delivery rate per 10 kV reduction and vice versa. For parenchymal CT a reduction of 10 kV leads to 10% reduction in dosing factor (g I/kg). The use of this rule of thumb results in significant CM volume reduction in addition to achieving comparable attenuation of arteries or parenchymal tissue at varying kV-settings.

Chapter 5 exposed large variations in CTPA radiation dose between several CT scanners and scan protocols, even within just one hospital. Especially when scanning younger or pregnant patients, being aware of such differences is of paramount importance to minimise chances of negative side effects of life-time cumulative radiation exposure. Furthermore, **Chapter 5** examined several dose reduction strategies for CTPA in pregnant patients, aimed at radiation dose reduction for the mother and the foetus. It details an effective method of optimising scan length from the lung apex to the top of the most caudal hemi-diaphragm, which led to radiation dose reduction of 30-33 % for the mother on all protocols and up to 83

% dose reduction for the foetus. This was achieved without missing a pulmonary embolism diagnosis in this study. This simple scan range reduction can be instantly copied anywhere in the world on all CT scanners.

The aforementioned chapters and their impact will even carry more weight if it's shown that these individualised protocols work in a real-world setting. To test the robustness of said protocols and the 10-to-10 Rule, **Chapter 6** reviewed the 5-year real-world performance of individualised CTPA imaging in a 24/7 clinical setting. By determining the incidence of repeat CTPA scans due to poor quality it was shown that in a cohort of 4.481 CTPA scans only 134 scans (3%) were repeated due to poor image quality. After an expert panel reviewed the 134 scans, they pointed to the contrast and scan protocol as insufficient in 13 cases. This indicates that the individualised CTPA protocol worked in clinical practice in 99,7% of scans. Through an iterative process, we achieved consistent and reliable image quality in a 24/7 clinical setting while minimising radiation and CM doses for all patients. The second important finding to emerge from the panel review was that 56 of 134 scans were in fact of diagnostic image quality and shouldn't have been repeated. This underscores the need for better guidelines regarding the definition of diagnostic image quality in CTPA. Clear criteria for what constitutes adequate image quality are crucial in order to avoid unnecessary rescanning.

Future research could focus on the influence of patient parameters on image quality and repeat rates to further reduce repeat scanning. The next two big leaps in radiology, the arrival of the photon-counting detector CT and the integration of Artificial Intelligence, hold great potential for advancing CTPA protocols and improving patient outcomes.