Decisive modification tools in coronary computed tomographic angiography

CHAPTER 9

Supplemental Material

Summary

Valorisation

Dankwoord

Curriculum Vitae

List of publications

In daily clinical routine, contrast media (CM) administration in coronary computed tomography angiography (CCTA) is generally applied as a standard injection protocol with a fixed amount of CM and a standard injection rate. However, attenuation of the coronary arteries and overall image quality in CCTA is influenced by numerous factors, divided in three major subgroups (e.g. scan related parameters, injection related parameters, and patient related factors). The underlying relation of these parameters has not been investigated extensively and hardly any literature neither consensus exists on the optimal scan protocol in CCTA. The aim of this thesis was to gain insight into the influence of various different injection parameters (e.g. CM concentration, flow rates, viscosity and iodine delivery rate [IDR]) on attenuation and image quality in CCTA.

In chapter 2, we presented a comprehensive overview of the existing literature in order to provide an update on the determining factors for optimal contrast enhancement of the coronary arteries. Contradicting outcomes were reported in the included publications. Arguable outcomes and conclusions with regard to image quality and attenuation of the coronary arteries were drawn when different CM concentrations were injected with variable injection parameters. In most of the included studies limited data concerning injection-, scan- and patient-related parameters were provided. These factors, however, may also have had a substantial impact on image quality in CCTA. Therefore, the influence of some of these individual injection parameters on vessel attenuation needed to be unravelled.

The aim of the study in chapter 3 was to evaluate the viscosity of different CM concentrations in a standardized manner at different temperatures and its influence on injection parameters, with focus on injection pressures. The results of these experiments show in a standardized way that low viscosity decreases injection pressure. This can be facilitated by prewarming CM (high temperature) and using CM with low iodine concentration. In these experiments, significant differences in peak pressure (psi) were found at 20˚C, 30˚C, and 37˚C for iodinated CM 240, 300, 370, and 400mg/ml. Overall, the lowest peak pressure was found for the lowest concentrated CM (e.g. 240mg/ml) at body temperature (92psi at 37˚C). Strikingly, the peak pressure for the highest concentrated CM (400mg/ml) was even higher at body temperature (135psi at 37˚C) in comparison to CM with 240mg/ml at room temperature (107psi at 20˚C). These findings not only stressed the positive effect of preheating CM to reduce viscosity and injection pressure, but also displayed the potential reduction in peak pressure, which can be generated when using lower concentrated CM. The latter finding subsequently creates the doorway towards injection with higher flow rates. Chapter 4 aimed to investigate the influence of CM concentration and IDR on intravascular attenuation in a circulation phantom. The influence of CM concentration on intravascular attenuation has been of great interest in the literature, with varying outcomes. Current evidence is controversial as to whether higher concentrated CM is beneficial in intravascular

attenuation, when the calculated IDR (e.g. CM concentration x injection rate) is kept identical. The use of a circulation phantom provided a unique opportunity for repetitive and standardized scanning of an identical subject, ruling out variables such as varying heart rate, blood pressure and cardiac output. In this study, comparison of protocols using different CM concentrations (varying between 240-400mg/ml) established comparable intravascular enhancement patterns when IDR and all other influencing factors were kept constant. Higher iodine concentrations on itself did not increase attenuation levels. This implicates that IDR, and not CM concentration, is the determinant factor in the opacification of the vascular tree. Based on these experiments, comparable attenuation levels should be feasible in daily clinical routine with very low CM concentrations (e.g. 240mg/ml) when IDR is kept identical. The aim of chapter 5 was to test high flow application of CM in a circulation phantom and to assess feasibility of high flow rates in a patient population. Injection with high flow rates proved to be feasible in a phantom setting (≤15ml/s). In a clinical cohort, maximum flow rate of 9.6ml/s were administered. These flow rates did not cause injection-related problems (e.g. extravasation at the injection site, material damage) or negative image-related side effects (e.g. streak artifacts or CM reflux) while reaching optimal vessel enhancement levels. The maximum injection pressure of 325psi was never reached in both the phantom and patient setting. In chapter 6, the results from the previous chapters form the basis for an additional pilot study. In this study we evaluated peak injection pressures and both objective and subjective image quality in CCTA using low concentrated CM (240mg/ml) injected at high flow rates in comparison to a standard injection protocol (CM: 300mg/ml) with identical IDR. No contrast related problems such as extravasation at the injection site or negative flow related effects (e.g. streak artifacts or CM reflux) were encountered. No significant differences in attenuation of the coronary arteries, peak pressure levels and image quality were found between both groups. This study proved again, that reluctance towards usage of high flow rates is merely based on hypothetical flow related issues. In addition, IDR is the decisive factor in intravascular attenuation. In chapter 7, a study was conducted in which vascular attenuation of the coronary arteries as well as all major injection parameters were evaluated using an individual tailored body weight adapted CM injection software. This software customizes a triphasic injection protocol for each patient and procedure, adapting the IDR and total iodine load based upon a non-linear relationship between patient weight and scan duration in order to achieve diagnostic attenuation. Diagnostic attenuation in all coronary arteries and a more homogeneous enhancement pattern between different weight groups was found in comparison to a fixed injection protocol. Total injected CM volume could be reduced for the majority of patients when utilizing body weight adapted individualized CM bolus application in comparison to a standard injection protocol. Chapter 8 discusses the main findings of this thesis in the light of existing literature and its future directions.