

Optimisation of scan and injection protocols to the individual patient in CT angiography

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Introduction

Computed tomographic angiography (CTA) is a widely used non-invasive imaging method for the evaluation of various vascular structures. Contrast media (CM) is used to provide intravascular enhancement and precise assessment of the arterial lumen. Previously used 'one-size-fits-all' protocols – every patient receives the same volume of CM – resulted in a suboptimal intravascular attenuation and thus suboptimal scan quality for either slim patients or patients with a high body weight; Patients with a low body weight need less CM volume compared to patients with a high body weight, underlining the need for adjustment of CM injection protocols to individual patients. The success of adapting scan and CM injection protocols to individual patients undergoing CTA has been studied extensively before, from which multiple conclusions can be made: the iodine delivery rate (IDR) is the most important factor for injection protocol optimisation, and various patient parameters (weight, cardiac output) can be used to further optimise the CM injection protocol. Adaptation of CM injection protocols (e.g. IDR and volume) lead to a short and compact CM bolus, especially in low weight patients. These protocols are favourable in faster scan acquisitions. However, with such a compact CM bolus, the number of non-diagnostic scans might increase due to suboptimal scan timing (scanning too late or too early), or due to low overall volume in relation to the total scan time.

Relevance

This thesis shows that scan and CM injection protocols should be adapted to the individual patient. This results in less hazard to the patient with regard to radiation dose and CM volumes, whilst maintaining diagnostic image quality. Several patient parameters for adaptation of the CM injection protocol were studied, and we concluded that more intricate equations (e.g. cardiac output) do not lead to higher image quality compared to more simple equations (e.g. body weight). We advise to use body weight adapted protocols for cardiac CTA (CCTA) and the 10-to-10 rule (**chapter 2**) for CTA of the aorta based on the results of this thesis: with every 10 kV subtraction, the iodine load can be reduced by 10%.

The adjustment of scan and injection protocols often lead to less radiation dose, which is beneficial for patients in terms of the 'as low as reasonably achievable' (ALARA) principle. Furthermore, with lower CM volumes, the chance of developing contrast induced nephropathy (CIN) may decrease.

Lastly, the reduction of CM volumes may result in a decreased overall cost per scan. Previously, a CM volume of 75 mL for CCTA and 120 mL for CTA of the aorta was used in every patient. This thesis showed that a lower CM volume can be used in both CCTA and CTA of the aorta

(approximately 47% in CCTA and 67% in CTA of the aorta) whilst maintaining diagnostic image quality. The adaptation of CM injection protocols in our radiology department has resulted in a decrease in total CM volume used over the years – despite the amount of CT scans increasing every year – and therefore, may result in a decreased total cost of CM volume.

In the second part of this thesis we investigated whether image quality of non-ECG gated, non-cardiac chest CTs was sufficient to assess the heart and coronary arteries. Due to technical advancements and subsequently higher image quality, more incidental findings can be seen. Adding a post-processing cardiac reconstruction offered the possibility to assess for incidental cardiac pathologies in patients with a diagnostic image quality. Furthermore, this thesis investigated the prevalence of cardiac pathologies on non-cardiac chest CT scans, and found that presence of coronary calcifications can be assessed in nearly all patients providing insight into their coronary status. The importance of this finding is twofold. First, in dedicated CCTA, the presence of coronary calcifications is the most robust predictor of cardiovascular events (CVE) in asymptomatic patients.¹ Considering the majority of patients referred for non-cardiac chest CTs already have a high risk of CVE, the presence of coronary calcifications on these scans is an important incidental finding. Second, presence of coronary calcifications is important for various patient groups, e.g. presence of coronary calcifications leads to an increased risk of developing post-surgery complications in non-cardiac chest surgery (e.g. lung cancer).²⁻⁵ Therefore, when technically possible, radiologists should assess the heart and coronary arteries on non-cardiac chest CTs, and add a severity score where feasible. The extra information on pathologies should be merged with the clinical history of the patient to detect new and clinically relevant information. The findings and severity score should be added to the discussion with emphasis on the new incidental findings.

Target groups

The optimisation of scan and injection protocols – i.e. reducing radiation dose and CM volume – and assessment of cardiac pathologies on chest CTs to reduce the risk of a cardiovascular events in the future is beneficial for the patient. Patients may benefit from early detection and/or management of coronary calcifications by life-style interventions or additional screening for and treatment of cardiovascular risk factors. Second, the results of this thesis are relevant for radiologists because they may improve understanding of the methods for scan and CM injection protocol optimisation. Knowledge on how to adapt scan and injection protocols, as well as which parameters to incorporate in these protocols is important. Furthermore, the results show that radiologists should assess the heart and coronary arteries on non-cardiac chest CTs for presence of coronary calcifications and/or other cardiac pathologies when possible. Lastly, the results from this thesis are important for referring clinicians, such as vascular surgeons and cardiologists. Knowledge of optimised protocols might aid in the

choice for CTA of the aorta and/or CCTA instead of other imaging techniques (e.g. MRI). Also, presence of coronary calcifications provides insight in the patients' coronary status, referring clinicians can use this information to pro-actively start secondary prevention and/or treatment.

The downside of reporting all incidental cardiac pathologies is that it might lead to a tidal wave of 'new' patients referred to the cardiology and/or general practitioners' departments. However, we do not know if all patients need referral and/or treatment, and not all patients may benefit from earlier diagnosis. Perhaps these incidental findings should be treated with the same stringency as a newly proposed screening program (i.e. Wilson's criteria). Guidelines on who should receive follow-up treatment must be developed and the cost-effectiveness of such a diagnosis and treatment strategy carefully analysed. In particular, it is important to establish whether patient prognosis is actually improved by early detection of incidental CCTA findings. To cite Gray et al: "all screening programmes do harm; some do good as well, and, of these, some do more good than harm at reasonable cost."⁶

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